Accuracy of MRI-based Diagnoses for Distal Upper Extremity Soft Tissue Masses

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Abstract To determine the accuracy of the pre-operative MRI-based diagnosis of soft tissue masses in the forearm, wrist, and hand, the records of 144 patients who underwent an MRI followed by excision of a soft tissue mass in the forearm, wrist, or hand were reviewed. The MRI-based diagnosis was compared to the histological diagnosis, which was considered the gold standard. The sensitivity, specificity, positive predictive value, and negative predictive value of the MRI-based diagnosis were calculated. A multivariate regression analysis was performed. While the accuracy of the MRI-based diagnosis varied widely, there was an overall sensitivity of 75 %. The most accurate diagnosis was an MRI-based diagnosis of ganglion cyst, which had a sensitivity of 94.7 % and a specificity of 94.4 %. Of particular concern was that the MRI-based diagnosis of a malignancy was only 66.7 % sensitive, with a positive predictive value of 44.4 %. On multivariate regression analysis, there was a trend towards improved accuracy in the wrist when compared to the finger, although this did not reach statistical significance. While pre-operative MRI remains a valuable tool for the evaluation of soft tissue masses in the distal upper extremity, caution is warranted when basing the diagnosis on MRI evidence alone. Level of Evidence: Level IV/Diagnostic

Keywords Benign tumor · Imaging · Malignant tumor · MRI · Upper extremity

Introduction

Soft tissue masses of the forearm, wrist, and hand are a common complaint in a hand surgeon's clinic. These masses are caused by a wide variety of processes, including cystic changes, vascular malformations, fibrosis, and neoplasia. While the majority of these are benign, locally aggressive and malignant soft tissue tumors can arise in the distal upper extremity [1].

The accurate diagnosis of soft tissue masses in the forearm, wrist, and hand prior to surgical intervention is crucial for preoperative planning. Being able to reliably differentiate between benign and malignant etiologies pre-operatively is particularly important. The location and orientation of the incision, the width of the margin of surrounding tissue included in the resection, and the management of nearby neurovascular structures all depends on the pre-operative differential diagnosis. The pre-operative differential diagnosis is determined by history and physical exam, plain radiographs, advanced imaging modalities, and occasionally tissue biopsy. While tissue biopsy is the gold standard for pre-operative diagnosis, it is invasive and potentially contaminates the soft tissues along the biopsy track.

Increasingly, magnetic resonance imaging (MRI) has been used to establish the pre-operative differential diagnosis of soft tissue masses throughout the body, including in the forearm, wrist, and hand. With the advent of extremity coils and higher Tesla magnets, MRI scans of the forearm, wrist, and hand have improved in quality [2, 3]. It is not clear, however, if the improvement in image quality has translated into more accurate pre-operative differential diagnoses for soft tissue masses.

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Prior studies have described the appearance of various soft tissue masses on MRI scans [4–6]. While benign lesions such as ganglion cysts and lipomas have a classic MRI appearance, multiple prior studies note that MRI cannot reliably distinguish between benign and malignant soft tissue masses in the distal upper extremity [7–9]. However, these studies all pre-date the recent MRI technological advances, and only one compared the pre-operative MRI diagnosis to the gold standard of post-operative tissue diagnosis.

The purpose of this study is to compare the pre-operative differential diagnosis based on MRI imaging to the post-operative histological diagnosis for patients with soft tissue masses of the forearm, wrist, and hand. We hypothesize that the MRI diagnosis and the histological diagnosis will demonstrate a high correlation.

Materials and Methods

After obtaining permission from our Institutional Review Board, we conducted a retrospective chart review. Patients were eligible for inclusion if they were over the age of 18 and underwent excision of a forearm, wrist, or hand soft tissue mass at our institution between January 1, 2008 and November 1, 2013. Patients were excluded if there was no pre-operative MRI scan available. To limit confounding variables, we also excluded all patients with an MRI scan that was performed or interpreted elsewhere. This allowed us to ensure that all MRI scans included in this study were of uniform quality. Patients were also excluded if there was no surgical pathology report available.

Data collected included patient age, hand dominance, duration of symptoms, involved extremity, location of lesion, and findings on plain radiographs. The MRI technique, including the administration of IV contrast, the use of an extremity coil, and the magnet strength were also noted. The MRI report was reviewed and all possible diagnoses listed by the attending radiologist were recorded. The radiologist's level of training, specifically whether or not they had completed a musculoskeletal radiology fellowship, was noted. Lastly, the surgical pathology report was reviewed for pertinent items, such as lesion size and histological diagnosis.

Once all data had been collected, the correlation between the differential diagnosis given on the MRI report and the confirmed histological diagnosis was examined. The histological diagnosis was considered the gold standard, and if the MRI-based diagnosis correlated with the histological diagnosis, it was considered a true positive. The number of true positive, true negative, false positive, and false negative MRI reads were recorded for each diagnosis seen in our population. The sensitivity, specificity, positive predictive value, and negative predictive value were calculated for each diagnosis using standard methods.

A multivariate regression analysis was conducted to identify any variables that were independently associated with the accuracy of the radiologist's pre-operative MRI interpretation. Continuous variables were expressed by their quartiles (i.e. 25th, 50th, 75th) along with their mean and standard deviation, categorical variables as frequencies and percentages. The distribution of continuous variables stratified by outcome was also displayed graphically using box-plots. To test the unadjusted univariate associations between risk factors and Group-Type, Pearson chi-square tests were used for categorical variables and Kruskal-Wallis tests were used for continuous variables. Multivariable regression analyses were constructed to examine which risk factors were independently associated with Group-Type, due to the binary form of the outcome variable a logistic regression model was fit. All risk factors were pre-specified, by default, continuous variables are modeled non-linearly with restricted cubic splines. But with each of the continuous variables in the model showing little to no evidence of non-linearity, with the smallest p-value of a non-linear effect equal to 0.11, continuous variables were modeled

Table 1 Diagnoses

Diagnosis	Number of Patients
Ganglion cyst	57
Lipoma	16
Giant cell tumor of tendon sheath	14
Vascular malformation	12
Inflammatory/reactive change	12
Benign nerve sheath tumor	9
<i>Schwannoma</i>	5
<i>Neurofibroma</i>	4
Fibrous lesion	8
<i>Superficial fibromatosis</i>	4
<i>Nodular fasciitis</i>	2
<i>Calcifying aponeurotic fibroma</i>	1
<i>Benign fibrous lesion NOS</i>	1
Malignancy	6
<i>High grade undifferentiated sarcoma</i>	2
<i>Metastatic renal cell carcinoma</i>	1
<i>Synovial sarcoma</i>	1
<i>Liposarcoma</i>	1
<i>Malignant peripheral nerve sheath tumor</i>	1
Benign skin lesion	5
<i>Epidermal inclusion cyst</i>	3
<i>Chondroid syringoma</i>	1
<i>Granuloma annulare</i>	1
Chondroma	2
Glomus tumor	2
Sarcoidosis	1
Total	144

Table 2 Statistics

	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Ganglion cyst	94.7	94.4	91.5	96.6
Giant cell tumor	85.7	93.2	57.1	98.4
Vascular lesion	66.7	97.8	72.7	97.1
Benign nerve sheath tumor	88.9	99.3	88.9	99.3
Lipoma	68.8	100	100	96.4
Fibrous lesion	12.5	100	100	95.3
Benign skin lesions	20	99.3	50	97.3
Inflammatory or reactive changes	58.3	99.3	87.5	96.5
Malignancy	66.7	96.4	44.4	98.5

as linear terms. Parameter estimates were exponentiated to obtain odds ratios and 95 % confidence intervals, and to avoid casewise deletion of records with missing covariates, we employed multiple imputation via predictive mean matching. All analyses were conducted in R version 3.1.0.

Results

One hundred and forty-four patients met our inclusion criteria. Average age in our population at time of presentation to the

clinic was 45 years old (range 18–89). There were 97 female and 47 male patients. The average time the mass had been present prior to seeking care was just over 2 years (range 2 weeks to 10 years). The MRI was done with intravenous contrast administration in 57 patients and without contrast in 87 patients. Nineteen patients had their MRI on a 1.0 Tesla machine, 62 on a 1.5 Tesla machine, and 63 on a 3.0 Tesla machine. All were done with the use of an extremity coil.

The five most common histological diagnoses seen in our population were ganglion cyst, lipoma, giant cell tumor of tendon sheath, vascular malformation, and inflammatory/

Fig. 1 Patient with pre-operative MRI based diagnosis of a ganglion cyst and post-operative histological diagnosis of a synovial sarcoma. Selected imaging. **a** Axial T2 **b** Sagittal T2

Table 3 Malignant tumors

	MRI report	Histologic diagnosis
Malignant tumors with <i>correct</i> MRI-based diagnosis	Metastatic disease is favored	Metastatic renal cell carcinoma
	Favored to represent a low grade liposarcoma	Well differentiated liposarcoma
	Primary soft tissue sarcoma is favored	High grade undifferentiated sarcoma
	Findings are most consistent with a malignancy	Undifferentiated pleomorphic sarcoma
Malignant tumors with <i>incorrect</i> MRI-based diagnosis	Dorsal ganglion cyst	Synovial sarcoma
	Soft tissue mass (not otherwise specified)	Malignant peripheral nerve sheath tumor
Benign tumors diagnosed as malignant on MRI	Suspicious for a low grade liposarcoma	Lipoma
	Most consistent with a low grade liposarcoma	Lipoma
	Highly concerning for soft tissue sarcoma	Chondroma
	Ewing's sarcoma is the favored diagnosis	Desmoid tumor
	Highly concerning for a neoplastic process	Granulomatous inflammation

reactive changes. These five entities accounted for 77 % of all masses. The remainder included a wide variety of diagnoses, such as nerve sheath tumors, fibrous lesions, benign skin lesions (such as epidermal inclusion cyst), and benign masses including chondromas and glomus tumors. There were five malignancies identified in this series; one metastatic renal cell carcinoma, one liposarcoma, one synovial sarcoma, and two high grade undifferentiated soft tissue sarcomas. See Table 1 for a complete list of all diagnoses in this series.

Overall, the pre-operative diagnosis based on the MRI correlated with the post-operative histological diagnosis in 108 of the 144 patients, for an overall sensitivity of 75 %. The sensitivity and specificity of the MRI diagnosis varied widely by the type of diagnosis, however. Table 2 demonstrates the variability

in sensitivity, specificity, positive predictive value, and negative predictive value for each of the diagnoses seen in this series.

It is particularly concerning that the sensitivity and positive predictive value of an MRI-based diagnosis of malignant soft tissues masses is limited. In one patient with a histologically diagnosed synovial sarcoma, the pre-operative MRI-based diagnosis was a ganglion cyst (Fig. 1). In another patient with a histologically diagnosed malignant peripheral nerve sheath tumor, the pre-operative MRI-based diagnosis was “soft tissue mass” with no attempt made at a differential diagnosis. In five other patients with histologically proven benign diagnoses, the pre-operative MRI-based diagnosis was a malignancy, including two MRI-based diagnoses of liposarcomas, two soft tissue sarcomas, and one Ewing's sarcoma (Table 3).

Fig. 2 Patient with pre-operative MRI based diagnosis of a liposarcoma and post-operative histological diagnosis of a lipoma. Selected imaging. **a** Axial T1, T2, and T2 post-contrast **b** Sagittal T1

Results of the multivariate regression analysis demonstrated that the pre-operative MRI based diagnosis was more likely to correlate with the post-operative histological diagnosis if the radiologist listed only one primary diagnosis on the MRI report. (OR 3.49, $p=0.009$) In addition, there was a trend towards increased accuracy in wrist masses when compared to finger masses. Finger masses made up 44 % of the group with inaccurate pre-operative diagnoses, but only 20 % of the group with an accurate pre-operative diagnosis. Conversely, wrist masses made up only 19 % of the inaccurate diagnosis group, and 47 % of the accurate diagnosis group. This trend did not reach statistical significance, however. (OR 0.35, $p=0.07$) No other variables showed significance in the multivariate regression analysis.

Discussion

Prior investigations have demonstrated that the accuracy of the MRI-based diagnosis of soft tissue masses in the forearm, wrist, and hand varies widely. A report on the MRI findings in 20 patients with histologically proven benign peripheral nerve tumors found a sensitivity of 75 %, with 15 of the 20 MRIs suggesting the correct diagnosis [10]. A report of 42 patients with clinically diagnosed glomus tumors that underwent an MRI as part of their pre-operative work-up showed a sensitivity of 86 % [11]. A review of the records of 87 patients with well-differentiated liposarcoma found that pre-operative MRI diagnosis had a sensitivity of 90.9 %, specificity of 37.0 %, positive predictive value of 46.7 %, and negative predictive value of 86.9 % [12]. Liposarcoma remains a histological diagnosis, since its appearance on imaging is very similar to that of a lipoma. Radiologists should avoid interpreting a fatty mass seen on MRI as a liposarcoma (Fig. 2).

Although MRI technology has improved in recent years, these advances may not have improved the accuracy of pre-operative diagnosis of soft tissue masses in the distal upper extremity. Investigations similar to this study conducted in the 1990s show similar results. In 1990 Binkowitz et al. reviewed 22 cases of soft tissue masses in the hand and wrist. In their series, all lesions were correctly identified as benign or malignant on pre-operative MRI. Of the benign masses, the radiologist identified the diagnosis correctly in 56 % of patients [8]. In 1994, Miller et al. found that MRI was 80 % sensitive in a review of 20 cases of benign soft tissue masses of the wrist and hand [9]. As these studies suggest, our study also shows that while pre-operative MRI for soft tissues masses in the distal upper extremity can be a helpful tool, caution is warranted when basing the pre-operative diagnosis on MRI analysis alone.

We are not aware of any investigations that have examined the accuracy of MRI for soft tissue masses in the finger. Although the trend towards decreased accuracy of MRI-

based diagnosis in soft tissues masses of the finger did not reach statistical significance in this study, further investigation into this issue is warranted.

Our study does have several limitations. The retrospective nature of this study limits the level of evidence. The small number of patients for each individual diagnosis limits statistical analysis and makes some subsets underpowered. This study is not able to comment on the use of MRI for monitoring tumor recurrence or as a modality for monitoring the changes in soft tissue masses over time. Lastly, in the clinical setting, the addition of the history and physical exam and other imaging modalities may potentiate the MRI findings. In fact, our results suggest that a history and physical exam remain very important in evaluating soft tissue masses since the MRI-based differential diagnosis is not as accurate as we hypothesized.

Differentiating between benign and malignant soft tissue masses pre-operatively is crucial for surgical planning. When resecting soft tissue masses in the distal upper extremity, clinicians should be cautious when basing intra-operative decisions on the pre-operative MRI diagnosis alone. With a sensitivity of 75 %, the MRI based diagnosis is not definitive. Other factors, such as the history and physical exam findings, should be taken into account, and obtaining a pre-operative tissue diagnosis should be considered.

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Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Conflict of Interest The authors have no conflicts of interest to disclose that relate to the submitted work. Dr. Donald Lee does have the following financial relationships outside of the submitted work: Biomet (Consultant, Speaker Fees, and Payments for Educational Presentations).

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