Differentiation Between Pyogenic Flexor Tenosynovitis and Other Finger Infections

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Abstract

Background: Hospital transfer decisions regarding pyogenic flexor tenosynovitis (PFT) are made difficult by emergency department presentations similar to other finger infections, with pain, redness, and functional limitation. Our objectives were to: (1) determine diagnostic sensitivity and specificity of Kanavel signs; and (2) identify existing factors most predictive of PFT during initial presentation. **Methods:** Adult patients who underwent surgical consultation for concern of PFT over a 5-year period were identified retrospectively. Bivariate screening identified clinical criteria for differentiation, and multivariate logistic regression was performed to control for confounding. We then created a prediction algorithm for diagnosis of PFT. Receiver operating characteristic (ROC) curve analysis was used to evaluate diagnostic accuracy. **Results:** Patients with PFT differed significantly from those with non-PFT finger infections in regard to the 4 Kanavel signs, duration of symptoms less than 5 days, and erythrocyte sedimentation rate. Sensitivity of the Kanavel signs ranged from 91.4% to 97.1%. Specificity ranged from 51.3% to 69.2%. Logistic regression identified independent predictors for PFT as tenderness along the flexor tendon sheath, pain with passive extension, and duration of symptoms less than 5 days. A prediction algorithm incorporating these 3 factors showed an area under the ROC curve of 0.91 (95% confidence interval, 0.840–0.979). **Conclusions:** Kanavel signs have high sensitivity for detecting PFT but have poor specificity on an individual basis. Clinical prediction algorithms that combine the relevant factors may be helpful in the development of clinical prediction tools and educational materials for optimization of emergency hand care systems. Further prospective study is needed.

Keywords: flexor tenosynovitis, Kanavel signs, diagnosis, hand infection, flexor tendon sheath

Introduction

Pyogenic flexor tenosynovitis (PFT) is an infection of the flexor tendon sheath of the finger that represents approximately 9.4% of hand infections.² Without treatment, it may result in infectious spread, tendon necrosis, and digit devitalization.^{8,9} Modern surgical management and antibiotics have reduced serious sequelae secondary to PFT, but functional outcome remains influenced by the timing of diagnosis and treatment. Differentiation of PFT from other infections such as finger abscesses and cellulitis is essential for safe and cost-effective emergency hand transfer systems but can be made difficult by similar presentations of pain, redness, and functional limitation.^{8,9}

In 1912, Dr Allen B. Kanavel⁴ described 3 cardinal signs of PFT: (1) exquisite tenderness over the course of the sheath; (2) flexion posture of the finger; and (3) exquisite pain on extending the finger. He noted also “the whole of the involved finger is uniformly swollen,” which later became a fourth cardinal sign: fusiform swelling.^{3,4} Despite the lack of systematic validation for their use, these 4

Kanavel signs have remained the primary diagnostic tool for PFT.⁵ There are differing opinions in the literature regarding which Kanavel signs are more suggestive of a PFT diagnosis than others.^{1,6,7} Moreover, additional variables independent of the cardinal signs are yet to be identified.

Better understanding of features that differentiate PFT from other finger infections can aid development of optimal emergency hand care systems. The purpose of this study was to: (1) determine the diagnostic accuracy of the 4 Kanavel signs; and (2) identify existing clinical and laboratory criteria for differentiating between PFT and abscess/cellulitis of the finger for adults presenting to the emer-

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Table 1. Patient Characteristics With Comparison Between Groups and Bivariate Screening for Differentiating Factors.

	Group		P value	Statistical test
	PFT (n = 35)	Other digit infection (n = 39)		
Age (N = 35 + 39)	44.3 y	45.4 y	.745	Independent samples <i>T</i> test
Male sex	24/35 (69%)	27/39 (69%)	1.000	Fisher exact test
Tender to palpation of tendon sheath	32/35 (91%)	12/39 (31%)	<.001	Fisher exact test
Pain with passive extension	34/35 (97%)	18/39 (46%)	<.001	Fisher exact test
Flexed posture of the digit	32/35 (91%)	19/39 (49%)	<.001	Fisher exact test
Fusiform swelling of the digit	33/35 (94%)	19/39 (49%)	<.001	Fisher exact test
Presence of penetrating trauma	26/35 (74%)	20/39 (51%)	.056	Fisher exact test
Tobacco use	12/35 (34%)	23/39 (59%)	.039	Fisher exact test
Duration of symptoms in days	2.8 ± 2.3	6.2 ± 11.6	.097	Independent samples <i>T</i> test
Pain/10	7.85 ± 2.2	7.56 ± 3.0	.65	Independent samples <i>T</i> test
Animal bite	6/35 (17%)	5/39 (13%)	.747	Fisher exact test
WBC	13.1 ± 8.9	10.8 ± 4.5	.16	Independent samples <i>T</i> test
ESR	22.3 ± 21.3	38.0 ± 32.9	.027	Independent samples <i>T</i> test
CRP	46.4 ± 63	71.0 ± 77	.17	Independent samples <i>T</i> test
Na	136 ± 2	136 ± 3	.33	Independent samples <i>T</i> test
IVDU	5/35	9/38	.380	Fisher exact test
Subjective fevers	11/33	7/39	.175	Fisher exact test

Note. PFT = pyogenic flexor tenosynovitis; WBC = white blood cell; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; Na = sodium level; IVDU = intravenous drug use.

gency department. We also aimed to develop an evidence-based clinical prediction algorithm for future validation.

Materials and Methods

Institutional review board approval was obtained for this retrospective review, and the authors adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. Our institutional coding database was queried to identify all patients with a finger infection referred to hand surgery consultation at a large academic medical center during a 5-year period from September 26, 2008, to September 26, 2013. Diagnoses included tenosynovitis, felon, paronychia, abscess, cellulitis, or other nonspecified infection of digits. Patient medical record numbers were retrieved from this query to create a deidentified research database on a secured password-protected file. A medical chart review was performed to verify that patients met inclusion criteria for the study and to divide patients into a PFT group and a group with other infections (ie, “non-PFT group”).

Study Population and Inclusion Criteria

Ninety-eight patients were identified for analysis. After exclusion of 20 patients with incomplete recordings of Kanavel signs and 4 pediatric patients, 74 patients were analyzed. Patient characteristics are displayed in Table 1.

All adult patients were included in the study if there were hand surgery consultation, entirety of treatment at our institution, and complete medical records.

PFT was diagnosed with visible infection in the flexor tendon sheath upon surgical drainage (purulence and/or fluid discoloration) or with culture growth from flexor tendon sheath fluid collected operatively. Otherwise, all cases that did not meet these criteria were classified as the absence of confirmed PFT (non-PFT). Patients treated outside of the operative theater with either bedside drainage or antibiotic management alone were excluded from the diagnosis of PFT. Exclusion criteria were patients younger than 18 years of age, those who had incomplete operative findings regarding definitive diagnosis, or those who had incomplete records.

Data Collection

The following data were collected from the medical record of each patient: patient demographics (age, sex, smoking status, history of intravenous drug use [IVDU]), pertinent history (reported fevers, duration of symptoms from onset to presentation), presence and type of penetrating trauma (cat bite, dog bite, human bite, thorn, splinter, nail, glass, crush, injection), preoperative serum laboratory studies that are routinely obtained in patients with concern for a hand infection and are utilized in other infection prediction algorithms (white blood cell [WBC] count, C-reactive protein

[CRP], erythrocyte sedimentation rate [ESR], sodium level),¹⁰ presence of each Kanavel sign (tenderness along the flexor tendon sheath, fusiform swelling, digit resting in flexed position, pain with passive extension of the digit), and operative or microbiological findings confirming or excluding a diagnosis of PFT.

Analysis and Study Groups

Study groups were: (1) PFT as defined above; and (2) non-PFT diagnosis that included cellulitis or abscess not communicating with the flexor tendon sheath. Statistical analysis was done with the assistance of a biomedical statistician. IBM SPSS version 19.0.0.2 (Armonk, New York) was used. Descriptive statistics were completed with the 2-sample Student *t* test for comparison of means and the Fisher exact test for proportions. The sensitivity, specificity, and positive predictive value of the various clinical features were calculated.

To identify clinical predictors, bivariate analysis was performed with the use of the 2-sample Student *t* test for continuous variables between the PFT group and the non-PFT group (abscess and cellulitis). The distribution of continuous variables between the 2 groups was evaluated using scatter diagrams, and receiver operating characteristic (ROC) curves were constructed to develop binary cutoff values for use in clinical prediction algorithms.

Logistic regression was then used to control for confounding and model potential relationships identified by the screening bivariate comparison. Variables with a *P* value of less than .20 in the bivariate screening analysis were chosen as candidates for the multivariate model. Adjusted odds ratios with 95% confidence intervals were calculated.

We used the relevant predictors from the multivariate analysis to determine likelihood ratios and construct a prediction algorithm for the diagnosis of PFT.

Results

Patient characteristics and presenting exam findings are shown in Table 1. No significant difference between groups was found with regard to age, sex, pain, animal bite mechanism, serum WBC count, CRP level, sodium level, IVDU status, or history of subjective fever.

Significant differences were noted in regard to the 4 Kanavel signs. Other differences between the PFT and non-PFT groups included the rate of penetrating trauma, tobacco use, duration of symptoms in days prior to presentation, and ESR level at hospital presentation. Scatter diagrams were performed for continuous variables with significant differences (*P* < .05). Based on ROC curve analysis and the Youden index, the selected cutoff for the duration of symptoms was 5 days (ie, PFT was more likely to be present if

Table 2. Sensitivity, Specificity, and Positive Predictive Value of Kanavel Signs.

Sensitivity	Sensitivity (%)	Specificity (%)	Positive predictive value (%)
Passive extension pain	97.1	53.8	65.4
Tenderness to palpation of tendon sheath	91.4	69.2	72.7
Held in flexion	91.4	51.3	62.7
Fusiform swelling	94.3	51.3	63.5

onset of symptoms was <5 days from presentation). For the ESR, a measure of <19 mm/h was associated with PFT. These cutoff values were then used for the multivariate regression.

The sensitivity, specificity, and positive predictive value for Kanavel signs each showed sensitivities ranging from 91.4% to 97.1% for detection of PFT and had specificity ranging from 51.3% to 69.2% (Table 2). Positive predictive values were in the range of 62.7% to 72.7%.

Multivariate regression was performed to reduce confounding and model potential relationships. Three independent predictors of PFT were identified: (1) tenderness along the flexor tendon sheath; (2) pain with passive extension; and (3) duration of symptoms less than 5 days. The Hosmer-Lemeshow goodness-of-fit test revealed no significant departure from good model fit (*P* = .996). The other 2 Kanavel signs, flexion posture of the digit and fusiform swelling, did not appear to be independently predictive within the model. ESR level similarly did not contribute significantly to the prediction model. Regression coefficients, likelihood ratios, *P* values, adjusted odds ratios, and 95% confidence intervals are presented in Table 3.

Using the 3 binary independent predictors identified by the multivariate regression, a total of 8 combinations are possible (presented in Table 4). The probability of diagnosis of PFT increased with the number of predictive variables present. A patient with all 3 factors present was 87.9% likely to have PFT, whereas a patient with no factors present was 0% likely to have PFT. The ROC curve for the prediction algorithm is presented in Figure 1. A prediction algorithm incorporating these 3 factors showed an area under the ROC curve of 0.91 (95% confidence interval, 0.840-0.979). Each variable was similar in regard to predictive value, so a simplified clinical algorithm was constructed based on the number of predictive variables and is presented in Table 5.

Discussion

The 4 Kanavel cardinal signs have contributed greatly to our ability to diagnose PFT, despite the lack of formal

Table 3. Results of the Multivariate Analysis for the 3 Independent Predictors of Pyogenic Flexor Tenosynovitis in the Model.

Multivariate predictor	Regression coefficient	Likelihood ratio	P value	Adjusted odds ratio	95% Confidence intervals
Pain with extension	3.36	1.89	.005	28.9	2.8-300
Tenderness of the flexor tendon sheath	3.00	2.67	<.001	20.0	3.9-103
Duration less than 5 d	2.81	1.38	.004	16.6	2.4-114

Table 4. Predicted Probability of Pyogenic Flexor Tenosynovitis for the 8 Various Combinations of the 3 Independent Predictive Factors ($2 \times 2 \times 2$).

Multivariate predictor			
Pain with extension	Tenderness of the flexor tendon sheath	Duration less than 5 d	Predicted probability of flexor tenosynovitis (%)
Yes	Yes	Yes	87.9
Yes	Yes	No	33.3
Yes	No	Yes	30.0
No	Yes	Yes	25.0
Yes	No	No	0.0
No	Yes	No	0.0
No	No	Yes	0.0
No	No	No	0.0

Figure 1. Receiver operating characteristic curve for the clinical prediction model developed from the study.

Note. CI = confidence interval.

validation studies, and many hand surgeons “know it when they see it.” However, decisions regarding management can be made difficult when other providers are performing the examination, findings are overlapping or inconsistent, and/or decisions for transfer can significantly increase the cost of care. In this retrospective study, we set out to evaluate the sensitivity and specificity of the Kanavel signs, and identify any features to best predict PFT and differentiate it from

other digit infections to help develop evidence-based algorithms and optimize care. We found that Kanavel signs have high sensitivity for detecting PFT but individually have poor specificity. Identifying the independently significant predictors and combining them with clinical prediction algorithms improves the diagnostic accuracy.

Kanavel⁴ described excessive tenderness along the tendon sheath as the most important cardinal sign, and our analysis concurred with this finding. We found that tenderness to the flexor tendon sheath and pain with passive extension are independent predictors of PFT. Flexion posture and fusiform swelling, although frequently present in patients with the condition, do not appear to independently differentiate it from other finger infections. Symptom duration less than 5 days may be an independent predictor of PFT, but further studies are needed to evaluate whether this might be a spurious result from our population sample or a true independent predictor. The 4 Kanavel cardinal signs should not be used themselves as a clinical prediction rule, as doing so assumes that each Kanavel sign is independently significant and that each Kanavel sign is equal to another in terms of diagnostic utility. Based on our results, this is not the case.

Our initial bivariate comparison also showed that PFT patients had lower ESR levels at hospital presentation than non-PFT patients. However, when incorporated into the logistic regression analysis, ESR level did not contribute significantly to the prediction model. ESR is inconsistently obtained in the evaluation of acute finger infection, and is

Table 5. Simplified Algorithm for the Predicted Probability of Flexor Tenosynovitis.

Number of predictors	Flexor tenosynovitis (n = 35), n (%)	Other infection (abscess, cellulitis, etc; n = 39), n (%)	Predicted probability of flexor tenosynovitis, %
3	29 (82.9)	4 (10.3)	87.9
2	6 (17.1)	14 (35.9)	30.0
1	0 (0)	14 (35.9)	0.0
0	0 (0)	7 (17.9)	0.0

more often used as a mid- to long-term marker of inflammation, so a low ESR level in patients with acute PFT infections may simply be due to short duration of symptoms and relatively small area of infection. It may be worthy of more study, but we expect that ESR level is unlikely to be of significant utility in a PFT prediction model.

Although we found that fusiform swelling was not of high diagnostic utility, Pang et al⁷ analyzed 75 patients with PFT and found that of the Kanavel signs, fusiform swelling was the most sensitive sign and was present in 97% of patients. Semiflexed posture was found in 69% of patients, pain on passive extension in 72%, and tenderness along the flexor sheath in 64% of patients. They devised a 3-tier classification system of PFT based on preoperative clinical assessment and identified preoperative risk factors associated with worse outcomes and higher risk of amputation. They found that tenderness along the tendon sheath was a late sign of proximal extension, suggesting that the lack of this Kanavel sign should not exclude a diagnosis of PFT.

Neviaser and Gunther⁶ found that the inability to flex the finger to touch the palm was an additional sign of PFT and suggested that the most reliable early Kanavel sign is pain on passive extension of the digit. Dailiana et al¹ performed a retrospective review of 41 patients with PFT and found that only 54% of patients demonstrated all 4 signs. They noted that all patients in their series had tenderness along the tendon sheath and pain with passive extension. These studies illustrate the discord in published literature regarding the reliability of Kanavel signs in predicting PFT.

Limitations of the present study include its retrospective design and use of institutional coding for the identification of patients. This increases the risks of bias in regard to patient selection and documentation, and limits the ability to identify new clinical criteria that could be used to accurately and efficiently diagnose PFT. Extracting data from the electronic medical record leaves one relying on the documented physical exam findings of physicians, with interobserver and intraobserver variability, and diagnoses and treatment decisions made in the absence of an objective confirmatory diagnostic test for the presence or absence of flexor tenosynovitis. Twenty patients required exclusion from the study due to a lack of full documentation of the presence or absence of the Kanavel signs, and we found that pertinent negative findings were documented

less frequently than the positive findings when Kanavel signs were present. Surgical and microbiological findings were used to confirm a diagnosis of PFT, which may lead to underdiagnosis of the PFT group. Patients with early PFT may not develop visible infection, and antibiotics may alter culture growth. Patients who were treated with antibiotics alone or with bedside irrigation and debridement in the emergency department were not included in this study. Thus, a subset of patients who may have had PFT were also not included in the study.

Despite these limitations, we feel that this study provides valuable information worthy of future validation and prospective study. Our study validates the Kanavel signs as a sensitive tool for evaluating a patient with potential PFT but reveals their limited specificity on an individual basis. Diagnostic algorithms that combine the relevant factors may be more helpful in predicting need for hospital transfer or other treatment decisions. Future studies explicitly defining each of the Kanavel signs, such as size measurement or contralateral digit comparison for assessing fusiform swelling, would be beneficial to combat limitations in interobserver and intraobserver variations. Use of photography to help confirm the presence or absence of a finding in an objective manner may be helpful. Future research on this topic would be strengthened by a prospective, longitudinal design with appropriate measures of functional outcome to further determine the pre-diagnostic and post-diagnostic value of predictive variables for PFT.

Ethical Approval

Written approval for this study was obtained by the University of Washington institutional review board (IRB) on March 31, 2015, as part of the University of Washington IRB-approved Retrospective Orthopaedic Outcomes Study protocol.

Statement of Human and Animal Rights

All 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 2008 (5).

Statement of Informed Consent

Informed consent was not obtained from individual participants included in the study.

Declaration of Conflicting Interests

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

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