Evaluation of Imaging Utilization Prior to Referral of Musculoskeletal Tumors

A Prospective Study

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Background: Imaging studies are essential when evaluating a patient with a musculoskeletal neoplasm, and they represent a potential waste of resources when used inappropriately. The objective of this study was to prospectively evaluate a consecutive series of patients for inappropriate utilization of imaging prior to referral to a tertiary care facility. Our hypothesis was that advanced imaging is overutilized prior to referral of musculoskeletal neoplasms to a tertiary care center.

Methods: All new patients referred for evaluation of a musculoskeletal neoplasm were prospectively analyzed over a three-month time period. All pre-referral imaging studies were recorded, including radiographs, computed tomographic scans, magnetic resonance imaging scans, bone scans, and 18-fluorodeoxyglucose positron emission tomography scans. Studies were reviewed by two musculoskeletal radiologists and two orthopaedic oncologists and were defined with use of specific preselected criteria as inappropriate if they were not indicated for diagnosis or treatment, if they required repeating because of excessive time since the study was obtained, or if they had poor image quality or technique.

Results: We evaluated 298 consecutive patients (550 imaging studies). The inappropriate utilization rate was 1.5% (three of 204) for radiographs, 36.5% (twenty-three of sixty-three) for computed tomographic scans, 26.7% (fifty-six of 210) for magnetic resonance imaging scans, 45.1% (twenty-three of fifty-one) bone scans, and 45.5% (ten of twenty-two) for positron emission tomography scans. The overall inappropriate use of advanced imaging (magnetic resonance imaging, computed tomography, bone scan, positron emission tomography) was 32.4% (112 of 346 images). With regard to inappropriate use of magnetic resonance imaging, there was no difference between orthopaedic surgeons (28.2%) and primary care physicians (26.5%).

Conclusions: Our data indicate a high prevalence (32.4%) of inappropriate advanced imaging of musculoskeletal tumors prior to referral. This represents a substantial cost to the patient and health-care system, a potential delay of referral, an increase in radiation exposure, and identification of other incidental findings.

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The overall prevalence of bone and soft-tissue sarcoma or other malignancy is exceedingly low, and most orthopaedic surgeons and primary care physicians see very few cases in their careers. When a questionable lesion or mass is encountered, it is important that an efficient work-up be per-

formed to evaluate the possibility of malignancy or other aggressive process and to expedite referral to a tertiary care center when needed. There are multiple imaging resources available to the clinician, including radiographs, computed tomography (CT), magnetic resonance imaging (MRI), radionuclide bone

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TABLE I Breakdown of Performance for Each Imaging Modality by Provider Category*

Imaging Modality and Provider Category	No. of Physicians	No. of Inappropriate Imaging Studies	P Value
Radiograph	204	3 (1.5%)	0.30
Orthopaedic surgeon	119	1 (0.8%)	
Primary care physician	58	2 (3.4%)	
Oncology specialist	12	0 (0.0%)	
Other provider	15	0 (0.0%)	
CT	63	23 (36.5%)	0.89
Orthopaedic surgeon	33	11 (33.3%)	
Primary care physician	11	4 (36.4%)	
Oncology specialist	7	3 (42.9%)	
Other provider	12	5 (41.7%)	
MRI	210	56 (26.7%)	0.45
Orthopaedic surgeon	124	35 (28.2%)	
Primary care physician	49	13 (26.5%)	
Oncology specialist	15	1 (6.7%)	
Other provider	22	7 (31.8%)	
Bone scan	51	23 (45.1%)	0.25
Orthopaedic surgeon	32	18 (56.3%)	
Primary care physician	9	3 (33.3%)	
Oncology specialist	4	2 (50.0%)	
Other provider	6	0 (0.0%)	
PET scan	22	10 (45.5%)	0.97
Orthopaedic surgeon	8	4 (50.0%)	
Primary care physician	2	1 (50.0%)	
Oncology specialist	10	4 (40.0%)	
Other provider	2	1 (50.0%)	

*Statistical analysis was performed to compare orthopaedic surgeons, primary care physicians, and oncology specialists; the other providers were not included in the analysis.

scintigraphy (bone scan), and positron emission tomography (PET) scan. These investigations also incur a substantial cost to the patient and the health-care system, so appropriate utilization is important.

The appropriate utilization of imaging resources for evaluating a musculoskeletal neoplasm has been studied recently with specific attention to MRI utilization^{1,2} as well as radiograph, ultrasound, CT, and bone scan¹. Conflicting reports exist with regard to MRI utilization^{1,2}. Martin et al. stated in a retrospective review that only 35% of new patients referred for a musculoskeletal tumor had undergone MRI². Of the 320 MRI scans performed in that series, only 6% were deemed inappropriate. The study concluded that use of MRI was not excessive, but was limited by its retrospective design. In contrast, Aboulafia et al. reported in a prospective evaluation of 100 patients referred for evaluation of a musculoskeletal tumor that 76% of patients presented with an MRI¹. Of those examinations, 34% were deemed unnecessary. This study was hampered by the lack of specific criteria designating the imaging studies as appropriate or inappropriate. Regional differences may explain some variation in the utilization practices of referring physicians as shown with

these two studies³. Other reports have indicated that overall imaging utilization may not be that disparate⁴.

The aim of this study was to prospectively evaluate the pre-referral imaging practices in musculoskeletal tumors^{1,2,5}. Our hypothesis was that there are a substantial number of inappropriate studies being performed. The ability to identify and to eliminate unnecessary advanced imaging studies represents an area of potential improvement in patient care and decreased health-care cost.

Materials and Methods

We performed a prospective evaluation of a consecutive cohort of patients presenting to a tertiary care referral center for a new evaluation of a potential bone or soft-tissue neoplasm. Patients were excluded if they were self-referred, were referred from a physician within our department, or were referred for a non-neoplastic condition. The study protocol was approved by our institutional review board, which deemed that informed consent was not required.

At the patient's initial evaluation, all pre-referral radiographic investigations were recorded, including radiographs, CT scans, MRI scans, bone scans, and PET scans. We also recorded patient demographic data, specialty of the referring provider, anatomic location of the lesion (exact bone or soft-tissue compartment), pre-referral diagnosis, and final diagnosis after completed evaluation.

The determination of whether a study was appropriate or inappropriate was made with use of carefully selected criteria (outlined below) determined prior to the onset of the study. Appropriate studies were those that both were indicated, as determined by two musculoskeletal radiologists and two orthopaedic oncologists, with use of the predetermined criteria, and were well performed technically. Imaging studies were designated as inappropriate if they were not indicated or were of poor technical quality, necessitating repeating for appropriate patient care. If a study was of suboptimal quality but still yielded adequate information for diagnosis or planning of a biopsy without repeating the study, it was not designated as inappropriate. All decisions were made on the day of the initial evaluation without the benefit of the final histologic diagnosis or final patient outcome.

Indications

Following a thorough review of the records from the referring provider, and performing our own history and examination, we determined whether the pre-referral studies that had been performed were indicated. Criteria were designed to give the benefit of the doubt to the referring providers with regard to their indications for the examination ordered. For example, MRI acquired for intra-articular knee pain with an incidental finding of an enchondroma was not considered inappropriate. However, MRI acquired for the evaluation of an enchondroma with no aggressive radiographic features was considered inappropriate, as radiographic follow-up at an interval of three to six months is considered to be appropriate surveillance.

For radiographs, findings qualifying an imaging study as appropriate were a report of pain localized to a bone or joint or a physical examination demonstrating a limb mass or deformity. For CT, the findings qualifying an imaging study as appropriate were if a radiographic examination suggested a bone lesion with questionable cortical destruction and/or stability, a lesion with a matrix requiring further characterization, or an evaluation of a lesion or mass meeting the criteria for MRI but with an incompatible implant or other contraindication precluding MRI. For MRI, the findings qualifying an imaging study as appropriate were a >5-cm soft-tissue mass in the extremity, any size mass involving, or distal to, the wrist or ankle, a mass with history of growth or that has recently become painful, soft-tissue pain not responsive to a trial of nonsurgical treatment, neurologic symptoms, a need to evaluate intra-articular pathology based on an abnormal clinical examination of the joint, a destructive bone lesion, or a biopsy suggestive of sarcoma with no previous MRI. For bone scan, the findings qualifying an imaging study as appropriate were a differential diagnosis after the above imaging studies or biopsy highly suggestive of primary bone sarcoma, metastatic disease, or disease with multifocal potential (for example, giant cell tumor of bone and eosinophilic granuloma), an evaluation for stress fracture, or an evaluation for activity within a heterotopic ossification lesion. For PET scan, the findings qualifying an image study as appropriate were if it was obtained for one of the Medicare-approved indications⁶, including the staging or restaging of breast cancer, colorectal cancer, esophageal cancer, head or neck cancer, non-small-cell lung cancer, lymphoma, and melanoma and evaluation of an indeterminate solitary pulmonary nodule; an additional accepted indication was evaluation for recurrent soft-tissue sarcoma.

If any study was performed that failed to meet these indications, it was designated as inappropriate. In addition, for radiographs, a study was designated as inappropriate if it was performed for evaluation of a skin lesion with diagnosis evident on physical examination. For CT, a study was designated as inappropriate if there were radiographs and physical examination diagnostic of a benign etiology that required no further characterization or surgical intervention or it was performed for the evaluation of a soft-tissue mass when MRI was more appropriate⁷. For MRI, a study was designated as inappropriate if there were physical examination, radiographs, and/or CT diagnostic of a benign lesion requiring no further characterization or surgical intervention (Figs. 1-A and 1-B). For bone scan, a study was designated as inappropriate if there was a physical examination, imaging, and/or biopsy diagnostic of a lesion not requiring staging with this imaging modality (Fig. 1-C). For PET scan, a study was designated as inappropriate if there was staging or restaging of a malignancy not listed above outside the setting of a clinical study.

Fig. 1

Imaging of a middle-aged patient evaluated for patellofemoral pain. The arrows demarcate an incidentally noted solitary, well-circumscribed, partially mineralized lesion eccentrically located along the distal femoral intramedullary canal without associated periosteal reaction or endosteal cortical scalloping. These findings are diagnostic of a benign enchondroma. Anteroposterior (**Fig. 1-A**) and lateral (**Fig. 1-B**) radiographic views. The referring physician then acquired unnecessary MRI solely for the purpose of further evaluation of the lesion. The T1-weighted sequence (**Fig. 1-C**) and the T2-weighted sequence (**Fig. 1-D**) demonstrate a geographic distal femoral intramedullary lesion that is isointense to skeletal muscle on the T1 sequence and hyperintense on the fluid-sensitive T2 image without associated endosteal scalloping or adjacent marrow edema.

Study Quality

Studies repeated at our institution with the intention to document biologic activity were not designated as inappropriate. Any imaging study repeated at our institution for the following reasons was designated as inappropriate: poor image quality of the original study, poor technique of the original study (failure to image entire lesion, failure to obtain proper sequences and reconstructions, and lack of intravenous contrast in a lesion where the differential diagnosis suggested that it would be helpful). Studies receiving this designation were reviewed by two musculoskeletal radiologists (C.W.D. and C.H.B.) who had to both concur that the study was of sufficiently poor quality to necessitate repeating. Any study that was poor quality, but not repeated (that is, sufficient for planning biopsy), was not designated as inappropriate.

TABLE II Estimated Unnecessary Spending for Inappropriate Imaging Studies Based on 2013 Medicare Reimbursement Schedules

Imaging Modality	Medicare Charges	No. of Patients	No. of Inappropriate Imaging Studies	Cost*
Radiograph	\$54.50	204	3 (1.5%)	\$163.50
CT	\$217.74	63	23 (36.5%)	\$5008.02
MRI	\$396.11	210	56 (26.7%)	\$22,182.16
Bone scan	\$295.31	51	23 (45.1%)	\$6792.13
PET scan	\$1056.12	22	10 (45.5%)	\$10,561.20

*The total cost is \$44,707.01.

Radiologist Recommendations

For all studies that were designated as inappropriate on the basis of indications alone (not study quality), we reviewed the accompanying radiology reports for all radiographic studies performed prior to referral. If we classified an imaging study as not indicated and it had been recommended by an outside radiologist in a written report from another imaging modality, the recommendation of that radiologist was recorded. If reports were incomplete or not available, that was similarly noted.

Cost Analysis

Excess cost was estimated on the basis of the combined 2013 Medicare physician fee and hospital reimbursement rates⁸. Total excess United States dollar amounts were calculated for each study as well as the average excess dollar amount per patient evaluated. Given the variety of anatomic locations that were imaged, an average cost for each modality was calculated on the basis of all anatomic sites included in this analysis. The values utilized for analysis were \$54.50 for radiographs, \$217.74 for CT scan, \$396.11 for MRI, \$295.31 for bone scan, and \$1056.12 for PET scan.

Statistical Analysis

Study data were collected and were managed with use of REDCap (Research Electronic Data Capture)⁹ tools hosted at the University of Florida. REDCap is a secure, web-based application designed to support data capture for research studies, providing an intuitive interface for validated data entry, audit trails for tracking data manipulation and export procedures, automated export procedures for seamless data downloads to common statistical packages, and procedures for importing data from external sources. The number and percentages of inappropriate or appropriate studies performed for each imaging modality were calculated. Subgroup analyses were performed comparing the rate of inappropriate usage for each imaging modality among primary care physicians, orthopaedic surgeons, and oncology specialists with use of chi-square analysis; significance was set at $p < 0.05$.

Source of Funding

There was no source of external funding for this study. Clinical and Translational Science Institute (CTSI) grant support through the National Institutes of Health National Center for Advancing Translational Sciences (NCATS) grant UL1 TR000064 provided institutional support for REDCap.

Results

Two hundred and ninety-eight consecutive new patients were enrolled over three months. The average patient age was forty-six years (range, two to ninety-four years). The majority of referrals were from orthopaedic surgeons (140 patients [47%]) and primary care physicians (eighty-four patients [28%]). The remaining referral sources were medical, surgical, or radiation oncologists (twenty-four patients [8%]), general surgeons (twenty patients [7%]), and other specialties (thirty patients [10%]).

Five hundred and fifty pre-referral imaging studies were performed. Twenty patients (6.7%) presented with no imaging studies. Two hundred and four radiographs were made, with only three (1.5%) designated as inappropriate.

Of the sixty-three CT scans performed, twenty-three (36.5%) were inappropriate. There was no significant difference ($p = 0.89$), based on our numbers, among provider categories in inappropriate utilization. The most common reason for an inappropriate CT was the evaluation of a soft-tissue mass when MRI would have been the most appropriate imaging modality and was not contraindicated (sixteen CT scans [69.6%]). Fifteen CT scans were ordered without prior radiographic evaluation, four of which (all appropriate) were performed to evaluate a symptom that led to the finding of a bone lesion. These four examinations were designated as appropriate as we acknowledged that, on the basis of the radiographic appearance, we would have ultimately ordered the CT scan.

Two hundred and ten MRI scans were ordered in 192 patients; fifty-nine (28.1%) of these scans were inappropriate. Three examinations were of very poor quality, although adequate for biopsy, and were not designated as inappropriate. Although no significant difference ($p = 0.45$) in inappropriate utilization rate was noted among provider categories, it was noted that only one of the fifteen MRI scans ordered by an oncology specialist was inappropriate. The most common reason for inappropriate MRI was imaging of a bone lesion that possessed clearly benign characteristics on radiography and/or CT scan and required no more than serial radiographic surveillance (twenty-eight MRI scans [47.5%]). In total, sixty-two MRI scans were ordered without prior radiographic evaluation. Of those, twenty (thirteen appropriate and seven inappropriate) were made for the evaluation of bone or joint pain or a bone lesion. The thirteen appropriate studies were considered as such as we conceded that, had the radiographs been seen, we would have ordered the MRI.

Twenty-three (46%) of fifty bone scans were inappropriate. No significant difference ($p = 0.25$) was noted among provider categories. Most inappropriate bone scans were obtained to evaluate lesions that were clearly benign on radiography, CT, or MRI and had no substantial risk of polyostotic disease (twenty bone scans [87.0%]).

Of the twenty-two PET scans, ten (45.5%) were inappropriate. Seven inappropriate studies were non-standard staging

examinations, and three were performed to evaluate benign diagnoses.

A review of radiologist reports identified that thirty (26.1%) of the 115 inappropriate studies performed were recommended in a report of a previous imaging study. An additional seventeen inappropriate imaging studies performed (14.8%) had a prior imaging study with no available written report for review.

A summary of the results is provided in Table I.

The total estimated cost for all inappropriate studies was \$44,707 based on 2013 Medicare reimbursement rates. This equates to an excess spending of \$150 per patient evaluated. The 2013 Medicare physician reimbursement and hospital charges and unnecessary cost for each imaging modality in this analysis are included in Table II.

Discussion

The literature contains discrepant results on inappropriate imaging of musculoskeletal neoplasms. Martin et al. noted that only twenty (6.25%) of 320 MRI scans were unnecessary or required repeating². In contrast, Aboulafia et al. noted inappropriate use of CT scans in 36.1%, MRI scans in 34.2%, and bone scans in 42.5%¹. The aim of this investigation was to objectively evaluate this discrepancy by designing strict predetermined criteria for designation of inappropriate studies to apply to a prospective consecutive series. We showed that the inappropriate utilization rate of all advanced imaging modalities was 32.4%, with 36.5% for CT, 26.7% for MRI, 45.1% for bone scan, and 45.5% for PET scan.

A concerning observation was the practice of ordering advanced imaging studies (sixty-three MRI scans and fifteen CT scans) without first evaluating a radiograph. Moreover, in twenty instances, MRI was the initial test for evaluation of pain related to a bone, joint, or osseous mass. In seven of these instances, the MRI was unnecessary, as a radiograph would have been diagnostic. In many instances, MRI would have been an eventual part of our work-up, and, as such, we did not include the performance of MRI without prior radiograph as inappropriate in this analysis. However, had we done so, inappropriate MRI utilization rates would have increased from 26.7% to 36.2%, suggesting that the practice of bypassing radiographs in favor of advanced imaging is highly prevalent.

A large number (26.1%) of the inappropriate imaging studies were recommended by a radiologist from the referring institution. The likely reason for this is that musculoskeletal neoplasms are as uncommon for general radiologists as for other specialties. Our recommendation is that if physicians find themselves in this situation, the patient should be referred to the tertiary care institution to complete any additional work-up needed.

When considering only MRI expenses, we noted an excess spending of \$22,182 (an average of \$74 per patient evaluated) attributed to this modality alone. This cost contrasts with the study by Martin et al. reporting \$11,474 of unnecessary MRI expenses (an average of \$12 per patient evaluated) in their analysis of 920 patients². Our cost analysis is likely an underestimation of the true cost, which is not readily measured. Further contributing to our underestimation of cost is that

Medicare reimbursement is generally lower than other health-care payers. Additionally, we have not accounted for the additional potential downstream costs incurred from further evaluation of incidental findings noted on the unnecessary imaging study such as additional clinical follow-ups, referrals to other specialists, additional diagnostic imaging tests, unnecessary surgical biopsy, time away from work, and travel costs. In addition to monetary costs, there are additional medical risks associated with additional work-up such as radiation exposure¹⁰⁻¹² and potential reactions to intravenous contrast¹³.

To our knowledge, this is the first study that evaluates the appropriate utilization of PET scans in patients with musculoskeletal tumors. Our criteria of appropriate utilization of PET scans were those that were performed for indications recognized as appropriate by Medicare⁶. Ten of the twenty-two PET scans were inappropriate in our analysis. Three were performed to evaluate benign neoplasms, and seven were performed as part of a non-standard staging process, including three for the initial staging of a soft-tissue sarcoma. Although there have been several studies demonstrating the potential utility of PET scans in sarcoma staging¹⁴⁻¹⁹, this staging modality is still considered investigational and should be limited to performance in a clinical study setting.

The limitations of this study included variable quality documentation from referring institutions that occasionally required the patients to recall supplemental information from the time of their initial examination. Nevertheless, we believe that our methods provided a clear delineation of appropriate and inappropriate evaluations. An additional weakness of this study was that none of the investigators were blinded to the goals of the study. However, all decisions were made without the benefit of the final histologic diagnosis or clinical outcome of the patient.

The work-up performed by referring providers was likely performed to expedite the evaluation process prior to referral. However, our data indicate that the inappropriate utilization rate is unacceptably high. We recommend that patients in whom further work-up is needed be referred directly to the tertiary care facility where the need for further imaging evaluation can be determined by a multidisciplinary team of orthopaedic oncologists and musculoskeletal radiologists. This allows the treating physician to order the minimum evaluation necessary and protocol the examination for optimal evaluation of the lesion in question. Following this recommendation would result in the most cost-effective and clinically effective treatment of patients with a musculoskeletal neoplasm. ■

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