Predicting Fracture Risk for Enchondroma of the Hand

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Abstract

Background: Enchondromas are benign cartilage tumors that can cause pathologic fractures involving the digits of the hand. The purpose of this study is to identify objective reproducible clinical criteria that are associated with fracture that can be used to guide clinical decision making. **Methods:** A total of 54 enchondroma cases involving the hand were retrospectively reviewed. Criteria examined included age, gender, the hand involved (left vs right), bone involved, the digit involved, and longitudinal percentage of the bone occupied by the lesion on anteroposterior (AP) radiographs. **Results:** There was a statistically significant difference between the fracture and nonfracture group in regard to age, the digit involved, bone involved, and the percentage of bone occupied by the lesion on AP radiographs. **Conclusion:** This investigation provides evidence that patient age, the affected finger, the affected bone, and the percentage of the bone occupied by the pathologic lesion on AP radiographs can be used to predict pathologic fracture risk for enchondromas.

Keywords: enchondroma, pathologic fracture, tumor, hand

Introduction

Enchondromas are benign cartilage tumors representing the most common primary bone tumor of the hand.^{2,8} Solitary enchondromas are believed to arise from remnant growth plate cartilage during bone development.^{5,10} They can be asymptomatic and are often found incidentally when radiographs are taken to evaluate clinical problems unrelated to the lesion. Despite their benign behavior, these lesions can compromise the structural integrity of bone resulting in pathologic fractures.

Common indications for surgical treatment of enchondromas include pain, malignant degeneration, and pathologic fracture requiring open reduction and internal fixation.⁹ The role of prophylactic surgery to treat asymptomatic lesions before they fracture is currently unclear. In many cases, asymptomatic enchondromas can be observed over time with serial radiographs and will never go on to fracture.⁷ However, when fractures do occur, they can result in significant damage to the joints, ligaments, tendons, and neurovascular structures of the hand. Subsequent surgical procedures necessary to treat fractured lesions are potentially made more complicated by the fracture, increasing the chances for tumor recurrence, postsurgical scarring, stiffness, and chronic pain.⁴

A variety of scoring systems have been developed to predict fracture risk in association with bone lesions; the most notable is Mirel's criteria for metastatic lesions involving the long bones.^{1,3,6} The bones of the hand however have

unique mechanical properties and physical demands placed on them making traditional scoring systems unreliable. In this investigation, surgically treated enchondromas were retrospectively reviewed to identify objective reproducible criteria that could potentially be used to develop a model for predicting the risk of pathologic fracture for bone lesions occurring in the hand.

Materials and Methods

Seventy-six surgical cases of biopsy proven enchondromas involving the hand were reviewed to determine if radiographic and clinical criteria could be used to determine the likelihood of a patient having a pathologic fracture. All cases were performed between 1994 and 2012 at a single institution by 14 different surgeons. Institutional review board approval in compliance with ethical standards for human research was obtained for this study.

The decision to operate on each lesion was made at the discretion of the treating surgeon using their best clinical judgment. The presence or absence of a fracture for each case was

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Table 1. Distribution of Enchondromas.

	Distal phalanx	Middle phalanx	Proximal phalanx	Metacarpal	Total
Thumb	1	—	2 (1)	1	4
Index	0	0	4 (3)	2	6
Long	1 (1)	5 (1)	3 (3)	1 (1)	10
Ring	4 (4)	2 (1)	5 (3)	3	14
Small	5 (5)	3 (3)	9 (8)	3 (3)	20
Total	11	10	23	10	

Note. Figures in parentheses indicate enchondromas that presented with a fracture.

determined based on review of the preoperative radiographs and direct intraoperative observation as documented in the surgical operative report. Cases in which preoperative radiographs were unavailable and syndromic cases of enchondromatosis (eg, Ollier, Maffucci syndrome) were excluded from analysis. In total, 22 cases were excluded leaving a total of 54 cases (in 54 patients) for statistical analysis. There were 37 bone lesions associated with a pathologic fracture, and 17 bone lesions that had no identifiable fracture (Table 1).

The criteria examined in this study included, gender, hand involved (right or left), affected finger (thumb, index, long, ring, small), bone involved (distal phalanx, middle phalanx, proximal phalanx, and metacarpal), age, and the longitudinal percentage of bone occupied by the lesion on anteroposterior (AP) radiographs. All the data collected for this study were obtained from chart review and examination of preoperative radiographs. AP radiographs were used for determining the longitudinal percentage of bone taken up by the lesion. Lateral radiographs were not used to measure enchondroma size, because of the variability in imaging techniques between patients, where oblique radiographs are commonly used instead of true lateral views to avoid superimposing fingers over one and other. The percentage of tumor involvement in the transverse plane was not assessed because the vast majority of the lesions were found to involve more than 90% of the transverse diameter of the bone. As the majority of the lesions did not show a measurable difference in transverse diameter, it was not possible to use this criterion as a clinical predictor of fracture risk in this study. The longitudinal length of the bone and the enchondroma were measured using the most distal and most proximal aspects of the bone/lesion that were located along the mid-axial line of the involved bone (Figures 1a-1c). Radiographic measurements were performed independently by 2 different clinicians (an orthopedic surgeon, and a medical student); the average of the 2 measurements was used for the final statistical analyses.

Statistical Analysis

Statistical analyses were used to compare clinical and radiographic criteria between the fracture and nonfracture groups. Odds ratios (ORs) were calculated for each clinical

Figure 1. (a) Enchondroma present in the proximal portion of the proximal phalanx. (b) A line along the mid-axial line is measured between the most distal and most proximal aspects of the lesion. (c) The entire length of the proximal phalanx is measured using a mid-axial line drawn between the most distal and proximal aspects of the proximal phalanx.

criterion; the chi-square test was used to assess the statistical significance of each variable. The intraclass correlation coefficient was used to assess the reliability of the tumor measurements made by the 2 independent clinical investigators. Statistical significance was set at $P < .05$.

Results

There was a statistically significant difference between the fracture and nonfracture group in regard to age ($P = .0271$), the digit involved ($P = .0075$), specific bone involved ($P = .0307$), and percentage of the bone invaded by the lesion on AP radiographs ($P = .0168$). A statistically significant association was

Table 2. Statistical Relationship Between Clinical Criteria and Presence of Pathologic Fracture.

	No fracture (n = 17)	Fracture (n = 37)	Total (N = 54)	
Gender				$P = .0582$
Male	3 (15.8%)	16 (84.2%)	19 (35.2%)	OR = 3.55 (0.96-17.34), $P = .0582$
Female	14 (40.0%)	21 (60.0%)	35 (64.8%)	Reference
Side				$P = .9393$
L	9 (31.0%)	20 (69.0%)	29 (53.7%)	OR = 0.96 (0.30-3.07), $P = 0.9393$
R	8 (32.0%)	17 (68.0%)	25 (46.3%)	Reference
Finger				$P = .0075$
Small	1 (5.0%)	19 (95.0%)	20 (37.0%)	OR = 12.67 (1.52-275.39), $P = .0176$
Ring	6 (42.9%)	8 (57.1%)	14 (25.9%)	OR = 0.89 (0.16-4.65), $P = .8886$
Long	4 (40.0%)	6 (60.0%)	10 (18.5%)	Reference
Index	3 (50.0%)	3 (50.0%)	6 (11.1%)	OR = 0.67 (0.08-5.31), $P = .6966$
Thumb	3 (75.0%)	1 (25.0%)	4 (7.4%)	OR = 0.22 (0.01-2.48), $P = .2287$
Bone				$P = .0307$
DP	1 (9.1%)	10 (90.9%)	11 (20.4%)	OR = 10.00 (1.19-221.39), $P = .0327$
MP	5 (50.0%)	5 (50.0%)	10 (18.5%)	Reference
PP	5 (21.7%)	18 (78.3%)	23 (42.6%)	OR = 3.60 (0.74-18.73), $P = .1112$
MC	6 (60.0%)	4 (40.0%)	10 (18.5%)	OR = 0.667 (0.11-3.93), $P = .6028$
Age				$P = .0271$
n	17	37	54	
Mean (SD)	45.6 (10.0)	36.6 (15.0)	39.5 (14.3)	
Median	47	35	39.5	
Range	(23-67)	(13-75)	(13-75)	
Age 0-25	2 (20.0%)	8 (80.0%)	10 (18.5%)	OR = 6.43 (0.79-138.82), $P = .0843$
Age 25-50	11 (34.4%)	21 (65.6%)	32 (59.3%)	OR = 4.71 (0.74-92.67), $P = .1089$
Age 50-75	5 (41.7%)	7 (58.3%)	12 (22.2%)	Reference
Per 10 year unit increase				OR = 0.62 per 10 year increase (0.38-0.95), $P = .0271$
Longitudinal ratio				$P = .0168$
n	17	37	54	
Mean	43.2 (18.4)	54.5 (15.2)	50.9 (17.0)	
Median	41.5	53.8	52.8	
Range	(22.2-87.9)	(30.0-93.6)	(22.2-93.6)	
0-0.33	6 (60.0%)	4 (40.0%)	10 (3.7%)	Reference
0.33-0.67	9 (26.5%)	25 (73.5%)	34 (42.6%)	OR = 4.17 (0.97-19.80), $P = .0543$
0.67-1.00	2 (20.0%)	8 (80.0%)	10 (46.3%)	OR = 6.00 (0.90-56.31), $P = .0632$
Per 10% unit increase				OR = 1.59 per 10% unit increase (1.08-2.49), $P = .0168$

Note. OR, odds ratio; DP, distal phalanx; MP, middle phalanx; PP, proximal phalanx; MC, metacarpal.

not observed between the fracture and nonfracture groups for gender ($P = .0582$) or the hand involved ($P = .9393$) (Table 2). The small finger was the most likely digit to present with a pathologic fracture, with a more than 10 times greater likelihood of having a fracture than any of the other fingers. In this series, it was associated with a fracture in 19 of 20 cases (95.0%), and was the only finger to show a statistically significant association ($P = .0176$). The distal phalanx and proximal phalanx were the most likely bones to be associated with a fracture (distal phalanx 10 of 11 cases [90.9%], proximal phalanx 18 of 23 cases [78.3%]). Age was inversely related to fracture risk, with younger patients being more likely to present with a fracture. Patients younger than 25 years of age had a

more than a 4 times greater chance of presenting with a fracture than patients 25 to 50 years of age (OR = 4.71), and a more than a 6 times greater fracture association than patients in the 50 to 75 age category (OR = 6.43). There was a direct relationship between the percentage of longitudinal bone involvement on AP radiographs and the presence of fracture, with an approximately 1.59 increase in the likelihood of having a fracture for every 10% increase in longitudinal bone involvement on AP radiographs. Lesions involving one-third to two-thirds of the bone length were more than 4 times as likely to be associated with a fracture than lesions involving less than one-third of the bone length (OR = 4.17), whereas lesions occupying more than two-thirds of the bone length were 6 times more

Table 3. Average Longitudinal Ratio of Tumor Involving Bone.

Involved finger	Average ratio	Involved bone	Average ratio
Index (n = 6)	0.50	Distal phalanx (n = 11)	0.59
Long (n = 10)	0.52	Middle phalanx (n = 10)	0.47
Ring (n = 14)	0.44	Proximal phalanx (n = 23)	0.54
Small (n = 20)	0.52	Metacarpal (n = 10)	0.39
Thumb (n = 4)	0.70		

likely to have a fracture (OR = 6.00). None of the lesions occupying lengthwise less than 30% of their associated bone had fractured. The measurements taken to determine the longitudinal involvement of the tumor on AP radiographs were found to be highly reproducible, with an intraclass correlation coefficient of 0.93.

Although the limited samples size (54 enchondromas) in this study did not allow us to perform a multivariate analysis examining the risk of fracture between specific bones within each finger, we did look at the association between longitudinal ratio of tumor involvement within each finger and bone separately to determine if the tumor-bone ration was driving the differences in fracture risk seen with the small finger, and the proximal phalanx (Table 3). We did not observe a statistically significant difference between the longitudinal ratio and each of the finger and bone groups. These findings indicate that longitudinal ratio is similar between groups and unlikely to be responsible for the increased fracture risk seen with the small finger, and the distal and proximal phalanges.

Activity level can readily predispose to pain and fracture; therefore, we also examined the association of traumatic injury and the finger affected by the enchondroma. In this study, 26 of the 54 cases reported a traumatic event prior to the discovery and diagnosis of their enchondroma; 14 (53.8%) traumatic cases involved the small finger, 6 (24.0%) affected the ring finger, 3 (12.5%) involved the long finger, 2 (8.3%) involved the index finger, and 1 (4.2%) included the thumb. This distribution is similar to the distribution when all fractures are considered together (Table 2). However, there is an increased representation of fractures involving the small finger in the traumatic group (53.8% vs 37.0%). This suggests that the small finger may be at greater risk of traumatic fracture in the setting of an enchondroma.

Discussion

The goal of this study was to identify objective reproducible clinical criteria that could be used by clinicians to help predict a patient's risk of developing a pathologic fracture through an enchondroma. In this investigation, several criteria were shown to be measurably reproducible and statistically different between the fracture and nonfracture

groups. These criteria have potential clinical utility and may also help us to understand why certain lesions go on to fracture whereas others do not.

Age was inversely related to fracture risk with younger patients presenting with a pathologic fracture more frequently than elderly patients. This observation may be related to the fact that asymptomatic lesions are more likely to be discovered in elderly patients because they are more likely to have hand radiographs performed for a clinical problem unrelated to their enchondroma. Lesions in the elderly may also be less likely to have an associated fracture because they have been present for an extended period of time without fracturing and thus represent a subset of enchondromas that are more resistant to fracturing. Activity level may also play a role with younger patients being more active and there by subjecting their bones to greater stress increasing their chances of fracturing through their lesion in comparison with the elderly patients.

The small finger showed a much higher association with fracture in comparison with the other digits. This may be due in part to the finger's peripheral location potentially making it more susceptible to injury. The smaller size of the bones in the small finger may also make them prone to structural compromise by the tumor in comparison with the other digits of the hand. When all fingers were considered together, the distal phalanx and proximal phalanx were more likely to be associated with a fracture than either the middle phalanx or the metacarpals. The small size of the distal phalanx as with the bones in the small finger may make it more susceptible to becoming structurally compromised by its associated lesion. The proximal phalanx is potentially subjected to greater torque forces due to its proximal location. It also lacks mechanical support from neighboring digits like the metacarpals, which may place it at greater risk of fracture in comparison with the middle phalanges and metacarpals.

Intuitively, one would expect larger lesions to have a higher fracture association, an observation that was supported by the data in this study. Although the transverse diameter of each enchondroma may also be linked to fracture risk, the longitudinal percentage of bone occupied by the tumor was found to strongly correlate with the presence of fracture and is more amenable to measurement in the clinical setting using plain radiographs.

We note that the thumb, which has unique mechanical properties and physical demands placed on it in comparison with the other fingers is represented by a small number cases ($n = 3$) in our series, and caution should be taken when clinically applying the results from this investigation to this digit. An additional limitation of this study is the fact that it only examines surgically treated enchondromas, creating a clear selection bias. It was expected that this selection bias would normalize the differences observed between the fracture and nonfracture groups, as the lesions that were judged to be the most benign clinically were probably less likely to be chosen for surgical intervention and thus excluded from analysis in this study. The inclusion of enchondromas that were treated without surgery would potentially enhance the differences observed between the fracture and nonfracture groups; however, despite this potential selection bias several criteria still emerged as statistically significant.

In this investigation we specifically examined the longitudinal ratio of bone occupied by the tumor because it is an inexpensive method that can be quickly and easily applied in the clinic. Methods that comprehensively examine the area or volume of tumor involvement within the digit are potentially interesting. The use of advanced imaging modalities such as magnetic resonance imaging or high-resolution computed tomography (CT) could allow accurate measurements to be made, but are more expensive, and in the case of CT result in increased radiation exposure for patients.

The original study of Mirel examining the risk of pathologic fracture involving the long bones was based on an analysis of 78 pathologic lesions and has proven itself over time to be a clinically powerful tool.⁶ Although the data in this investigation are based on a relatively small sample size, many of the findings show a high degree of statistical significance, and as with Mirel's data, have the potential to be clinically relevant. Patients with medical comorbidities that weaken bone, such as osteoporosis and chronic steroid use, may have a greater chance of fracture, and thus warrant more aggressive surgical intervention.

Ethical Approval

This study was approved by the Mayo Clinic Institutional Review Board (IRB 12-000513) institutional review board.

Statement of Human and Animal Rights

Procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional

and national) and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

Statement of Informed Consent

This study was carried out with a waiver of informed consent with approval from the Mayo Clinic Institutional Review Board.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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