Factors Affecting the Prognosis of Pyogenic Flexor Tenosynovitis

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Background: Pyogenic flexor tenosynovitis is a closed space infection involving the digital flexor tendon sheaths of the upper extremity that can cause considerable morbidity. The purpose of the present report is to describe the various risk factors leading to poor outcomes and to recommend a clinical classification system for this condition.

Methods: We studied seventy-five patients with pyogenic flexor tenosynovitis over a six-year period. The amputation rate and total active motion were used as outcomes measures. The clinical factors influencing outcomes were identified and analyzed.

Results: The five risk factors associated with poor outcomes were (1) an age of more than forty-three years, (2) the presence of diabetes mellitus, peripheral vascular disease, or renal failure, (3) the presence of subcutaneous purulence, (4) digital ischemia, and (5) polymicrobial infection. On the basis of the clinical findings and outcomes, three distinct groups of patients could be identified, each with a progressively worse outcome. Patients in Group I had no subcutaneous purulence or digital ischemia; these patients had the best prognosis, with no amputations and a mean 80% return of total active motion. Patients in Group II demonstrated the presence of subcutaneous purulence but no ischemic changes; these patients had an amputation rate of 8% and a mean 72% recovery of total active motion. Patients in Group III had both extensive subcutaneous purulence and ischemic changes; these patients had the worst prognosis, with an amputation rate of 59% and a mean 49% return of total active motion.

Conclusions: We propose a three-tier clinical classification system that can aid in prognosis and guidance in the treatment of pyogenic flexor tenosynovitis of the upper extremity.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Pyogenic flexor tenosynovitis is an aggressive closed-space infection of the digital flexor tendon sheaths of the upper extremity that can cause severe disability if not treated expediently and appropriately[1]. Kanavel classified it among the grave infections of the hand[2]. The prevalence of this infection has ranged from 2.5%[3] to 9.4%[4] in large series of hand infections. Stern et al.[5] reported a high rate (38%) of complications, including stiffness, persistent infection, boutonniere deformity, and amputation. However, some authors have reported good results with few complications in the treatment of this condition[6,7].

Michon[8] classified flexor tenosynovitis into three stages. In the first stage, the inflamed synovial sheath is distended with serous exudative fluid. In the second stage, purulent fluid causes progressive distension of the tendon sheath. The tendon is still viable. In the third stage, there is septic necrosis of the tendon and the pulleys. The prognosis worsens with increasing stage. Michon proposed that stages I and II could be treated with limited incision with drainage and irrigation of the sheath, whereas stage III should be treated with open débridement. Michon believed that the progression of the disease is influenced by the virulence of the bacteria and the patient's response to treatment. However, he did not identify any clinical indicators of severity or preoperative factors predict-

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ing poor outcome. The present study was designed to identify the preoperative risk factors associated with poor outcomes and to propose a clinical classification system for flexor tenosynovitis based on these factors.

Materials and Methods

With the approval of institutional authority, we reviewed all of the operative records in our department's surgical logbook from 2001 to 2006. In addition, we generated a list of patients with the diagnosis of suppurative tenosynovitis (International Classification of Diseases [ICD], Ninth Revision, code 7270) from the Medical Records Office. Seventy-five consecutive records were found, and verbal consent was obtained from these patients for the use of their medical reports. The diagnosis of pyogenic flexor tenosynovitis was made clinically on the basis of the presence of one or more of the Kanavel signs[2] of fusiform swelling, a semiflexed posture of the digit, pain on passive extension, and tenderness along the tendon sheath. Where there was subcutaneous purulence, it could often be detected as an area of boggy swelling. Occasionally, it could present with purulent drainage from a preexisting puncture wound or an area of skin necrosis. The presence of ischemic changes, including blistering, skin necrosis, and delayed capillary refill, was similarly noted.

The study group included forty-seven male and twenty-eight female patients with a mean age of forty-seven years (range, seventeen to seventy-four years). All infections were community-acquired infections. The dominant hand was more commonly involved (fifty patients; 67%). The middle finger was most commonly involved (thirty-two patients; 43%), followed by the index finger (sixteen patients; 21%) and the ring finger (thirteen patients; 17%). The average number of surgical débridements was 1.5 (range, one to five), and the mean time-interval to wound-healing and closure after the débridement was five days (range, two to seventeen days). The mean duration of hospitalization was nine days (range, five to fifteen days), and the mean duration of follow-up was twenty-six months (range, fourteen to thirty-six months).

We agree with Stern et al.[5] that the complications of pyogenic flexor tenosynovitis include amputation and stiffness of the surviving digits. Therefore, we specifically studied the amputation rate and total active motion[9] as measures of outcome related to the severity of the disease process at the time of presentation. The total active motion for each digit was calculated by modifying the formula used by Strickland and Glogovac for the grading of digital function[10].

The total active motion for each finger was calculated as the sum of the active ranges of motion of the metacarpophalangeal (MCP) joint, the proximal interphalangeal (PIP) joint, and the distal interphalangeal (DIP) joint, divided by 265°. The percentage of a normal 265° of motion at these three joints (total active motion) was determined with use of the formula: (active MCP + PIP + DIP flexion)/265° × 100%.

For the thumb, total active motion was calculated as the active range of motion in the interphalangeal (IP) and metacarpophalangeal (MCP) joints, divided by 140°. The percentage of a normal 140° of motion at these two joints (total active motion) was determined with use of the formula: (active MCP + IP)/140° × 100%.

The possible risk factors that were analyzed included age, comorbidities, the presence of subcutaneous purulence, ischemic changes, and the number of bacterial types that grew on culture. The patients were then classified into three distinct groups according to the clinical findings and the rates of amputation. We further analyzed the percentage recovery of total active motion in each group.

Statistical analysis was performed with SPSS statistical software (version 11.0; SPSS, Chicago, Illinois). The box-plots demonstrating the age distributions within the groups of patients with and without amputation were analyzed. The age cutoff was determined by performing univariate analysis for each age-group. Univariate analysis was performed with use of the chi-square or Fisher exact test for comparison of proportions between two categorical data. The Mann-Whitney U test was used to compare the nonparametric data between two independent samples. The level of significance was set at $p < 0.05$.

Surgical Treatment of Infections

All operations were performed with the patient under general anesthesia with use of tourniquet control, except in the cases of three patients who had ipsilateral arteriovenous fistulae. In early stages of the disease, when the infection was localized to the tendon sheath, we used the method of limited incision with drainage and irrigation as described by Neviaser[6]. In cases in which there was concomitant subcutaneous purulence, we used the zigzag (Bruner) incision[11]. Although many surgical approaches have been described[12,13] including the midaxial and serial transverse incisions, the use of a zigzag incision allowed for better exposure, visualization of the tendon sheath in its entirety, and proximal extension to assess the full extent of the infection.

We practice excisional débridement in our institution. If the carpal tunnel was involved, we performed a carpal tunnel release and débrided the synovium. The wound was then irrigated with a copious amount of saline solution and was left open with tulle gras dressing (Smith and Nephew, London, England). The tulle gras dressing is useful as a form of continuous open drainage. A bulky dressing was applied with the hand immobilized in the functional position. Postoperatively, the hand was elevated, and daily chlorhexidine irrigations and dressing changes were performed. On the third postoperative day, a decision was made for either further débridement or secondary closure.

Results

Amputation was performed for thirteen (17%) of the seventy-five patients. Amputation was performed at a mean of nine days (range, five to fourteen days) after admission and a mean of three days (range, two to six days) after the initial débridement. The mean percentage recovery of total active motion of the surviving digits in the remaining sixty-two patients was 73% (range, 4% to 100%). Table I summarizes the

TABLE I Summary of Demographic Data and Treatment

Categorical Variables*	
Gender	
Male	47 (63%)
Female	28 (37%)
Comorbidities	
Diabetes mellitus	26 (35%)
Peripheral vascular disease	7 (9%)
Renal failure	14 (19%)
Presence of penetrating injuries	46 (61%)
Site of infection	
Dominant hand	50 (67%)
Nondominant hand	25 (33%)
Digital involvement	
Thumb	9 (12%)
Index finger	16 (21%)
Middle finger	32 (43%)
Ring finger	13 (17%)
Little finger	5 (7%)
Clinical signs	
Fever	13 (17%)
Fusiform swelling	73 (97%)
Semiflexed posture	52 (69%)
Pain on passive extension	54 (72%)
Tenderness along flexor sheath	48 (64%)
Subcutaneous purulence	51 (68%)
Skin necrosis	17 (23%)
Elevated total white blood-cell count	44 (59%)
Michon classification	
Stage I	29 (39%)
Stage II	28 (37%)
Stage III	18 (24%)
Amputation performed	13 (17%)
Continuous variables†	
Age *(yr)*	47 (17 to 74)
Time interval to intravenous antibiotics *(d)*	3 (1 to 17)
Time interval to surgery *(d)*	6 (3 to 21)
Number of débridements	1.5 (1.0 to 5.0)
Time interval to closure after débridement *(d)*	5 (2 to 17)

*The data are given as the number of patients, with the percentage in parentheses. †The data are given as the mean, with the range in parentheses.

demographic characteristics of the patients, their clinical presentation, and the treatment that they received.

Time to Definitive Treatment

The mean interval from the onset of symptoms to the commencement of intravenous antibiotics was three days (range, one to seventeen days), and the mean interval from the onset of symptoms to surgery was six days (range, three to twenty-one days). However, with the numbers available, there was no significant correlation between the interval to definitive treatment and the rate of amputation ($p > 0.05$).

Comorbidities

The rate of amputation among patients who were more than forty-three years old was 24.4% (eleven of forty-five). Patients who were more than forty-three years old had a 4.5 times higher risk of amputation (odds ratio, 4.5; 95% confidence interval, 0.9 to 22.2; $p = 0.041$) than patients who were forty-three years old or younger.

Thirty-nine patients (52%) had one or more of the medical comorbidities of diabetes mellitus, peripheral vascular disease, and end-stage renal failure requiring dialysis. The average number of comorbidities was 1.4 (range, zero to three). The diabetic patients had had insulin-dependent diabetes mellitus for more than five years and an elevated glycosylated hemoglobin (Hba1c) level of >6.4% (the upper limit of the normal range for the Hba1c level at our institution) at the time of admission. The comorbidities that were associated with a higher risk of amputation included diabetes mellitus (rate of amputation, 39% [ten of twenty-six patients]; $p = 0.003$), peripheral vascular disease (rate of amputation, 71% [five of seven patients]; $p = 0.003$), and renal failure (rate of amputation, 64% [nine of fourteen patients]; $p = 0.002$). We also analyzed other common comorbidities of hypertension, specifically, hyperlipidemia and previous strokes, and found that, with the numbers available, these factors were not significantly associated with a higher rate of amputation ($p > 0.05$).

Clinical Findings

Thirteen patients (17%) had fever. None had systemic signs of infection such as hypotension or tachycardia. The most com-

TABLE II Microbiological Findings Associated with Pyogenic Flexor Tenosynovitis*

Microbiological Findings	Number of Patients
Bacterial involvement	
No bacteria found	17 (23%)
One species	43 (57%)
Two species	14 (19%)
Three species	1 (1%)
Type of bacteria	
Staphylococcus aureus	32 (43%)
Gram-negative bacilli	18 (24%)
Group-B streptococcus	5 (7%)
Group-A streptococcus	6 (8%)
Other gram-positive cocci	5 (7%)
Anaerobes	2 (3%)

*The data are given as the number of patients, with the percentage in parentheses.

Fig. 1

A twenty-five-year-old patient in Group I presented with Kanavel signs of a semiflexed posture of the little finger, fusiform swelling, and pain on passive extension. The patient had none of the identified risk factors and recovered well, with 100% recovery of total active motion of the little finger.

mon Kanavel sign was fusiform swelling of the digit, which was found in 97% of the patients. This was followed by pain on passive extension (noted in 72% of the patients) and a semiflexed posture of the digit (noted in 69% of the patients). Tenderness along the flexor sheath was a somewhat less common finding (noted in 64% of the patients).

Thirteen patients (17%) underwent digital amputation. Subcutaneous purulence was detected in fifty-one patients (68%). The amputation rate in this group of patients was 24% (twelve of fifty-one), and these patients had a 6.8 times higher risk of amputation (odds ratio, 6.8; 95% confidence interval, 0.8 to 55.6; $p = 0.039$). Seventeen patients (23%) demonstrated signs of ischemia, and these patients had a 25.6 times higher risk of amputation (odds ratio, 25.6; 95% confidence interval, 5.7 to 117.6; $p = 0.002$).

Microbiological Findings

Table II presents the microbiological findings associated with pyogenic flexor tenosynovitis based on tissue specimens obtained during surgical débridement. One bacterial species grew on culture of specimens from forty-three patients (57%); two species grew on culture of specimens from fourteen patients (19%); and three species grew on culture of specimens from one patient (1%). Bacterial cultures were negative for seventeen patients (23%). Patients for whom cultures were positive for two or more bacterial species had a 5.0 times higher risk of amputation (odds ratio, 5.0; 95% confidence interval, 1.4 to 18.5; $p = 0.035$). The most common organism was *Staphylococcus aureus,* which grew on culture of specimens from thirty-two patients (43%). However, with the numbers studied, no specific species or combination was associated with a higher risk of amputation.

Trauma

Fifty-seven patients (76%) reported antecedent injuries involving the fingers. The most common injury was a penetrating wound (prevalence, 61%; forty-six of seventy-five patients) fol-

Fig. 2

A forty-year-old man in Group II sustained a penetrating injury from a wooden splinter to the volar aspect of the middle phalanx of the right middle finger. He presented with all four Kanavel signs and subcutaneous purulence, with purulent drainage from the puncture wound. At the time of surgery, there was pus in both the subcutaneous tissue and the tendon sheath. The patient received surgical and antibiotic treatment and had 65% recovery of the total active motion at the time of the one-year follow-up.

lowed by blunt trauma (prevalence, 11%; eight of seventy-five patients). Eighteen patients (24%) could not recollect any injury. With the numbers available, neither a history of trauma nor the type of trauma predicted severity or amputation.

Risk Factors

Univariate analysis showed that five factors were significantly associated with an increased rate of amputation ($p < 0.05$). These included (1) an age of more than forty-three years, (2) the presence of diabetes mellitus, peripheral vascular disease, or renal failure, (3) the presence of subcutaneous purulence, (4) ischemic changes at the time of presentation, and (5) involvement of more than one bacterial type (Table III).

Clinical Classification and Analysis

The patients were classified into three groups on the basis of the clinical severity of pyogenic flexor tenosynovitis at the time of presentation (Table IV). The patients in Group I presented with Kanavel signs of tenosynovitis but no evidence of subcutaneous purulence or ischemia (Fig. 1). The patients in Group II had concurrent localized subcutaneous purulence but no ischemia (Fig. 2). The patients in Group III had concurrent extensive subcutaneous purulence involving more than one phalangeal segment or spreading circumferentially as well as signs of ischemia (Fig. 3). The rate of amputation was 0% in Group I, 8% (three of thirty-seven) in Group II, and 59% (ten of seventeen) in Group III ($p = 0.002$). Among the surviving digits in each group, the average recovery of total active motion was 80% (range, 34% to 100%) in Group I, 72% (range, 4% to 100%) in Group II, and 49% (range, 8 % to 68%) in Group III.

TABLE III Risk Factors Affecting Rate of Amputation

Factors	P Value*
Age of more than forty-three years	0.041
Presence of poorly controlled diabetes mellitus	0.003
Presence of peripheral vascular disease	0.003
Presence of renal failure	0.002
Presence of subcutaneous purulence	0.039
Signs of ischemia	0.002
Involvement of more than one bacterial species	0.035

*$p < 0.05$ indicates that the factor contributed to an increased rate of amputation according to univariate analysis.

Discussion

There have been numerous reports on the treatment of pyogenic flexor tenosynovitis. Apart from the report by Michon, we are not aware of any attempt to classify this condition according to severity and prognosis. The present study of seventy-five consecutive patients allowed us to statistically analyze possible risk factors for poor outcomes, particularly amputation and stiffness. On the basis of our analyses, we were able to classify patients with flexor tenosynovitis into three

Fig. 3

A fifty-year-old patient in Group III who had a long-standing history of diabetes mellitus and peripheral vascular disease presented with signs of ischemia and skin necrosis. The infection failed to respond to multiple surgical débridements, and the patient eventually underwent a ray amputation.

TABLE IV Proposed Clinical Classification System for Pyogenic Flexor Tenosynovitis and Observed Outcomes in Each Group

Group	Positive Kanavel Signs	Presence of Subcutaneous Purulence	Presence of Digital Ischemia	Number of Patients	Number of Digits Amputated*	Percentage Return of Total Active Motion
I	Yes	No	No	21	0 (0%)	80%
II	Yes	Yes	No	37	3 (8%)	72%
III	Yes	Yes	Yes	17	10 (59%)†	49%

*The data are given as the number of patients, with the percentage in parentheses. †$p = 0.002$.

groups with distinct clinical features and outcomes. Patients with more risk factors had more severe disease and a greater risk of poor outcomes.

In this group of patients, amputation was performed for those who had digital ischemia and residual infection despite the initial débridement. The likelihoods of amputation and recovery of total active motion were influenced by five factors: (1) an age of more than forty-three years, (2) the presence of diabetes mellitus, peripheral vascular disease, or renal failure, (3) the presence of subcutaneous purulence, (4) ischemic changes, and (5) the growth of more than one bacterial species on culture of specimens obtained at the time of surgery. However, we acknowledge that we could not control for other variables, such as smoking and preexisting stiffness resulting from arthritis, which might have affected the outcome.

The presence of diabetes mellitus, peripheral vascular disease, or renal failure led to a higher risk of amputation. This finding is consistent with the findings of Mann and Peacock[14], who found high rates of amputation in diabetic patients with hand infection. It also reaffirms the findings of Kour et al.[15], who noted an increased risk of amputation in patients with hand infection who had both diabetes and renal failure concurrently. We postulate that a combination of immunosuppression[16,17] and vascular disease leading to poor tissue perfusion contributed to the poor prognosis in these patients.

The patients in Group I had no subcutaneous purulence or signs of ischemia. They had good outcomes, with no amputations and with an average functional return of 80% of total active motion of the affected digit. Kanavel[2] described the four cardinal signs of acute flexor tenosynovitis, but not all of these signs need to be present in the early course of the disease. Kanavel[2], Pollen[18], and Boles and Schmidt[19] believed that excessive tenderness along the tendon sheath was the most reliable and reproducible sign. Neviaser[6] believed that pain on passive extension is the most valuable sign and that it is the only sign that presents early in the process. We noted that pain on passive extension was a specific finding that occurred early in the infection and that tenderness along the tendon sheath was a late sign of proximal extension.

The patients in Group II demonstrated the presence of subcutaneous purulence. These patients had a poorer prognosis, with an 8% rate of amputation and with an average recovery of 72% of total active motion. Concurrent subcutaneous purulence was found in 68% (fifty-one) of the seventy-five patients. There are two possible explanations for the presence of subcutaneous purulence in patients with flexor tenosynovitis. As the disease progresses, the pus distends the flexor sheath, which may rupture and introduce infection into the subcutaneous plane. Subcutaneous purulence could also be caused by the inoculation of the subcutaneous plane by penetrating injuries, which was the mechanism of injury in 61% of our patients. Concurrent subcutaneous purulence requires more extensive débridement, with an increased potential for delayed resolution and mobilization, adhesion formation, or devascularization of the digit.

The patients in Group III demonstrated the presence of extensive subcutaneous purulence and ischemic changes. These patients had the worst prognosis, with a 59% rate of amputation and only 49% recovery of total active motion. The rapid accumulation of pus causes increased tissue compartment pressure, which compromises the blood supply to the skin, causing blistering, necrosis, and gangrene. Tissue ischemia and necrosis also decrease antibiotic penetration, resulting in slow resolution of hand infections[4]. The combination of extensive débridement, delayed resolution, and tendon ischemic damage, as in Michon stage III, results in poor function of any surviving digits.

The presence of two or more pathogens resulted in a more serious infection and was associated with an increased rate of amputation. With the numbers available, the type of bacteria did not affect the final outcome. Grinnell[20] noted that the prevalence of tendon slough was higher in cases of mixed infections. Other reports have described mixed organisms especially in immunocompromised patients such as intravenous drug abusers, patients with diabetes mellitus, and patients taking steroids[1,3,21,22]. In the present study, diabetic and nondiabetic patients had similar bacteriological findings. We did not find an increase in gram-negative bacterial infection in this group as reported by Kour et al.[15].

This proposed classification system is based on preoperative clinical assessment, and we believe that it can guide treatment and prognosis. We propose early sheath irrigation as described by Neviaser[6] for patients in Group I. In addition, we recommend open débridement for patients in Group II be-cause they have concomitant subcutaneous purulence that will require more extensive débridement. Patients in Group III have the worst prognosis. If the infection does not respond to the initial débridement, amputation may be considered to shorten the period of morbidity, especially when there are signs of digital ischemia and necrosis. A future prospective study applying this treatment algorithm is needed to affirm the validity of these recommendations. ■

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