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Case Report

Mycobacterium heraklionense: An emerging cause of hand tenosynovitis

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ABSTRACT

Misdiagnosis of *Mycobacterium heraklionense* tenosynovitis is common due to the challenging identification and perceived rarity of the disease. This can result in delayed therapy initiation and potentially irreversible consequences. In this report, we present an additional case of hand tenosynovitis, which highlights the diagnostic and management challenges of *Mycobacterium heraklionense* tenosynovitis and provides further evidence of its emergence as a cause of tenosynovitis. Additionally, we provide a comprehensive summary of published case reports that describe *Mycobacterium heraklionense* tenosynovitis.

1. Introduction

Nontuberculous mycobacteria (NTM) are ubiquitous microorganisms widely distributed in environmental habitats, including soil, water sources, and animal reservoirs [1]. NTM species are emerging causes of human diseases of global significance and have been increasingly reported as primary pathogens causing pulmonary and, less frequently, extrapulmonary infections [2–7]. While NTM infections typically involve the lungs, NTM tenosynovitis represents a rare yet but potentially serious condition that often affects the hand and wrist and is typically caused by *Mycobacterium marinum* or *Mycobacterium avium complex* [8,9]. NTM tenosynovitis is usually related to prior trauma, surgical interventions, local corticosteroid injections, or exposure to contaminated water sources [10]. However, exposure to these organisms is probably a constant occurrence, and infection requires a combination of environmental-related factors, such as a high organism load in hot tub aerosols, the introduction of the bacteria through surgical incisions [11], and host factors, such as genetic susceptibility and immunosuppression [12–14]. Diagnosing and managing NTM tenosynovitis poses significant challenges due to low suspicion, nonspecific clinical presentations, and suboptimal laboratory identification techniques [8]. Consequently, NTM tenosynovitis is frequently misdiagnosed, leading to delays in treatment initiation [8,15]. Although tenosynovitis is rare, comprehensive epidemiological data is lacking. Recent advancements in the differentiation of *Mycobacterium* species using molecular methods have led to increased reporting and identification of additional NTM species [16]. These enhanced speciation methods play a crucial role in elucidating the clinical and epidemiological characteristics of rare NTM infections, offering novel insights into their clinical and epidemiological features.

In 2013, through genotypic analysis of 150 strains belonging to the *Mycobacterium terrae complex*, a previously unknown species named *Mycobacterium heraklionense sp (M. heraklionense). Nov* was identified based on a distinctive sequence in the 16S rRNA gene [1]. Among the 150 strains analysed, twenty-three strains were collected between 2002 and 2011 from Greece (including several strains from Heraklion in Crete), Italy, and India. In 2014, the first case of hand tenosynovitis caused by *M. heraklionense*, a member of the *Mycobacterium terrae* complex, was reported [17]. Since then, only a few cases have been documented [8,17–23]. However, this entity should be considered in the differential diagnosis of chronic tenosynovitis, as it can lead to consequent aggressive and repetitive surgical interventions, prolonged

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antibiotic therapies with potential drug side effects, and irreversible sequelae. This report presents the clinical course of a patient diagnosed with hand tenosynovitis caused by *M. heraklionense*. This case contributes additional insights to our understanding of *M. heraklionense* infection and provides further evidence of the emergence of *M. heraklionense* as a cause of tenosynovitis. We also provide a comprehensive summary of published case reports describing *M. heraklionense* tenosynovitis.

2. Case report

A 52-year-old woman was admitted for a painful inflammatory tumefaction of the right fifth finger. She had a nine-month history of gradual swelling and stiffness of her right thumb (Fig. 1A), which subsequently extended to her hand and wrist upon returning from a trip to Jamaica. During this time, she experienced a series of misdiagnosis, including successively severe idiopathic carpal tunnel syndrome, De Quervain's tenosynovitis, rheumatoid arthritis, and complex regional pain syndrome type II, leading to multiple unsuccessful treatments of non-steroidal anti-inflammatory drug, sulfasalazine, local corticosteroid (CS) injections and systemic CS (Fig. 1A–C). She had no fever, and the laboratory markers showed no abnormalities. Although she did not report any history of trauma, she was gardening in her usual capacity and sometimes sustained unnoticed minor injuries. The investigations did not reveal any cause of immunosuppression, including notably HIV infection and diabetes. Ultrasound of the hand revealed marked and diffuse synovitis with a low vascular flow and tenosynovitis of the common flexor tendons extending into the thumb and the fifth finger's flexor tendon sheath. Subsequently, she underwent drainage of the collection in the 5th ray (R5) and limited debridement of the flexor tendon sheath. However, one month later, she was re-admitted for acute clinical deterioration with extension of the infection to the forearm (Fig. 1D). Histopathological analysis of the synovial tissue collected a month earlier showed intense chronic inflammation features with both necrotising and non-necrotizing granulomas. Cultures from perioperative samples, including aerobic culture and mycobacterial liquid media culture using the BACTEC MGIT 960 System, demonstrated the presence of methicillin-sensitive Staphylococcus aureus (MSSA) and mycobacteria after eight days of incubation. After the Ziehl-Neelsen staining, acid-fast bacilli (AFB) were observed. She was diagnosed with chronic NTM flexor tenosynovitis complicated by MSSA cellulitis. She was started empirically on rifampicin (600 mg once per day), clarithromycin (1000 mg once per day), ethambutol (1200 mg once per day), and cefazolin (six g/24 h). As specific detection of Mycobacterium tuberculosis Complex by Real-Time PCR was negative, species identification through 16S ribosomal RNA sequencing (16S rRNA) revealed *M. heraklionense* [1]. Antimycobacterial susceptibility testing (AST) was tested using broth microdilution method with Thermofisher Scientific™ Sensititre Slow Growing Mycobacteria (SLOMYCO2) Plate. Minimum inhibitory concentrations (MICs) were interpreted in accordance with the guidelines of the Clinical and Laboratory Standards Institute (CLSI) (document M24-A2) [24] and were reported in μg/mL as follows: clarithromycin, 0.25; rifabutin, ≤0.25; rifampin, >8; ethambutol, 2 (Table 1). Despite antibiotic therapy, two surgical interventions were necessary, including drainage of the abscessed collection and synovectomy. The procedures revealed a complete absence of pulleys and partial and complete ruptures of the flexor tendon sheaths of the R1 and R5, respectively. After a 10-day hospital stay, she was discharged on a combination of rifampicin, clarithromycin, and ethambutol. Cefazolin was substituted with minocycline (100 mg twice daily) for a month. Due to persistent flexor tenosynovitis in R4 and R5 after two months, she underwent a repeat synovectomy and neurolysis of the median nerve. Following negative per-operative mycobacterial culture, she continued the same antibiotic therapy for an additional four months, resulting in clinical improvement. Notably, rifampicin was replaced with rifabutin after two months due to gastrointestinal side effects. However, due to major functional impairment, subsequent management focused on hand rehabilitation and required serial reconstructive surgeries, including a second median nerve neurolysis, wrist flexors tenolysis, flessum plasty (Fig. 1E), and then arthrodesis of 5th finger (Fig. 1F). Currently, more than six years from the initial presentation, she has successfully returned to work despite experiencing residual stiffness and limitations in finger flexion movements.

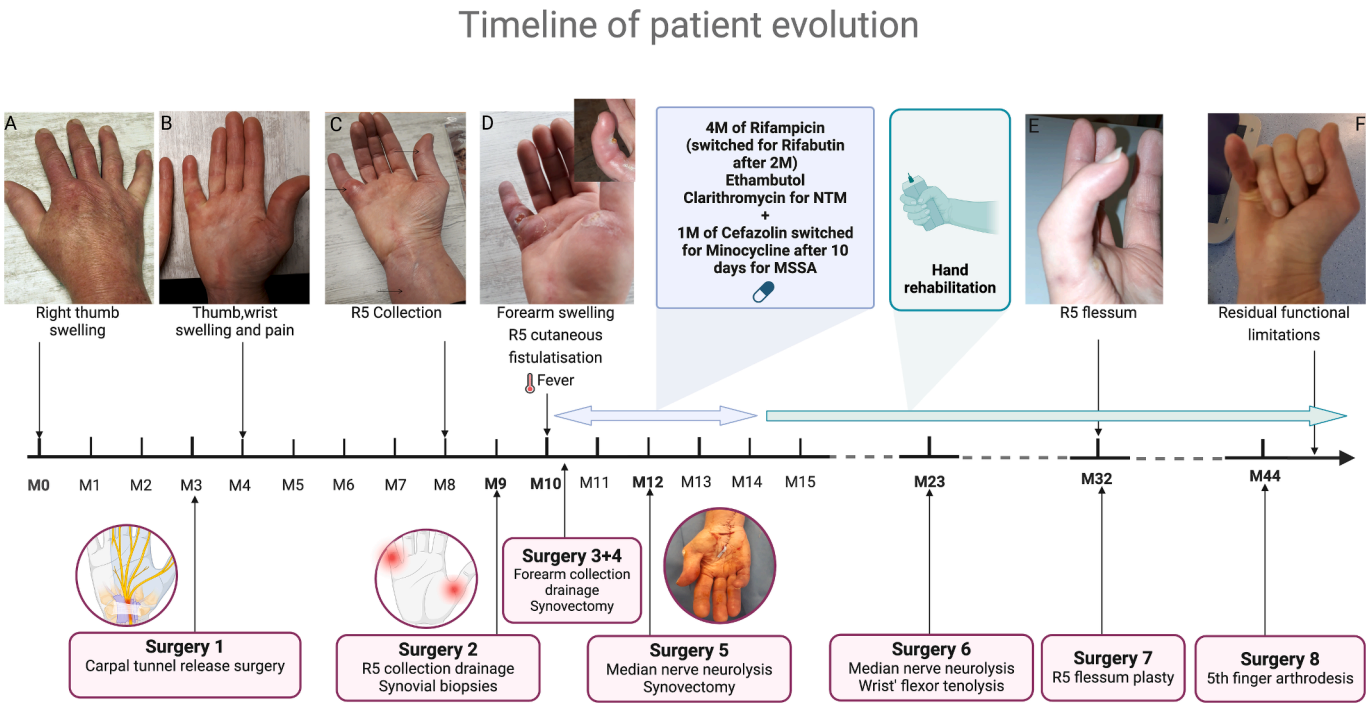

Fig. 1. Timeline of patient evolution. Abbreviations: M, months; R5, MSSA, Methicillin- susceptible Staphylococcus aureus; NTM, Nontuberculous Mycobacteria; R5, 5th rayon.

Table 1
Characteristics of 19 previously reported cases from patients with tenosynovitis due to *Mycobacterium heraklionense*.

First author	Gender	Age (years)	Underlying immune deficiency	History of trauma	Exposure History	Localisation	Method of diagnosis	Diagnosis delay (months)	Treatment before diagnosis	Susceptibility testing, MICs (ug/mL)	Antibiotic therapy	ATB duration (months)	Surgery	Number of surgery	Outcome
El Moussaoui, 2023	F	52	No	No	Gardening	R hand	Culture + in 8 days (liquid media culture, BACTEC MGIT 960 System) And 16S rRNA sequencing	9	NSAIDs, Oral + local CS injections	AMK, 32; RMP, >8; RBT, ≤0.25; CLA, 0.25; EMB, 2; CIP, >16; MOX, >8; DOX>16; LZD, 16; INH, >8; STR, 64; TMP-SMX, 2/38	RMP (switch for RBT because of GI side effects) + CLA+EMB 1 month of MIN for MSSA infection	4	Yes	4	Favorable (4 months) with no relapse at 5 years, but limitation of his finger movements and residual stiffness
Dutronc, 2023[4]	M	31	No	Yes	Palm thorn	R PIP index finger	Culture + in 16–24 days and 16S rRNA Sequencing	12	NSAIDs	Unknown	RBT + CLA	1,5	Yes	1	Favorable (6 months) but lost follow-up after
Dutronc, 2023[4]	M	52	No	Yes	Gardening	L third finger	Culture + in 16–24 days and 16 s rRNA Sequencing	7	Oral + local CS injections	Unknown	RBT (switch for RMP because of stock-out) + CLA (switch for AZI due to GI side effects)	6	Yes	1	Complete resolution (6 months)
Dutronc, 2023[4]	M	58	No	Yes	Nail that fell on the ground into his right hand	R second and fifth fingers	Culture + in 16–24 days and 16 s rRNA Sequencing	10	CS	Unknown	RMP + CLA + EMB	7	Yes	1	Complete resolution (7 months)
Mason, 2021[5]	F	58	HTA, Epilepsy, Lupus treated by immune-modulating agents recently stopped	No	Potential injuries during seizures	R index finger	Culture + in 28 days and 16 s rRNA Sequencing	>2	Local CS injections	S to AMK, RMP, RBT, CLA, EMB, LZD, and R to CIP, MOX, and TMP-SMX	RBT + AZI + EMB	12	Yes	2	Favorable (12 months) but residual stiffness up to 2 years after
Turner, 2021[9]	M	66	HTA, Coronary artery disease, Nephrolithiasis	Yes	Injury while handling water damaged plywood	R fifth finger	Culture + and 16S sequencing and WGS	6	Unknown	AMK, 16; CLA, 2; CLO, 0.12; Bedaquiline, 0.008	AZI + DOX + LZD (changed to LEV for GI side effects)	6	Yes	2	Favorable (at 6 months) with no relapse at 1 year
Bouchet, 2017[8]	M	41	No	Yes	Working in his vines	L third fingertip	Culture + in 14 days and rpoB and hsp65 sequencing	5.8	Amoxicillin-clavulanic acid, TMP-SMX	AMK, 16; RMP, 2; RBT, < 0.25; CLA, 4; EMB 2; CIP, 16; MOX>8; LZD, 64; SMX, 9.5	CLA	6	Yes	2	Favorable (at 6 months)
Aburjania, 2016[6]	M	72	No	No	Gardening and picking up golf balls	R middle finger	Some AFB on Ziehl-Neelsen-stained smears, No growth, rpoB sequencing	9	Local CS injections	No AST available due to negative culture	RMP + CLA (switched for AZI due to GI side effects) + EMB +	3	Yes	2	Favorable (2–3 months) but limitation of his finger movements

(*continued on next page*)

Table 1 (*continued*)

First author	Gender	Age (years)	Underlying immune deficiency	History of trauma	Exposure History	Localisation	Method of diagnosis	Diagnosis delay (months)	Treatment before diagnosis	Susceptibility testing, MICs (ug/mL)	Antibiotic therapy	ATB duration (months)	Surgery	Number of surgery	Outcome
											1 month of LEV for MSSA infection				
Greninge, 2015[7]	F	53	Unknown	Yes	Right Achilles tendon surgery after a gardening accident 20 years before	R medial soft-tissue ankle mass	Culture + in 14 days and partial rpoB sequencing	Unknown	Unknown	AMK, ≤ 2; RMP, >16; RBT, 0.25; CLA, ≥ 4; EMB, 1.25; CIP, >4; MOX, >2; KAN, 8; STR, 4	Unknown	Unknown	Yes	1	Unknown
Abedalthagai, 2014[2]	M	37	No	Yes	Tree pruning	L middle finger	16S rRNA sequencing	4	No	AMK, 8; RMP, ≤0.5; RBT, ≤0.12; CLA, ≤4; EMB, 2.5; CIP, >4; CLO, 0.5; STR, 8	RBT + CLA (switched after 2 weeks for AZI due to GI side effects) + EMB	3	Yes	2	Recurrence at 2 months after discontinuing treatment → AZI+EMB
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	R hand	16S rRNA sequencing	Unknown	Unknown	AMK, 8; RMP, 2; CLA, 2; EMB, 4; CIP, 8; MIN, >32; SMX, 8	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	Hand	16S rRNA sequencing	Unknown	Unknown	AMK, 8; RMP, 8; CLA, 1; EMB, 16; CIP, >8; MIN, >32; SMX, 16	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	Finger	16S rRNA sequencing	Unknown	Unknown	AMK, 64; RMP, 8; RBT, ≤0.25; CLA, 1.025; EMB, 2; CIP, >16; MOX, >8; DOX, >16; LZD, 8; TMP-SMX, 1/19	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	Finger	16S rRNA sequencing	Unknown	Unknown	AMK, 64; RMP, >8; RBT, 1.1; CLA, 1; EMB, 4; CIP, >16; MOX, >8; DOX, >16; LZD, 32; TMP-SMX, 2/38	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	R index finger	16S rRNA sequencing	Unknown	Unknown	AMK, 16; RMP, 4; RBT, 0.5; CLA, 2; EMB, 2; CIP, >16; MOX, >8; DOX, >16; LZD, 64; TMP-SMX, 1/19	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	L hand	16S rRNA sequencing	Unknown	Unknown	AMK, 16; RMP, 1; RBT, ≤0.25; CLA, 0.5; EMB, 2; CIP, >16; MOX, >8; DOX, >16; LZD, 32; TMP-SMX, 2/38	Unknown	Unknown	Unknown	Unknown	Unknown

(*continued on next page*)

Table 1 (*continued*)

First author	Gender	Age (years)	Underlying immune deficiency	History of trauma	Exposure History	Localisation	Method of diagnosis	Diagnosis delay (months)	Treatment before diagnosis	Susceptibility testing, MICs (ug/mL)	Antibiotic therapy	ATB duration (months)	Surgery	Number of surgery	Outcome
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	R index finger	16S rRNA sequencing	Unknown	Unknown	AMK, 64; RMP, 0.5; RBT, ≤0.25; CLA, 0.5; EMB, 8; CIP, 16; MOX, >8; DOX, >16; LZD, >64; TMP-SMX, ≤0.12/2.38	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	R index finger	16S rRNA sequencing	Unknown	Unknown	AMK, >64; RMP, 8; RBT, 0.5; CLA, 4; EMB, 2; CIP, >16; MOX, >8; DOX, >16; LZD, 64	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	R index finger	16S rRNA sequencing	Unknown	Unknown	AMK, 16; RMP, >8; RBT, ≤0.25; CLA, 0.5; EMB, 2; CIP, >16; MOX, >8; DOX, 8; LZD, 16; TMP-SMX, 1/19	Unknown	Unknown	Unknown	Unknown	Unknown
Vasiredy, 2016[3]	Unknown	Unknown	Unknown	Unknown	Unknown	Index finger	16S rRNA sequencing	Unknown	Unknown	AMK, 32; RMP, >8; RBT, 0.5; CLA, 0.5; EMB, 2; CIP, >16; MOX, >8; DOX, >16; LZD, 32; TMP-SMX, 1/19	Unknown	Unknown	Unknown	Unknown	Unknown

Abbreviations: M, male; F, female; HTA, hypertension; PIP, interphalangeal; R, right; L, left; CS, corticosteroid; NA, not available; S, susceptible; R, resistant; CLA, clarithromycin; AZI, azithromycin; EMB, ethambutol; RBT, rifabutin; RMP, rifampicin; AMK, amikacin; DOX, doxycycline; CIP, ciprofloxacin; MOX, Moxifloxacin; LZD, linezolide; LEV, levofloxacin; CLO, clofazimine; KAN, Kanamycin; STR, Streptomycin; TET, Tetracycline; MIN, minocycline; TMP-SMX, Trimethoprim-sulfamethoxazole; BDQ, bedaquiline; GI, gastrointestinal; NSAIDs, MSSA, methicillin-sensitive S. aureus; Non-steroidal anti-inflammatory drugs, WGS, whole genome sequencing.

3. Discussion

M. heraklionense is an intermediate-growing member of the *Mycobacterium terrae complex* (MTC), initially identified in 2013 from many strains in Heraklion [1]. *M. heraklionense* has been isolated from various human specimens, including musculoskeletal, sputum, broncho-alveolar lavage, and urine samples, notably in a case series involving 12 elderly patients with underlying health conditions at Heraklion Hospital in Greece [25]. However, despite its detection in various clinical contexts, a definitive link between *M. heraklionense* and patient mortality remains elusive, except for musculoskeletal involvement. In the environment, *M.* heraklionense has been detected in water treatment sludge (Makovcova J, Babak V, Slany M, Slana I. 2015) [26] and Bolaños and colleagues identified *M. heraklionense* in milk samples obtained from cows that tested positive for the tuberculin test, thereby emphasising the potential route of pathogen transmission from bovines to humans via milk or dairy products [27].

Since the first description of a patient with hand tenosynovitis in 2014, 19 additional patients have been described [8,17–23]. Among these, ten were previously diagnosed as unspecified MTC tenosynovitis or osteomyelitis using nonmolecular methods between 1984 and 2015 [18]. Patients' characteristics are displayed in Table 1. Most patients were male, with a median age of 52.5 years (range 31–72). Tenosynovial or osteoarticular infections caused by *M. heraklionense* typically manifest with an insidious course, presenting as long-standing pain and swelling involving either the wrist or the hand. Due to its challenging diagnosis, most patients experienced a delay between the onset of symptoms and diagnosis, with a median time of 7 months (range, 2–12). Consequently, some patients had received corticosteroids before the diagnosis, potentially promoting bacterial coinfection, such as the reported Staphylococcus aureus infection in two cases. While most patients showed no evidence of immunosuppression, all reported either a history of hand trauma or an occupation that increased the risk of trauma (typically gardening), suggesting that direct environmental inoculation was the infection mechanism.

A definitive diagnosis relies on a tissue specimen culture from liquid or solid media incubated at several temperatures. Mature growth is achieved after at least eight days of incubation (range 8–24 days, Table 1), and establishing a diagnosis may necessitate multiple tissue specimens and serial debridement [28]. Acid-Fast Bacilli (AFB) smear is often negative [18]. Molecular diagnostics using sequencing of 16S ribosomal RNA (16S rRNA) or sometimes beta subunit of RNA polymerase (rpoB), heat shock protein (hsp65), or even whole-genome sequencing, can be invaluable in establishing a diagnosis, particularly when the culture is negative despite a high suspicion of NTM tenosynovitis [18].

There are no standardised breakpoints or interpretative procedures for MTC, and the correlation between in vitro susceptibility and clinical efficacy remains unknown [28]. While some authors have extrapolated data from *Mycobacterium kansasii* for interpreting MIC [17,23,28], the current recommendation is to use broth microdilution method and report only the MIC without interpretation. As illustrated in Table 1, *M. heraklionense* strains are generally susceptible to rifabutin, clarithromycin, and ethambutol while displaying resistance to rifampin, trimethoprim-sulfamethoxazole, tetracycline, and quinolones.

Although one patient reported was treated only with a single agent [23], most patients were treated with a combination of three agents. Various antimicrobials were administrated, with the most common combinations being rifampin or rifabutin plus ethambutol and clarithromycin. The most common drug side effect reported involved the gastrointestinal system in 5 patients (clarithromycin; n = 2, rifampicin; n = 2, linezolide; n = 1) and required therapy modification.

The median duration of antibiotic therapy was six months, ranging from 1.5 to 12 months. Clinical improvement is reported after at least two months of treatment. Most patients were free from infection after a median follow-up of 6 months (ranging from 2 months to 5 years), with only one recurrence noted. At the last follow-up, three patients reported experiencing finger movement limitations and residual stiffness (Table 1). All patients underwent surgical treatment with an average of 1,8 surgeries per patient (range, 1–4).

Although the optimal duration of antibiotic therapy in NTM is unclear, prolonged treatment is frequently recommended, typically spanning a minimum of three to six months, with some cases necessitating therapy for up to 12 months, depending on the clinical severity [29–31]. The extended duration of treatment beyond 12 months does not appear to be associated with a better outcome. While microbiological cure is generally achieved, most long-term issues like persistent pain or stiffness are primarily mechanical, highlighting the significance of hand rehabilitation. Although antimycobacterial therapy alone may lead to complete remission in the early stages of the disease in rare case reports, delayed diagnosis is common, and an aggressive surgical approach surgery for source control remains a key component of managing NTM hand infection. This strategy seems crucial in locally advanced diseases to reduce the overall bacterial tissue load and give chemotherapy a better chance of eradicating the residual infection. It may also potentially shorten the duration of drug therapy and subsequently minimise drug side effects.

In conclusion, our report provides a detailed overview of *M. heraklionense* infection. The true epidemiology remains unknown, requiring more molecular methods for NTM identification. Due to challenging diagnosis and potential severe hand infections, *M. heraklionense* should be considered in chronic flexor tenosynovitis differential diagnosis to minimise sequelae. NTM infection should be suspected in patients who have a history of trauma or repeated steroid injections if their symptoms do not improve with conventional treatment. Future research is crucial to defining optimal therapeutic strategies for NTM tenosynovitis. Further research is essential to define the optimal therapeutic strategy for nontuberculous mycobacteria tenosynovitis.

4. Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

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CRediT authorship contribution statement

Majdouline El Moussaoui: Writing – original draft, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicolas Lambert:** Writing – review & editing. **Patrick Massage:** Writing – review & editing. **Cécile Meex:** Writing – review & editing. **Marie-Pierre Hayette:** Writing – review & editing, Investigation. **Philippe Delvenne:** Writing – review & editing, Investigation. **Charline Rinkin:** Writing – review & editing, Investigation. **Michel Moutschen:** Writing – review & editing. **Gilles Darcis:** Writing – review & editing. **Olivier Malaise:** Writing – review & editing, Validation, Investigation, Data curation. **Jean-Baptiste Giot:** Writing – review & editing, Validation, Supervision, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jctube.2024.100479.

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