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Relevance of Compartmental Anatomic Guidelines for Biopsy of Musculoskeletal Tumors: Retrospective Review of 363 Biopsies over a 6-Year Period

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ABSTRACT

Purpose: To retrospectively assess percutaneous core needle biopsies performed by radiologists and the association with tumor seeding along the biopsy tract when anatomic compartment guidelines are not consistently observed.

Materials and Methods: Retrospective data from computerized patient records and digital images from 363 consecutive computed tomography–guided biopsies of the lower extremity (thigh and leg) performed by radiologists at a single institution from August 2002 to August 2008 were analyzed for breaches of biopsy guidelines.

Results: Of the 363 biopsies, 243 (67%) were of soft tissue lesions and 120 (33%) were of bony lesions. There were 188 (52%) malignant and 175 (48%) benign lesions. The following biopsy breaches were observed: 13 (3.6%) of anatomic compartment, 42 (11.6%) of "vital structures," and 82 (68.3%) of needle path for bony tumors. Vital structures as defined by the literature included, but were not limited to, the following: knee joint capsule, greater trochanteric bursa, rectus femoris and vastus intermedius muscles, tibial tubercle, peroneus brevis and peroneus longus distal tendons, and neurovascular bundles. No cases of tumor recurrences could be attributed to needle seeding along a biopsy tract for any of these biopsy guideline breaches.

Conclusions: The concern for needle tract seeding with musculoskeletal tumors is more widespread than the evidence supporting it as a significant or frequent complication. In this study, breaching anatomic compartment, vital structures (other than neurovascular structures), and suggested exact needle path guidelines were not associated with needle tract seeding in the lower extremity.

Studies have shown that percutaneous core needle biopsies of musculoskeletal lesions are accurate and effective procedures, and carry the advantages of decreased complications and cost compared with open biopsy (1–4).

Despite a lack of data in the literature, there is concern in the radiology and orthopedic oncology communities that tumor seeding and recurrence occurs along the needle tracts of percutaneous core needle biopsies of musculoskeletal tumors (5–8). This has led to widespread publications detailing exact instructions on how to perform core needle biopsies of such tumors (9–13).

Although most standard biopsy recommendations for any anatomic structure suggest considering factors such as shortest skin-to-lesion distance and general avoidance of neurovascular structures, the literature regarding biopsy for musculoskeletal lesions strongly suggests that the biopsy be performed along a strict anatomic compartment with avoidance of "vital structures" as defined by the literature in the lower extremity to include detailed anatomic structures such as the knee joint capsule, greater trochanteric bursa, rectus femoris and vastus intermedius muscles, tibial tubercle, peroneus brevis and peroneus longus distal tendons, and several neurovascular bundles that are subsequently described in more detail. For bony lesions, specific needle paths are recommended to be concordant with the surgical excision to assure that the entire biopsy tract can be excised during surgery (9,10). When referring to biopsy guidelines

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This article includes Figures E1 and E2 and Tables E1 and E2 that are available online at *www.jvir.org*.

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subsequently in this article, the authors are referring to these aforementioned anatomic compartment, vital structure, and bony lesion needle path suggestions from the literature.

The present study aims to prove that there is no significant association with percutaneous core needle biopsy technique and tumor seeding along the biopsy tract in musculoskeletal tumors of the lower extremity.

MATERIALS AND METHODS

Retrospective data from consecutive computed tomography (CT)–guided biopsies of the lower extremity (thigh and leg) performed by the radiologists at a single institution between August 2002 and August 2008 were abstracted for the following information: patient age and sex; interventionalist; lesion depth, size, and location; needle type and size; compartments and detailed anatomy breached by the biopsy needle; pathology results; pertinent surgical treatment; and development of tumor recurrence. Data abstraction was performed in August 2010 for a follow-up time period of 24–96 months. The data were acquired from reviewing biopsy images from the picture archiving and communication system workstation and through a review of computerized patient records. The decision to analyze the lower extremity data for the purposes of this study was twofold. First, the compartment anatomy for the lower extremity, in particular with respect to biopsy planning, is adequately described in the literature. Second, biopsies were performed more frequently in this anatomic region than in any other region in the musculoskeletal system at the authors' institution.

If the results from the percutaneous biopsy were nondiagnostic, all available data, including subsequent pathologic findings obtained from an open biopsy, surgical excision, and clinical records were accessed in an attempt to capture all malignant results for the purposes of needle seeding follow-up.

For the cases included in this study, there was no direct collaboration regarding which anatomic compartment to traverse or avoid during biopsy between the radiologists and orthopedic oncology surgeons. The surgeons did not give detailed instructions to the radiologists performing the biopsy how the biopsy should be executed to facilitate concordant en bloc tumor excision that would eventually include the biopsy site.

Biopsy Breaches

Anatomic compartment. Biopsies that breached more than one anatomic compartment were quantified. Anatomy per compartment is listed in **Table 1** and illustrated in **Figure 1** (10,11).

Vital structures. **Table 1** lists vital structures that should not be infiltrated by the biopsy tract according to the literature (9). These vital structure breaches were quantified.

Biopsy path. **Table 1** describes the recommended needle tract for bony lesions, which is pictorially demonstrated in **Figure 2** (9). Biopsies that did not adhere to these suggested tracts were quantified.

The determination of biopsy guideline breaches was made by a single author according to published guidelines. In difficult cases, a second author assisted in evaluating anatomy breached by the needle. All cases had adequate images for this evaluation.

Tumor Recurrences

Patients with malignant results were separated into two groups for the purposes of further analysis. Group I included patients who had a percutaneous core needle biopsy performed by radiologists at the authors' institution as their primary invasive workup. Group II included patients who had histologic diagnosis from a procedure performed at an outside hospital (usually via biopsy or resection) at the time of presentation to the authors' institution or began their diagnostic evaluation with an invasive procedure other than a core needle biopsy. Group I patients were further evaluated for the possibility of needle tract tumor seeding from biopsy technique. Tumor recurrences and the possibility of seeding were also analyzed for group II patients, after their biopsy from the authors' institution, although these patients had undergone other invasive procedures at outside hospitals and/or were inherently at higher risk, primarily presenting with a tumor recurrence.

The appearance of the lesion was evaluated on cross-sectional images to determine the possibility of needle seeding, described in the literature as tumor satellites extending noncontiguously outward along the needle tract (6). This step was performed by at least two authors.

The pathology reports of recurrence cases were reanalyzed to ensure that there was no reported tumor seeding occurring along the biopsy tract, a finding that would be reported by a pathologist who subspecializes in bone and soft tissue tumors and had 15 years of total experience.

The surgical operative reports of tumor recurrence cases were also reanalyzed to ensure that there was no report of the need to transition to amputation or complications expected based on the core biopsy tract at the time of surgery.

There were a total of 363 lower-extremity biopsies included. All were performed by fellowship-trained musculoskeletal radiologists. The majority, 336 of the 363 studies, were performed by two radiologists, one with 8 years of experience (n = 179) and the other with 20 years of experience (n = 157) in performing such biopsies.

Patient and lesion demographics are outlined in **Table E1** (available online *www.jvir.org*). With the exception of two cases that used a Jamshidi needle (Cardinal Health, McGaw Park, Illinois), all were coaxial systems (359 of 361; 99.4%). A total of 343 soft-tissue and bone biopsies (particularly lytic lesions with cortical loss) were performed with a coaxial 11- or 12/14-gauge system (Cook, Bloom-

Table 1. Biopsy Guidelines (9,10)

Anatomic Compartment (10)

Do not breach > 1 anatomic compartment

- Thigh (**Fig 1**)
  - Anterior
    - Iliotibial tract, tensor fascia lata muscle (m.), sartorius m., quadriceps muscles (rectus femoris m. and vastus lateralis, intermedius, and medialis ms.)
  - Medial
    - Gracilis m., adductor muscles (adductor brevis, longus, and magnus ms.)
  - Posterior
    - Short head biceps femoris m., hamstring muscles (long head biceps femoris m., semimembranosus m., semitendinosus m., ischiocondylar portion of adductor magnus m.)
- Leg (**Fig 1**)
  - Anterior
    - Tibialis anterior m., extensor digitorum longus m., extensor hallucis longus m.
  - Lateral
    - Peroneus longus m., peroneus brevis m.
  - Posterior (deep)
    - Tibialis posterior m., flexor digitorum longus m., flexor hallucis longus m., popliteus m.
  - Posterior (superficial)
    - Gastrocnemius m., soleus m., plantaris m.

Vital Structures (9)

Do not breach the following vital structures:

- Thigh
  - Greater trochanteric bursa
  - Femoral neurovascular bundle anterior to the femoral neck
  - Transverse branch of the lateral femoral circumflex artery
  - Anterior quadriceps muscles (rectus femoris and vastus intermedius muscles)
  - Sciatic nerve
  - Profunda femoris artery
  - Superficial femoral neurovascular bundle in the adductor canal
  - Popliteal neurovascular bundle in the popliteal fossa
  - Knee joint capsule
  - Medial and lateral superior genicular arteries
- Leg
  - Tibial tubercle
  - Anterior and posterior tibial neurovascular bundles
  - Peroneal neurovascular bundle in the deep posterior compartment of the calf
  - Deep peroneal nerve at the deep surface of the peroneus longus muscle
  - Peroneus brevis and peroneus longus tendons distally
  - Common peroneal nerve around the fibula neck just caudal to the knee

Intraosseous Biopsy Path (9)

Follow these recommended needle paths for an intraosseous lesion:

- Femur
  - Femoral head and neck lesion (**Fig 2a**)
    - Inferolateral to the hip region in the subtrochanteric region and angle superomedially up through the femoral neck taking an intraosseous course to avoid contamination of the joint capsule
  - Femoral shaft lesion (**Fig 2b**)
    - Penetrate the posterolateral skin site just anterior to the lateral IMS with permission to pass through a small portion of the posterolateral aspect of the vastus lateralis muscle
  - Distal femoral metaphysis and epiphysis (**Fig 2c, 2d**)
    - Lateral approach: just anterior to the lateral IMS but lateral to the knee joint capsule
    - Medial approach: alignment with the adductor tubercle and passing through the posteromedial portion of the vastus medialis muscle

Continued on next page

Table 1. Biopsy Guidelines (9,10) (Continued)

Tibia (**Fig 2e, 2f, 2g**)
Anteromedial longitudinal line overlying the anteromedial tibial cortex
Fibula
Proximal and distal fibular ends (**Fig 2e, 2g**)
Directly into the fibula through the skin and subcutaneous fat
Fibular shaft (**Fig 2f**)
Anterior to the posterior IMS through the posterior border of the peroneus longus muscle, although an approach posterior to the posterior IMS may also be necessary depending on tumor location relative to the deep peroneal nerve

Note.—IMS = intermuscular septum.

ington, Indiana), with nine of these also using a Bonopty needle (AprioMed, Uppsala, Sweden). All bone biopsies with intact cortex were performed with bone biopsy kits (**Table E1**), with 12 (3.3%) using a Kyphon needle (Kyphon, Sunnyvale, California).

Of the 363 biopsies, 243 (67%) were soft-tissue lesions and 120 (33%) were bony lesions. There were 188 (52%) malignant and 175 (48%) benign lesions (**Table E1**). There were 160 group I patients (85%) and 28 group II patients (15%) within the malignant lesion group. Although there were a variety of malignant pathologic processes included in the sample, the most common of the malignant tumors were diverse subtypes of sarcomas (143 of 188; 76%; **Table E2**, available online *www.jvir.org*).

For the malignant tumors, 131 treatment-related surgeries were performed at the authors' institution. None of the operative surgical reports documented the need to transition to amputation as a result of complication from a percutaneous biopsy tract at the time of surgery. This suggests that the biopsy technique used resulted in a good outcome, as is expected with percutaneous biopsy.

RESULTS

Biopsy Breaches

There were 13 (3.6%) breaches in the form of biopsy needles traversing more than one anatomic compartment and 42 (11.6%) breaches of vital structures. Based on published guidelines recommending an exact tract to take when performing biopsies of bony lesions, 82 of the 120 bony lesion biopsies did not comply with the recommendations (68.3%).

Among the malignant lesions in which the biopsy was in breach of recommended guidelines, there were no cases of tumor recurrence that could be attributed to tumor seeding along a biopsy tract (**Fig 3a–3c**).

Tumor Recurrences

Of the 188 malignant lesions, there were a total of 22 tumor recurrences found in computerized patient records, but only seven of these had their primary core biopsy performed at this institution (ie, group I patients; **Fig 3d**). The seven group I cases of tumor recurrences demonstrated that the recurrences were not caused by needle seeding as a result of the biopsy technique, as they occurred in an entirely different path, pattern, or location as that of the biopsy tract (**Fig E1**, available online *www.jvir.org*). In addition, none of these cases had any biopsy guideline breaches in their primary biopsies performed by the radiologists at the authors' institution. The time frame for tumor recurrence presentation in the seven group I cases ranged from 10 to 27 months, with a mean of 18 months.

Among the 15 tumor recurrence cases from the group II patients, four showed subsequent tumor recurrences after biopsy at the authors' institution. None of these four patients had any evidence of needle seeding. Interestingly, seven of the 15 patients who had tumor recurrence had biopsy breaches, including three of the four patients who had tumor recurrences after biopsy at the authors' institution; however, no evidence of needle seeding was identified (**Fig 3d**).

DISCUSSION

At the authors' institution, biopsy planning attends primarily to patient comfort, safety, and finding the shortest distance and most direct pathway possible without strict adherence to published biopsy guidelines. The biopsy is not planned around the necessity to approach through the same compartment as the lesion; however, most were performed through the same compartment as the lesion, as this was usually the shortest skin-to-lesion distance. Also, attention to avoiding vital structures listed in the literature (other than adjacent neurovascular structures) was not prioritized. Finally, the exact needle path for biopsy of a bony lesion suggested by the literature was not routinely followed. Rather, the area of maximum cortical loss, if present, was accessed.

Studies in nonmusculoskeletal tumors have attempted to quantify the frequency of needle seeding tumor recurrences, identifying incidences of 0.003%–0.009% for abdominal tumors, 2.7% for hepatocellular carcinoma, and 0.012% for intrathoracic masses (14–16). To our knowledge, there have not been any published data quantifying the frequency of needle tract seeding in musculoskeletal tumors. Despite the few individual case reports in the literature, other studies with a combined experience of 4,620 cases (2,17–21) demonstrated no evidence of needle

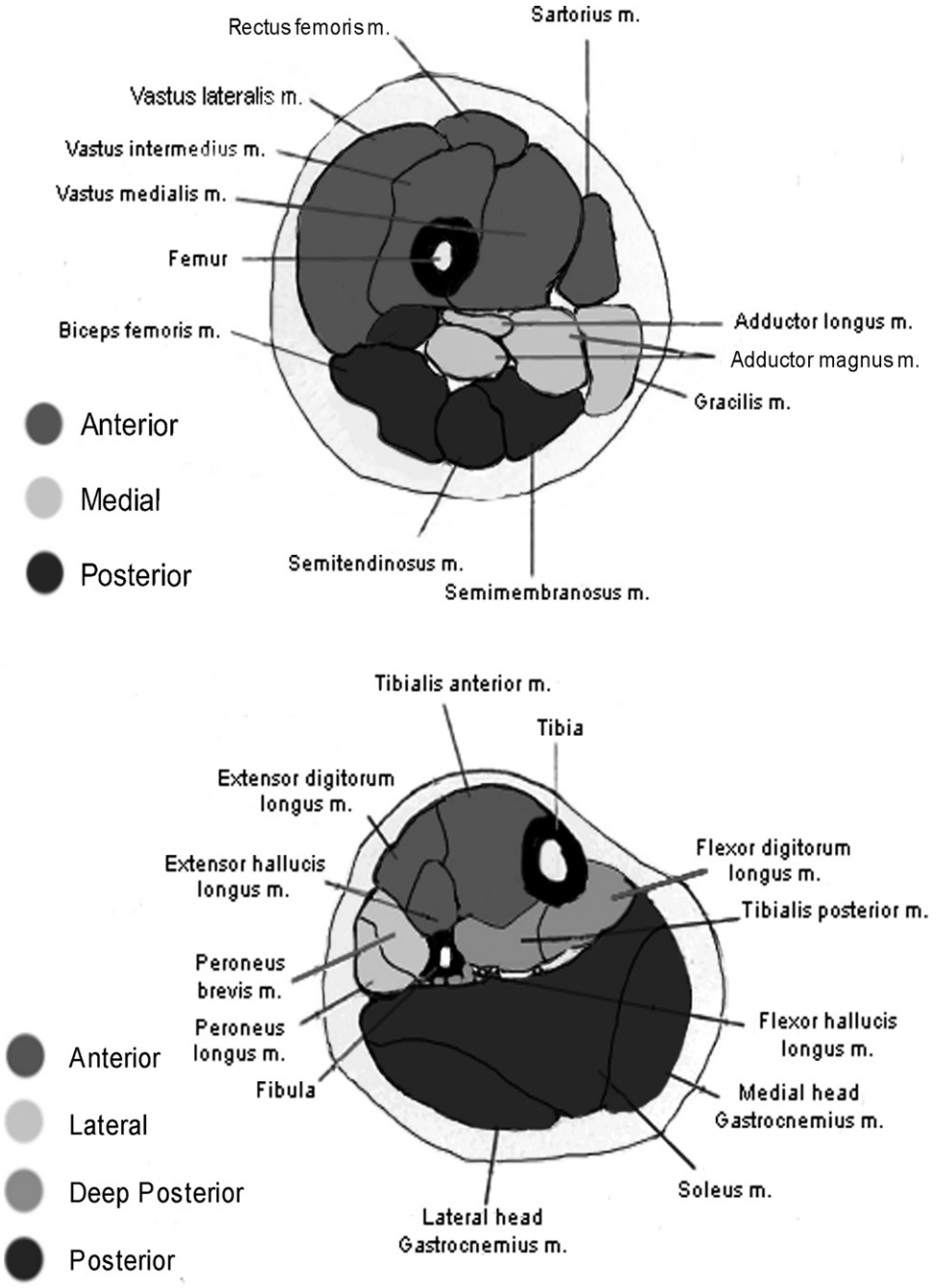

Figure 1. Anatomic compartments of the thigh (upper image) and leg (lower image). Biopsy guidelines state that more than one compartment should not be breached.

tract tumor seeding for musculoskeletal lesions, findings concordant with those of the present study.

There are many reasons accounting for the rigorous and precise biopsy guidelines for musculoskeletal lesions despite fewer cases of reported needle seeding compared with nonmusculoskeletal tumors. Studies have shown that adverse patient outcomes have resulted from poorly executed biopsies (22–25). Mankin et al (22) reported in 1982 that there was an 18.2% rate of significant alteration in the treatment or outcome resulting from difficulty with the initial biopsy, most performed in referring institutions rather than treatment centers, and 4.5% of these patients had unnecessary amputations as a result. A repeat study in 1992 by the same group (23) again demonstrated similar unfortunate findings. These adverse results were actually caused by a multitude of factors discussed by the authors, including errors in diagnosis, nonrepresentative or poorly stained biopsy material, and wound-healing problems at the biopsy site, which were found significantly more frequently in referring rather than treatment centers (22,23). The study also included incisional and excisional biopsies, with needle biopsies representing a minority of their sample group.

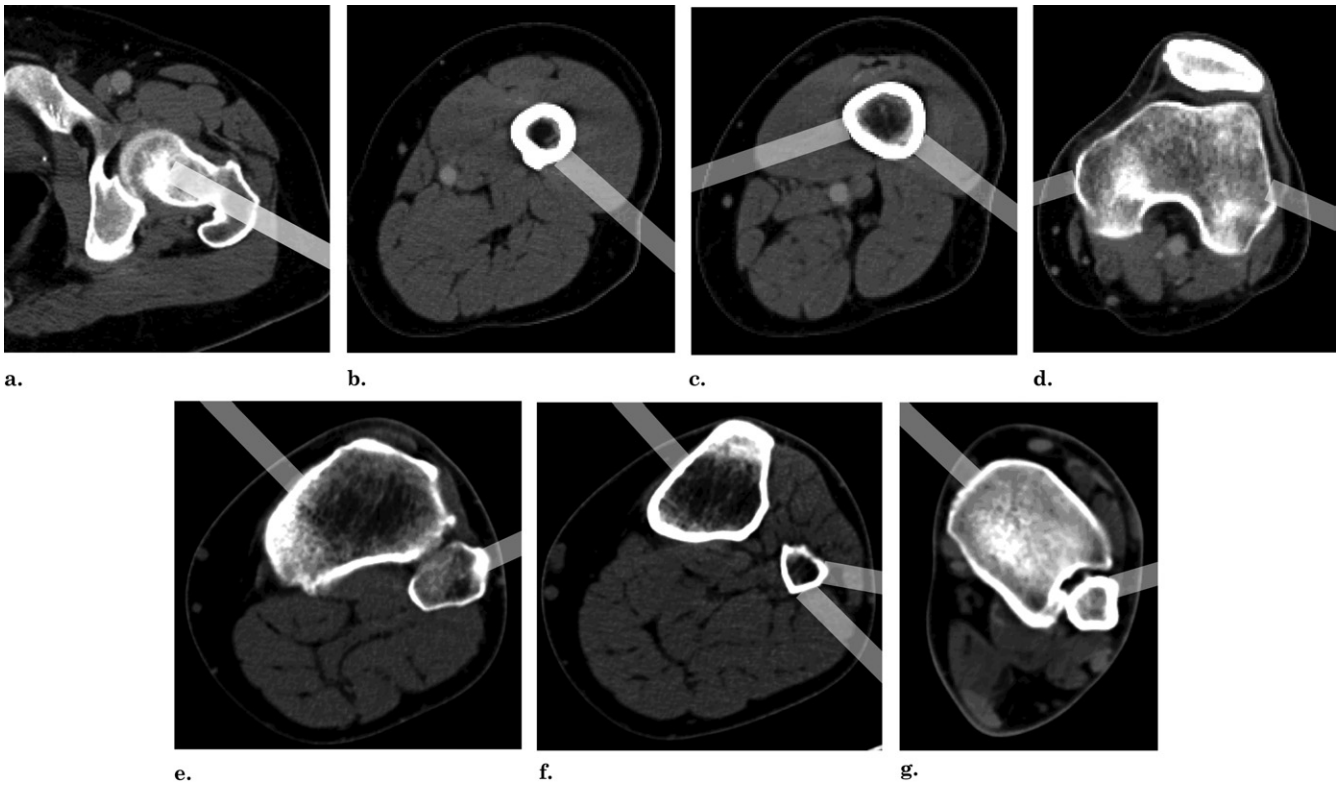

Figure 2. Recommended tracts for the biopsy needle (shaded gray path) for bony tumors of the thigh at the levels of the femoral head and neck **(a)**, femoral diaphysis **(b)**, distal femoral metaphysis **(c)**, and femoral condyles **(d)**; and, for the leg, at the levels of the tibial plateau **(e)**, diaphysis **(f)**, and distal metaphysis **(g)**. This is presented in the manner suggested by Liu et al (9).

Noria et al (25) demonstrated that, when unplanned excisional biopsies or resections occur in referring institutions, residual microscopic disease as the source of local tumor recurrence is present in at least one third of the specimens despite lack of detectable tumor on physical examination or cross-sectional imaging. These studies suggest that, although complications do certainly occur from suboptimal biopsies of musculoskeletal tumors, they are more often directly caused by other technical factors and less experienced staff from referring institutions, and less often from needle tract seeding, which was not separately evaluated by these studies. Even with surgical removal of tumors, surgical bed seeding can rarely occur in addition to tumor recurrences occurring from incomplete margins excised during surgery.

However, it is true that local recurrence is the most significant factor independently associated with decreased survival. Patients who develop local tumor recurrence were reported to be 2.89 times more likely to die from their disease than those without local recurrence (26). It is understandable based on these data that there is significant attention to preventing local recurrences at all cost, and strict biopsy guidelines are published in the literature.

Of the 120 biopsies of bony lesions in the present study sample, 82 did not follow the suggested needle path to performing the biopsy. Of the 82 cases that were noncompliant with this suggestion, 39 (48%) did not comply in view of a shorter skin-to-lesion distance that was prioritized. Other factors accounting for the remaining 52% of these guideline breaches likely included patient comfort and targeting areas of cortical loss and/or soft tissue extension to maximize the chances of obtaining a diagnostic sample. If the authors had been compliant with the suggested intraosseous path to performing the biopsy, it would have entailed unnecessarily breaking through intact cortex, possibly converting a local anesthesia procedure into one requiring sedation (**Fig E2**, available online *www.jvir.org*).

Of the 361 cases that reported the needle type, only 0.6% of cases (n = 2) did not use coaxial technique. Arguably, the use of a coaxial system has the potential of decreasing needle tract tumor seeding rates, as the use of an introducer that remains in the same position during multiple passes of an inner biopsy needle obtaining the sample protects adjacent normal tissue and prevents repeated infiltration of the tract. Maturen et al (27) stated that, despite the published range of seeding rates from 0.6% to 5.1% for hepatocellular carcinoma with the use of various biopsy techniques, their study found a 0% tumor seeding rate after the consistent use of a coaxial needle technique. More studies to attempt to quantify differences in seeding rates with the use of coaxial versus noncoaxial technique are necessary to further evaluate this hypothesis.

In the study of Mohana et al (7), tumor seeding along the biopsy tract was found histologically in three cases of closed biopsy osteosarcoma: two of these had amputations

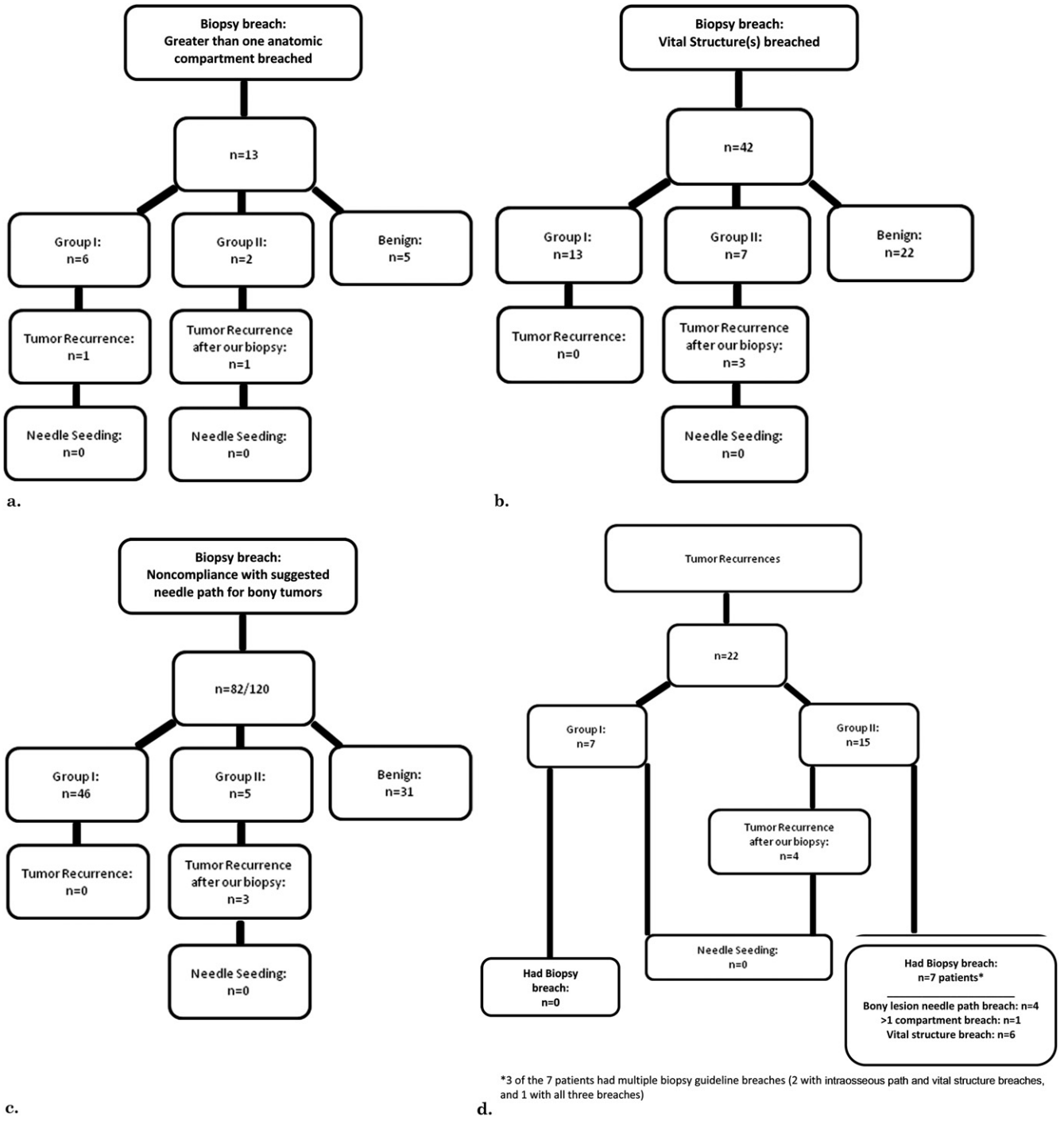

Figure 3. **(a)** Compartment anatomy biopsy breaches and association with tumor recurrences and needle seeding. **(b)** Vital structure(s) biopsy breaches and association with tumor recurrences and needle seeding. **(c)** Suggested needle path biopsy breaches and association with tumor recurrences and needle seeding. **(d)** Tumor recurrences and needle seeding. (*Three of the seven patients had multiple biopsy guideline breaches: two with intraosseous path and vital structure breaches and one with all three breaches.)

before chemotherapy and the third patient showed a poor response to chemotherapy. The significant advances in neoadjuvant chemotherapy for treatment of musculoskeletal tumors is a potential cause of decreased rates of needle tract seeding, and could help explain results in this study demonstrating lack of such recurrences, although the study was not designed to look at efficacy of different treatment methods, and chemotherapy would not be applicable to all the malignant tumors included in the sample.

Musculoskeletal tumors are relatively rare compared with other cancer types and are difficult to study, particularly when assessing for tumor recurrences, which represent an even smaller percentage overall. The present study yielded only 22 patient tumor recurrences, which is a limited number of cases

to evaluate for needle seeding purposes. Statistically, the total number of biopsies may not be large enough to provide the needle tract seeding incidence suggested in the literature. More salient, however, is the number of total biopsy guideline breaches present in this sample, of which none resulted in a tumor recurrence, presuming that needle seeding would always present clinically as a tumor recurrence.

It is possible that not enough time has elapsed, with a follow-up time period of 24–96 months to capture all eventual tumor recurrences for the evaluation of needle tract seeding. Based on reported time to local recurrence for sarcomas in the literature, however, this follow-up interval would be adequate to allow the capture of a significant amount of such recurrences.

An additional limitation of the present study is the lack of means to reliably quantify the rate of patients who are lost to follow-up after the biopsy. A total of six patients among the 188 malignant cases were lost to follow-up, as defined by the absence of clinical notes on the computerized patient records after the date of their biopsy. The mean number of follow-up days was 762, with a median of 637 days and a range of 0–2,863 days.

A total of 231 of the 363 cases in the present sample were performed from 2005 to 2008 and were included in a recent publication by Omura et al (3) to assess for accuracy in biopsy technique at the authors' institution. The authors found their technique to be diagnostic 71% of the time (defined as providing a definitive pathologic diagnosis or being regarded as clinically useful) and accurate 86% of the time (defined as being concordant with the ultimate diagnosis). The cohort of cases from 2002 to 2004 that was included in the present study ($n = 132$) but not in the study of Omura et al (3) did not have any differences in biopsy technique, methodology, or interventionalists performing the procedure and would not be expected to have significantly differing accuracy results. Repeating the analysis for an accuracy rate for the entire sample size in this study is beyond the scope of the present study.

The topic of needle seeding is controversial and plagued with many challenges. Difficulties with performing such studies include the relative rarity of primary musculoskeletal lesions and tumor recurrences, inconsistent reporting of needle seeding when it occurs (along with the associated variable biopsy techniques used), the effect of needle seeding directly on patient outcomes, and differing institutional viewpoints and methodology. A significant amount of additional research is needed to clarify these questions, which would ideally be performed via multiinstitutional collaborations.

In summary, needle seeding has been reported as a real threat in biopsies of musculoskeletal tumors. Although this is possible, the present data suggest that it does not occur frequently. Breaching literature guidelines on performing such biopsies did not cause needle tract seeding in this study, suggesting that other factors such as minimizing patient pain, traversing the shortest skin-to-lesion distance, and avoiding neurovascular structures can also be prioritized, as they are for nonmusculoskeletal biopsies.

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Table E1. Patient and Lesion Demographics

Characteristic	Value
Sex	
Male	187 (51.5)
Female	176 (48.5)
Age (y)	
Range	7–94
Mean	46.5
Location	
Thigh	231 (63.6)
Leg	132 (36.4)
Lesion characteristics	
Lesion compartment	
Intraosseous	120 (33.1)
Soft tissue	243 (66.9)
Lesion size (cm)	
0–3	61 (16.8)
> 3–5	116 (31.9)
> 5–10	126 (34.7)
> 10–20	38 (10.5)
> 20	2 (0.6)
Irregular	20 (5.5)
Lesion depth (cm)	
0–1	19 (5.2)
> 1–3	167 (46.0)
> 3–5	128 (35.3)
> 5–7	34 (9.4)
> 7	15 (4.1)
Pathology and patient group	
Malignant	188 (51.8)
Group I	160 (85.1
Group II	28 (14.9)
Benign	175 (48.2)
Needle type	
Cook 11- or 12/14-gauge	334 (92.0)
Cook 11- or 12/14-gauge and Bonopty	9 (2.5)
Kyphon	12 (3.3)
Bonopty	2 (0.6)
Jamshidi	2 (0.6)
Ostycut/Cook Greene 14.5/18-gauge	1 (0.3)
Parallax	1 (0.3)
Not stated or not reported	2 (0.6)
Surgery	
Total no. of surgeries	131 (69.7)
Total malignant cases	188
Surgery type	
Limb-sparing	110 (84.0)
Amputation	21 (16.0)

Note.—Values in parentheses are percentages.

Table E2. Pathology Results

Malignant	Total
Epithelioid neoplasm	1
Leukemia	1
Lymphoma	9
Metastatic	23
Myeloma/plasmacytoma	4
Myxoid neoplasm (high grade)	1
Peripheral nerve sheath tumor	6
Sarcomas	
Alveolar sarcoma	3
Angiosarcoma	1
Chondrosarcoma	11
Ewing's sarcoma	10
Fibromyxoid sarcoma	2
Giant cell tumor–malignant	2
Leiomyosarcoma	6
Liposarcoma	24
Malignant solitary fibrous tumor	1
Myxofibrosarcoma	7
Myxoid chondrosarcoma (extraskeletal)	2
Myxoid sarcoma	1
Osteosarcoma	19
Osteosarcoma (extraosseous)	1
Osteosarcoma (periosteal)	1
Osteosarcoma (telangiectatic)	1
Rhabdomyosarcoma	2
Sarcoma, not otherwise specified	39
Synovial sarcoma	10
Total malignant	**188**
Benign	
Abscess	3
Aneurysmal bone cyst	5
Baker's cyst	3
Bone cyst solitary	2
Chondroblastoma	6
Chondroma	2
Chondromyxoid fibroma	1
Desmoplastic fibroma	2
Desmoid fibromatosis	6
Enchondroma	1
Fibroma	1
Fibrous histiocytoma	1
Ganglion	6
Giant cell tumor	12
Giant cell tumor tendon sheath	3
Gouty tophus	2
Hemangioma	12
Hematoma	16
Hibernoma	3
Lipoma	10
Myositis	3
Myxofibroma	2
Myxoma	6

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Table E2. Pathology Results (Continued)

Malignant	Total
Nonossifying fibroma	2
Neurofibroma	3
Other elements	33
Osteochondroma	1
Osteomyelitis	7
Pigmented villonodular synovitis	7
Schwannoma	5
Solitary fibrous tumor	2
Smooth muscle tumor (uncertain malignancy)	1
Synovial chondromatosis	1
Stress fracture	1
Tenosynovitis	2
Vascular/venous malformation	2
Total benign	**175**

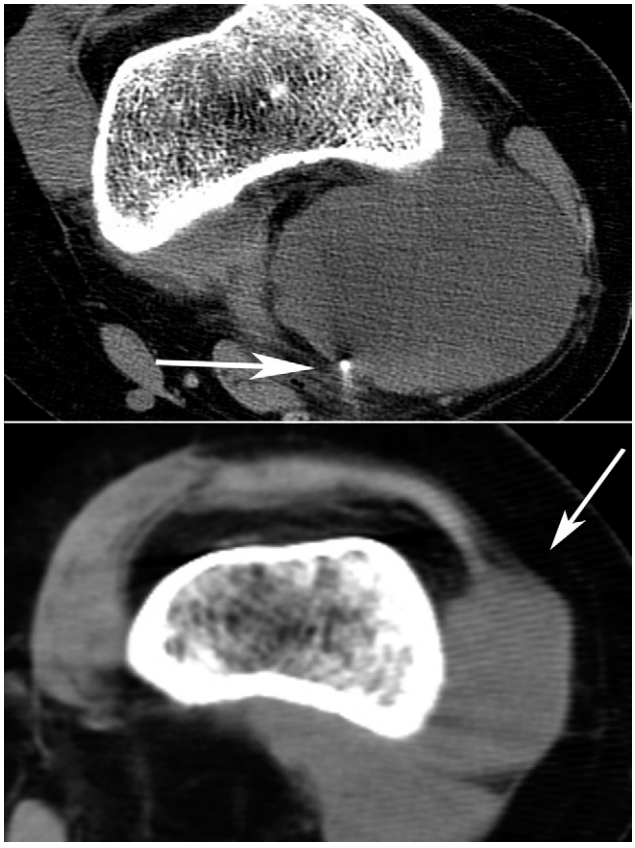

Figure E1. Local tumor recurrence not caused by tumor seeding: axial CT studies of the left distal thigh of a 23-year-old woman with initial biopsy (upper image) demonstrating a large soft-tissue mass in the posterior compartment, with the tip of the biopsy needle identified (arrow); pathologic examination revealed synovial sarcoma. The biopsy needle traversed a posterior approach infiltrating the skin and subcutaneous tissue and entering directly into the mass. Lower image: 14 months later, the patient presented with a local recurrence arising from or invading the vastus lateralis muscle (arrow) in a location clearly separate from the biopsy needle tract.

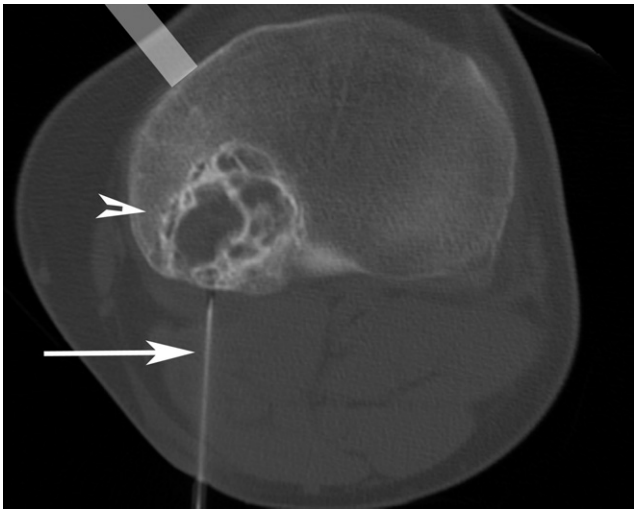

Figure E2. Location of the lesion and choice of biopsy path: axial CT of the proximal tibia. Lobulated bony lesion in the posterior tibial plateau with a thick irregular sclerotic margin and dense septations centrally (arrowhead); pathologic examination proved this to be chondroblastoma. The suggested path for the needle to take is overlying the anteromedial tibial cortex (shaded gray path), though adherence to this guideline would have significantly increased the difficulty level of the biopsy as it would require traversing thick intact cortex before the lesion, with a longer skin-to-lesion distance. Instead, a posterior approach was chosen (arrow marks the needle), allowing for direct entry into thinner abnormal cortex, where the lesion was abutting the posterior aspect of the tibial plateau.