Nontuberculous Mycobacterial Cutaneous Infections: An Updated Review

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Nontuberculous mycobacteria (NTM) cause cutaneous infections more commonly than Mycobacterium tuberculosis, *and the incidence of infection with these organisms is increasing with the use of immunosuppressive agents. Diagnosis of NTM cutaneous infections is not always straightforward. Therefore, a high index of clinical suspicion is needed to make a diagnosis of NTM cutaneous infection.*

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The term *nontuberculous mycobacteria* (NTM) has evolved from prior nomenclature including *anonymous* or *atypical mycobacteria*. Riehl and Paltauf[1] described a localized form of skin tuberculosis in 1886. In 1932, Pinner[2] postulated that almost any *Mycobacterium* might invade human tissue and elicit disease characterized by tubercle formation.

Subsequently, NTM were isolated from subcutaneous abscesses and ulcerative skin lesions by Freeman[3] and McCallum et al[4] in 1938 and 1948, respectively. Nontuberculous mycobacteria were identified as the agents of dermatologic lesions in 7 patients seen at a referral center from 1969 to 1979. In each of these instances, mycobacterial etiology was not suspected, and diagnosis was made only after careful microbiologic studies.[5] Hence presentation of these infections is variable, which can lead to missed diagnoses.

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Epidemiology

Nontuberculous mycobacteria are found almost worldwide in soil, water, vegetation, and indigenous animals. They also can colonize body surfaces. Although the modes of transmission are incompletely understood, human-to-human transmission is not known to occur. True incidence of NTM infections in the United States is difficult to determine because they are not communicable diseases and are not reportable. Most environmental isolates are *Mycobacterium avium*, *Mycobacterium kansasii*, and *Mycobacterium fortuitum*.[6-9] Isolation of these organisms when medical sterilization techniques are inadequate also is a problem (eg, improper sterilization techniques associated with mesotherapy have been reported).[10]

In recent literature, NTM cutaneous infection has been described in an immunocompromised patient after acupuncture treatment.[11] Similarly, a recent outbreak of NTM skin infection after tattoos was described by Drage et al.[12] Three cases of NTM cutaneous infection associated with subcutaneous insulin therapy have emerged in the current literature.[13]

Outbreaks of *M fortuitum*[14,15] and *Mycobacterium bolletii*[16] furunculosis associated with whirlpool footbaths at nail salons also have been seen. Risk factors for NTM cutaneous infections include local factors.[17,18] Dodiuk-Gad et al[19] published their experience with NTM infections of the skin in a retrospective analysis. Overall cutaneous infections have been described in both immunocompetent and immunocompromised hosts.[11,20-25]

Mycobacteriology

Nontuberculous mycobacteria are slender, nonmotile, acid-fast bacilli. In 1896, *Mycobacterium* was recommended as the genus for a group of bacteria that grew moldlike pellicles when cultured in liquid media.[26]

Classification of NTM—In 1959, Runyon[27] introduced the classification of more than 400 NTM into 4 groups (Table) based on growth rate and colony pigmentation on Lowenstein-Jensen medium; it has

gone through a few revisions over the years. This classification has become less useful nowadays as the growth rates and pigment production vary, and many organisms do not fit into the categories.

A newer classification system divides NTM infections into clinical disease groups based on the organ system involved (ie, pulmonary, lymphatic, cutaneous, disseminated).[28] Clinically important NTM include M *kansasii*, *Mycobacterium genavense*, *Mycobacterium marinum*, *Mycobacterium simiae*, *Mycobacterium scrofulaceum*, *Mycobacterium szulgai*, M *avium*, *Mycobacterium haemophilum*, *Mycobacterium intracellulare*, *Mycobacterium malmoense*, *Mycobacterium ulcerans*, *Mycobacterium xenopi*, *Mycobacterium abscessus*, *Mycobacterium chelonae*, and M *fortuitum*.[24,29] Because of their similar clinical, etiologic, and antigenic characteristics, certain groups of NTM are considered together as complexes. For instance, M *avium* and M *intracellulare* produce identical diseases and are found together endemically; therefore, they are grouped together as the *Mycobacterium avium-intracellulare complex*. Likewise M *fortuitum* and M *chelonae* are many times grouped together as the *Mycobacterium fortuitum-chelonae complex*.

Pathogenesis

Nontuberculous mycobacteria are opportunistic pathogens that are capable of causing pulmonary, synovial, tendon, bursa, and skin soft tissue infections. Cutaneous infections may be a result of direct inoculation associated with trauma or surgical wounds or a consequence of hematogenous seeding.[30] The human immunodeficiency virus pandemic has drastically changed the overall picture of NTM infections. In patients with AIDS and other immunocompromised individuals, NTM infection usually is disseminated and may not be associated with trauma or use of immunosuppressants.[31-34]

Selective susceptibility to weakly pathogenic mycobacteria, such as attenuated *Mycobacterium bovis* in BCG vaccine and environmental NTM, has been suspected to be a mendelian disorder for several years and various mutations more recently have been identified in a number of patients with severe NTM infection.[35,36]

Histopathology

Different histopathologic patterns in cutaneous NTM infections depend on host immunity. A granulomatous inflammatory infiltrate with tuberculoid granuloma formation, sarcoidlike granulomas, or rheumatoidlike nodules frequently are seen, but dermal or subcutaneous abscesses, diffuse dermal or subcutaneous histiocytic infiltration, or even chronic nonspecific inflammation have been described. Bartralot et al[37] reported deeper infiltrates in immunosuppressed patients. Figure 1 illustrates histopathologic findings of a lesion in an 8-year-old girl who underwent multiple debridements for presumed staphylococcal infection.[38] Final culture revealed M *marinum*.

Clinical Presentation

Mycobacterium marinum infection primarily is localized to the skin at the innoculation site. It commonly

Modified Runyon[27] Classification

Group I Photochromogens

Mycobacterium kansasii, Mycobacterium marinum (at 25°C)

Group II Scotochromogens

Mycobacterium scrofulaceum, Mycobacterium gordonae, Mycobacterium xenopi, Mycobacterium szulgai (at 37°C)

Group III Nonphotochromogens

Mycobacterium haemophilum, Mycobacterium avium-intracellulare complex, Mycobacterium ulcerans

Group IV Rapid Growers (3–5 days)

Mycobacterium fortuitum, Mycobacterium chelonae, Mycobacterium smegmatis

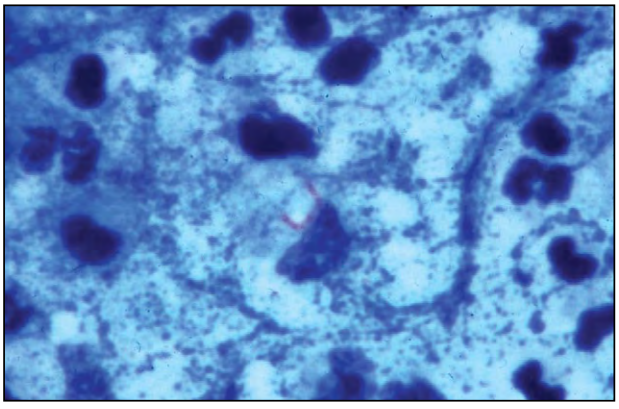

Figure 1. Biopsy of a *Mycobacterium marinum* lesion in an 8-year-old girl who underwent multiple debridements for presumed staphylococcal infection (acid-fast stain, original magnification ×100). The patient's history included exposure to her brother's fish tank. Beaded acid-fast bacilli were noted. Reprinted with permission from Bottone.[38]

appears as a solitary papulonodule, a granulomatous nodule with central ulceration, a verrucous plaque with central clearing, or as a sporotrichoid lesion on areas predisposed to trauma.[30,39] Most M *marinum* infections are contracted during cleaning of an aquarium or submersion of an extremity into aquarium water. Few patients may report direct trauma from an aquarium wall.[40] Disseminated lesions or deep infection involving bone have been documented in the literature.[41] Small superficial lesions may spontaneously heal, while large and deeper lesions may take months to years to heal (Figure 2).

Mycobacterium ulcerans produces an indolent cutaneous infection known as Buruli ulcers. The patient usually has no systemic symptoms. Spontaneous healing of the ulcer has been described; healing starts at the proximal end of the ulcer and extends to the distal portions, resulting in a depressed scar that contracts and may produce severe deformities.[21]

Mycobacterium chelonae and M *abscessus* are responsible for approximately 95% of disseminated cutaneous infections caused by the rapidly growing mycobacteria. Unlike patients with a localized infection, patients with disseminated cutaneous disease have multiple painful draining small abscesses that involve the arms and legs. Localized cellulitis, osteomyelitis, and small-joint arthritis also are commonly associated with M *chelonae*.[17,20]

The skin lesions in M *haemophilum* infection usually occur in multiple locations on the extremities and occasionally on the trunk, with red to violaceous papules that gradually enlarge to become tender, crusted, ulcerated nodules or abscesses and fistulae draining purulent material (Figure 3). Rarely, patients may develop bone involvement.[22,23,34]

Rapid growers such as M *fortuitum* can cause a wide spectrum of clinical diseases. Cutaneous infections may present as cellulitis, abscesses, nodules, sinuses, and ulcers with serosanguineous or purulent discharge. They may induce extensive subcutaneous necrosis and pus formation. Regional lymphadenitis also is usually present.[11,18] Figure 4 demonstrates an M *fortuitum*–associated ulcerated lesion on the leg with sinus tracts after a surgical procedure.

Cutaneous disease with M *kansasii* usually manifests as papules, pustules, sporotrichoid verrucous nodules, ulcers, or cellulitis associated with history of trauma and immunosuppression.[42] *Mycobacterium avium complex* typically has little virulence in the immunocompetent host, but in immunocompromised patients (eg, patients with AIDS), disseminated forms of infection have been described. Cutaneous lesions begin as multiple painful subcutaneous nodules, scaling plaques, and verrucous ulcers, which then ulcerate and drain a purulent material.[31,33,37]

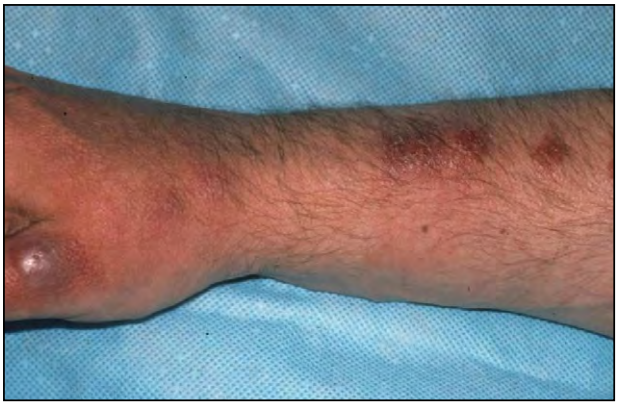

Figure 2. Sporotrichoid progression of abscessed lesions along the lymphatics from *Mycobacterium marinum* infection. Reprinted with permission from Bottone.[38]

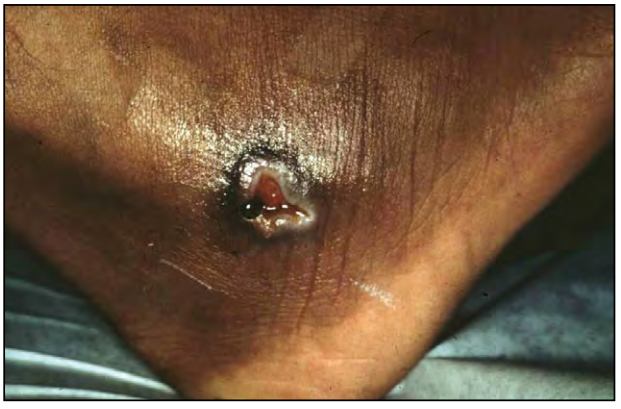

Figure 3. An ulcerative lesion on the ankle from *Mycobacterium haemophilum* infection in a patient with AIDS. Reprinted with permission from Bottone.[38]

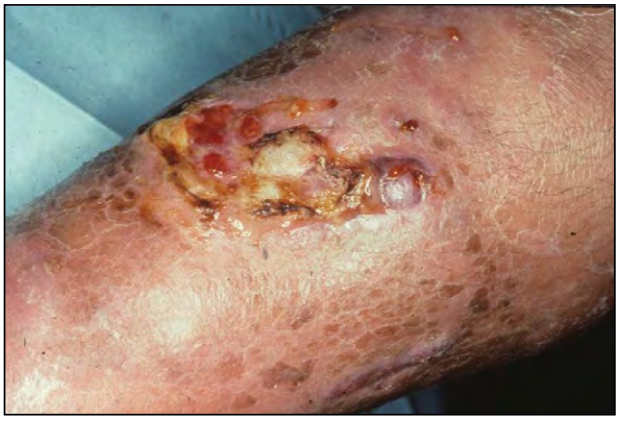

Figure 4. An ulcerated lesion on the leg with sinus tracts from *Mycobacterium fortuitum-chelonae complex* infection, which developed following a cosmetic fat transplant to the leg. Reprinted with permission from Bottone.[38]

Diagnosis

Nontuberculous mycobacteria as a cause of cutaneous lesions are often overlooked because of their varied presentations and low index of suspicion

and/or inadequate culture techniques. Diagnostic criteria involve epidemiologic, clinical, microbiologic, and pathologic findings. Identification of *Mycobacterium* species in cultures is the gold standard. Acid-fast stains are crucial in the workup of these bacteria. Routine culture media, such as blood or chocolate agar, will support growth of some of the NTM including M *haemophilum*. Lowenstein-Jensen medium with contaminant-inhibiting antimicrobials is the preferable medium with 2% ferric ammonium citrate added if M *haemophilum* is suspected. All cultures for suspected NTM should be saved under refrigeration for sensitivity testing and biochemical identification by a reference laboratory. Temperature effects on growth of NTM, as evident from Runyon[27] classification, are useful for colony survival and differentiation among the various species of NTM. The properly inoculated Lowenstein-Jensen medium cultures are incubated at 25°C, 30°C, and 37°C, with a 5% to 10% CO_2 atmosphere.[24] Detection of mycobacterial DNA by amplification of ribosomal RNA has emerged as a vastly used modality in recent literature.[43,44]

Treatment

Generally, excision or debridement may be necessary for most lesions. Large gaps still exist in our knowledge and limitations in systematic data have made it necessary for many of the recommendations in this and other reports to be based on expert opinion rather than well-performed clinical trials. The drug susceptibility profile of NTM usually is quite different from *Mycobacterium tuberculosis*, which makes susceptibility testing an essential tool[45] with demonstration of excellent in vitro activity of drugs such as clarithromycin, imipenem, cefoxitin, and amikacin for most NTM. Expert consultation for close management and follow-up is highly recommended, not only due to the variability in treatment choices and duration of therapy but also to monitor for the potential of drug resistance or adverse reactions.

Based on results of case studies of patients with NTM cutaneous infections, guidelines have been suggested for drug therapy for rapidly growing NTM. Rapidly growing NTM generally are resistant to usual antituberculous agents; they are frequently susceptible to traditional antibacterial agents, including amikacin, ciprofloxacin, sulfonamides, cefoxitin, imipenem, clarithromycin, and doxycycline. Newer agents (eg, tigecycline) are under investigation.[46,47] Surgical treatment is recommended by most authorities for M *fortuitum* infections, along with antimycobacterial therapy, but there have been cases in which oral therapy may be adequate.[46] While waiting for susceptibility data, empiric therapy with quinolones, tetracyclines, macrolides, or trimethoprim-sulfamethoxazole may be beneficial.[48] It may be reasonable to start dual-agent therapy to minimize potential for development of resistance. Similarly combined surgical and pharmacologic treatment is recommended for M *abscessus* infections. Initial empiric agents that have been recommended include clarithromycin along with amikacin or high-dose cefoxitin for at least the initial 2 weeks of therapy.[24] Choi et al[49] recently described in a prospective nonrandomized study better clinical response with a combination regimen comprised of moxifloxacin and clarithromycin. Prolonged therapy for at least 3 to 6 months depending on the extent of infection generally has been recommended. For serious skin infections, a minimum of 4 months of therapy has been recommended to provide likelihood of cure, while for bony involvement, 6 months of therapy is recommended.[24]

Treatment of M *chelonae* usually is difficult due to the high degree of antimicrobial resistance; therefore, therapy needs to be modified in accordance with the susceptibility profile. With antimicrobials, surgery usually is not needed, but debridement may sometimes be warranted for deeper infections. Usual intravenous agents of choice are amikacin and imipenem.[24] Most isolates are susceptible to clarithromycin and one-fourth of the isolates are sensitive to doxycycline or ciprofloxacin.[25] Combination therapy with at least 2 agents must be considered to decrease the likelihood of resistance.[50] Cutaneous infection with M *marinum* is relatively rare and single skin papules associated with M *marinum* may spontaneously heal in 24 to 36 months; however, some may persist for several years, which makes initiation of treatment logical. The organism usually is sensitive to tetracycline, minocycline, doxycycline, trimethoprim-sulfamethoxazole, rifampin, ethambutol, and clarithromycin.[24] Clarithromycin is bactericidal against M *marinum* and also the combination of ethambutol and clarithromycin has synergistic activities in vitro and is recommended for persistent lesions.[51] Therefore, initial therapy may consist of a combination of ethambutol and rifampin or minocycline.[22] According, to the current literature, the treatment duration range is 4 to 38 weeks, including at least 4 to 8 weeks of treatment after the lesions have healed.[52]

Treatment of M *ulcerans*–associated lesions/ulcers primarily is surgical and includes wide excision, debridement, and possible skin grafting. Rifampin in combination with amikacin and streptomycin has been studied extensively in mice and warrants further study for the treatment of M *ulcerans* infection in humans.[45-47,53] Nakanaga et al[54] recently published their experience with 19 cases of M *ulcerans*.

There are no adequate data on treatment of M *haemophilum*, but it is thought that some patients

may improve as their immune status improves while on treatment with isoniazid and rifampin.[47] *Mycobacterium haemophilum* does exhibit in vitro susceptibility to amikacin, ciprofloxacin, clarithromycin, and rifampin. Treatment with rifampin along with clarithromycin with or without the addition of amikacin has been described.[34,43]

Therapy for M *kansasii* includes isoniazid, rifampin, and ethambutol administered daily for 18 months.[45] Successful treatment with interferon as an adjunct to antimicrobial therapy for M *abscessus* and M *chelonae* infection has been described.[55,56]

Prevention

Preventive measures include adequate chlorination of swimming pools, protection of traumatized skin from contaminated water, and reduction of skin trauma in individuals who are exposed to natural water sources or fish tanks. Nontuberculous mycobacteria in addition to other infections can be prevented by using sterile surgical equipment, syringes/needles, and adherence to aseptic techniques during surgical procedures.

Conclusion

Nontuberculous mycobacteria are known to cause skin lesions in both immunosuppressed and immunocompetent patients. Organisms can either enter skin via direct inoculation or by hematogenous seeding, particularly in an immunosuppressed host. *Mycobacterium marinum*, M *ulcerans*, M *fortuitum*, M *chelonae*, and M *haemophilum* are the most common NTM identified as causes of cutaneous infections. A high clinical index of suspicion is essential. It is important to alert the microbiology laboratory of your suspicion for mycobacterial etiology. Diagnosis involves epidemiologic, clinical, microbiologic, and pathologic findings. Identification of *Mycobacterium* species in cultures is the gold standard. Real-time polymerase chain reaction methods are being increasingly utilized for rapid differential identification of various *Mycobacterium* species.

Clinicians should always include the possibility of mycobacterial infection in their differential diagnosis when evaluating skin lesions that develop, especially at traumatized sites, regardless of immune status of the patient, especially when these lesions follow a chronic course despite conventional antimicrobial therapy and drainage. Treatments and duration of therapy vary for various species and sites. Therefore, it is imperative to obtain sensitivities as appropriate. A combined therapeutic approach, including surgical drainage, debridement, and prolonged (>3–6 months) treatment has been used in many cases of NTM cutaneous infections.

REFERENCES

1. Riehl G, Paltauf R. Tuberculosis verrucosa cutis. *Vierteljahrschrift für Dermatologie (Wien)*. 1886;13:19-49. Cited by: Collins CH, Grange JM, Noble WC, et al. *Mycobacterium marinum* infections in man. *J Hyg (Lond)*. 1985;94:135-149.
2. Pinner M. Atypical acid-fast organisms. *Proc Soc Exp Biol Med*. 1932;30:214-216.
3. Freeman G. Minimal mycobacterial infections. *Am Rev Tuberc*. 1938;38:612-623.
4. MacCallum P, Tolhurst JC, Buckle C, et al. A new mycobacterial infection in man. *J Pathol Bacteriol*. 1948; 60:93-122.
5. Damsker B, Bottone EJ. Nontuberculous mycobacteria as unsuspected agents of dermatological infections: diagnosis through microbiological parameters. *J Clin Microbiol*. 1980;11:569-572.
6. Horsburgh CR Jr. Epidemiology of disease caused by nontuberculous mycobacteria. *Semin Respir Infect*. 1996;11: 244-251.
7. Kullavanijaya P. Atypical mycobacterial cutaneous infection. *Clin Dermatol*. 1999;17:153-158.
8. Gbery IP, Djeha D, Yobouet P, et al. Atypical mycobacterial skin infections [in French]. *Sante*. 1996;6:317-322.
9. O'Brien RJ, Geiter LJ, Snider DE Jr. The epidemiology of nontuberculous mycobacterial disease in the United States. results from a national survey. *Am Rev Respir Dis*. 1987;135:1007-1014.
10. Sañudo A, Vallejo F, Sierra M, et al. Nontuberculous mycobacteria infection after mesotherapy: preliminary report of 15 cases. *Int J Dermatol*. 2007;46:649-653.
11. Castro-Silva AN, Freire AO, Grinbaum RS, et al. Cutaneous *Mycobacterium haemophilum* infection in a kidney transplant recipient after acupuncture treatment. *Transpl Infect Dis*. 2011;13:33-37.
12. Drage LA, Ecker PM, Orenstein R, et al. An outbreak of *Mycobacterium chelonae* infection in tattoos. *J Am Acad Dermatol*. 2010;62:501-506.
13. Sousa TS, Matherne RJ, Wilkerson MG. Case report: cutaneous nontuberculous mycobacterial abscesses associated with insulin injections. *J Drugs Dermatol*. 2010;9: 1439-1442.
14. Winthrop KL, Abrams M, Yakrus M, et al. An outbreak of mycobacterial furunculosis associated with footbaths at a nail salon. *N Engl J Med*. 2002;346:1366-1371.
15. Vugia DJ, Jang Y, Zizek C, et al. Mycobacteria in nail salon whirlpool footbaths, California. *Emerg Infect Dis*. 2005;11:616-618.
16. Wertman R, Miller M, Groben P, et al. *Mycobacterium bolletii/Mycobacterium massiliense* furunculosis associated with pedicure foot baths: a report of 3 cases. *Arch Dermatol*. 2011;147:454-458.
17. Wallace RJ Jr, Brown BA, Onyi GO. Skin, soft tissue and bone infections due to *Mycobacterim chelonae*: importance of prior corticosteroid therapy, frequency of disseminated

infections, and resistance to oral antimicrobials other than clarithromycin. *J Infec Dis*. 1992;166:405-412.
18. Kuritsky JN, Bullen MG, Broome CV, et al. Sternal wound infections and endocarditis due to organisms of the *Mycobacterium fortuitum* complex. *Ann Intern Med*. 1983;98:938-939.
19. Dodiuk-Gad R, Dyachenko P, Ziv M, et al. Nontuberculous mycobacterial infections of the skin: a retrospective study of 25 cases [published online ahead of print March 26, 2007]. *J Am Acad Dermatol*. 2007;57:413-420.
20. Satta R, Cottoni F, Molicotti P, et al. Cutaneous *Mycobacterium chelonae* infection in a presumably immunocompetent host. *Acta Derm Venereol*. 2002;82:156-157.
21. van der Werf T, van der Graaf WT, Tappero JW, et al. *Mycobacterium ulcerans* infection. *Lancet*. 1999;354: 1013-1018.
22. Davis BR, Brumbach J, Sanders WJ, et al. Skin lesions caused by *Mycobacterium haemophilum*. *Ann Intern Med*. 1982;97:723-724.
23. Smith S, Taylor GD, Fanning EA. Chronic cutaneous *Mycobacterium haemophilum* infection acquired from coral injury [published online ahead of print September 5, 2003]. *Clin Infect Dis*. 2003;37:e100-e101.
24. Weitzul S, Eichhorn PJ, Pandya AG. Nontuberculous mycobacterial infections of the skin. *Dermatol Clin*. 2000;18:359-377, xi-xii.
25. Jogi R, Tyring SK. Therapy of nontuberculous mycobacterial infections. *Dermatol Ther*. 2004;17:491-498.
26. Savin JA, Wilkinson DS. Mycobacterial infections including tuberculosis. In: Rook A, Wilkinson DS, Ebling FJG, et al, eds. *Textbook of Dermatology*. Vol 1. 4th ed. Boston, MA: Blackwell Scientific Publications; 1986:791-822.
27. Runyon EH. Anonymous mycobacteria in pulmonary disease. *Med Clin North Am*. 1959;45:273-290.
28. Diagnosis and treatment of diseases caused by nontuberculous mycobacteria. *Am Rev Respir Dis*. 1990;142:940-953.
29. French AL, Benator DA, Gordin FM. Nontuberculous mycobacterial infections. *Med Clin North Am*. 1997;81:361-379.
30. Chow SP, Stroebel AB, Lau JH, et al. *Mycobacterium marinum* infection of the hand involving deep structures. *J Hand Surg*. 1983;8:568-573.
31. Sanders JW, Walsh AD, Snider RL, et al. Disseminated *Mycobacterium scrofulaceum* infection: a potentially treatable complication of AIDS. *Clin Infect Dis*. 1995;20:549.
32. Piersimoni C. Non-tuberculous mycobacteria infection in solid organ transplant recipients [published online ahead of print July 7, 2011]. *Eur J Clin Microbiol Infect Dis*. doi:10.1007/s10096-011-1329-4.
33. Bekou V, Büchau A, Flaig MJ, et al. Cutaneous infection by *Mycobacterium haemophilum* and *kansasii* in an IgA-deficient man. *BMC Dermatol*. 2011;11:3.
34. Elsayed S, Read R. *Mycobacterium haemophilum* osteomyelitis: case report and review of the literature. *BMC Infect Dis*. 2006;6:70.
35. Döffinger R, Dupuis S, Picard C, et al. Inherited disorders of IL-12-and IFNgamma-mediated immunity: a molecular genetics update. *Mol Immunol*. 2002;38:903-909.
36. Casanova JL. Mendelian susceptibility to mycobacterial infection in man. *Swiss Med Wkly*. 2001;131:445-454.
37. Bartralot R, Pujot R, Garcìa-Patos V, et al. Cutaneous infections due to nontuberculous mycobacteria: histopathological review of 28 cases. comparative study between lesions observed in immunosuppressed patients and normal hosts. *J Clin Pathol*. 2000;27:124-129.
38. Bottone EJ. *An Atlas of the Clinical Microbiology of Infectious Diseases: Bacterial Agents*. Vol 1. New York, NY: The Parthenon Publishing Group; 2004.
39. Ekerot L, Jacobsson L, Forsgren A. *Mycobacterim marinum* wrist arthritis: local and systemic dissemination caused by concomitant immunosuppressive therapy. *Scan J Inf Dis*. 1998;30:84-87.
40. Engbaek HC, Thormann J, Vergmann B. Aquarium-borne *Mycobacterium marinum* granulomas. *Scand J Infect Dis*. 1980;12:74-78.
41. Sivan M, Bose D, Athanasou N, et al. *Mycobacterium marinum* osteomyelitis of a long bone. *Joint Bone Spine*. 2008;75:600-602.
42. Connick E, Levi ME. *Mycobacterium kansasii* cutaneous abscesses occurring as immune reconstitution inflammatory syndrome. *Int J Tuberc Lung Dis*. 2011;15:993.
43. Collina G, Morandi L, Lanzoni A, et al. Atypical cutaneous mycobacteriosis diagnosed by polymerase chain reaction. *Br J Dermatol*. 2002;147:781-784.
44. Ngan GJ, Ng LM, Jureen R, et al. Development of multiplex PCR assays based on the 16S-23S rRNA internal transcribed spacer for the detection of clinically relevant nontuberculous mycobacteria. *Lett Appl Microbiol*. 2011;52:546-554.
45. American Thoracic Society. Diagnosis and treatment of disease caused by nontuberculous mycobacteria. *Am J Respir Crit Care Med*. 1997;156(2, pt 2):S1-S25.
46. Wallace RJ Jr, Swenson JM, Silcox VA, et al. Treatment of nonpulmonary infections due to *Mycobacterium fortuitum* and *Mycobacterium chelonei* on the basis of in vitro susceptibilities. *J Infect Dis*. 1985;152:500-514.
47. Wallace RJ Jr, Brown-Elliott BA, Crist CJ, et al. Comparison of the in vitro activity of the glycylcycline tigecycline (formerly GAR-936) with those of tetracycline, minocycline, and doxycycline against isolates of nontuberculous mycobacteria. *Antimicrob Agents Chemother*. 2002;46:3164-3167.
48. Winthrop KL, Albridge K, South D, et al. The clinical management and outcome of nail salon-acquired *Mycobacterium fortuitum* skin infection [published online ahead of print December 8, 2003]. *Clin Infect Dis*. 2004;38:38-44.
49. Choi WS, Kim MJ, Park DW, et al. Clarithromycin and amikacin vs. clarithromycin and moxifloxacin for the treatment of post-acupuncture cutaneous infections due to

Mycobacterium abscessus: a prospective observational study. *Clin Microbiol Infect*. 2011;17:1084-1090.

50. Driscoll MS, Tyring SK. Development of resistance to clarithromycin after treatment of cutaneous *Mycobacterium chelonae* infection. *J Am Acad Dermatol*. 1997;36:495-496.
51. Bonnet E, Debat-Zoguereh D, Peti N, et al. Clarithromycin: a potent agent against infections due to *Mycobacterium marinum*. *Clin Infec Dis*. 1994;18:664-666.
52. Ang P, Rattana-Apiromyakij N, Goh CL. Retrospective study of *Mycobacterium marinum* skin infections. *Int J Dermatol*. 2000;39:343-347.
53. Bentoucha A, Robert J, Dega H, et al. Activities of new macrolides and fluoroquinolones against *Mycobacterium ulcerans* infection in mice. *Antimicrob Agents Chemother*. 2001;45:3109-3112.
54. Nakanaga K, Hoshino Y, Yotsu RR, et al. Nineteen cases of buruli ulcer diagnosed in Japan, 1980-2010 [published online ahead of print August 31, 2011]. *J Clin Microbiol*. JCM.00783-11v1-JCM.00783-11.
55. Colsky AS, Hanly A, Elgart G, et al. Treatment of refractory disseminated *Mycobacterim abscessus* infection with interferon gamma therapy. *Arch Dermatol*. 1999;135:125-127.
56. Jousse-Joulin S, Garre M, Guennoc X, et al. Skin and joint infection by *Mycobacterium chelonae*: rescue treatment with interferon gamma. *Joint Bone Spine*. 2007;74:385-388.