Nontuberculous Mycobacterial Breast Implant Infections

Sheina A. Macadam, M.D.
Blair M. Mehling, M.D.
Anne Fanning, M.D.
John A. Dufton, M.Sc.
Kinga T. Kowalewska-Grochowska, M.D.
Peter Lennox, M.D.
Alexander Anzarut, M.D.
Mabel Rodrigues, Ph.D.

Edmonton, Alberta, and Vancouver, British Columbia, Canada

Background: For reasons that are unclear, the incidence of nontuberculous mycobacterial disease is increasing worldwide. Periprosthetic nontuberculous mycobacterial infections following augmentation mammaplasty and breast reconstruction have been reported previously in the form of case reports.
Methods: This retrospective case series examines periprosthetic nontuberculous mycobacterial infections in two western Canadian cities (Edmonton, Alberta, and Vancouver, British Columbia) over a 10-year time period.
Results: Ten patients were identified, four of whom had bilateral infections. The most common isolate was *Mycobacterium fortuitum*. Clinical features were similar to nonmycobacterial periprosthetic infections. The median time to onset of symptoms was 4.5 weeks and the median time to culture an organism was 5.4 weeks. The median duration of antibiotic therapy was 22 weeks. Patients required a mean of three additional operations after diagnosis. Nine patients underwent explantation of the involved implant(s). Reimplantation was performed in six patients a median of 11.5 months after explantation. All cases of reimplantation were successful.
Conclusions: Experience with this postoperative complication is limited, as nontuberculous mycobacteria represent a minority of the pathogens responsible for periprosthetic infections. In the absence of specific features with which to identify patients at risk, the surgeon must be aware of the possibility of this infection. To achieve earlier diagnosis, the clinician should have a high index of suspicion in a patient with delayed onset of symptoms, negative preliminary cultures, and a periprosthetic infection that fails to resolve following a course of conventional antimicrobial treatment. With appropriate treatment, nontuberculous mycobacterial periprosthetic infections can be managed successfully. (*Plast. Reconstr. Surg.* 119: 337, 2007.)

The overall incidence of periprosthetic infection following augmentation mammaplasty is 1 to 2 percent and is slightly higher following breast reconstruction (2 to 6 percent).[1–6] The majority of these infections are caused by *Staphylococcus aureus* and coagulase-negative *Staphylococcus*; however, infections caused by the mycobacteria are increasing in frequency. The cause of these infections is a matter of debate, but the source has been hypothesized to be the breast ducts, which provide a passageway from the external skin surface to the underlying breast parenchyma.[7] Periprosthetic infection is uncommon, but the attendant morbidity is significant, as patients commonly face additional surgery, prolonged administration of antimicrobials, and potentially compromised aesthetic results.

The nontuberculous mycobacteria are members of the genus *Mycobacterium*, which includes the *Mycobacterium tuberculosis* complex (*M. tuberculosis, M. bovis, M. africanum*) and *Mycobacterium leprae*. These organisms are environmental commensals found in soil and water. They were originally classified by Runyon in 1970 according to colony morphology, growth rate, and pigmentation, but are now differentiated from the *M.*

From the Departments of Plastic and Reconstructive Surgery, Infectious Disease, Medicine and Pathology, and Public Health Sciences, University of Alberta; and Provincial Laboratory for Public Health; and Faculty of Medicine, Department of Plastic and Reconstructive Surgery, University of British Columbia; and Department of Laboratory Medicine, Mycobacteriology Laboratory, British Columbia Center for Disease Control.
Received for publication July 7, 2005; accepted October 14, 2005.
Presented at the Annual Meeting of the Canadian Society of Plastic Surgeons, in Hamilton, Ontario, Canada, June 2 through June 5, 2004.

DOI: 10.1097/01.prs.0000244924.61968.d2

tuberculosis complex by molecular techniques and speciated by biochemical testing.[8,9]

As opportunistic pathogens, the nontuberculous mycobacteria cause a broad range of human diseases. Surgical wound infections attributed to nontuberculous mycobacteria have occurred following rhytidectomy,[10] liposuction,[11] corneal surgery,[12] lacrimal duct probing,[13] venous stripping for varicose veins,[14] and cardiac surgery.[15] In addition, several cases of infection following placement of breast prostheses have been reported.[16–20] The source of infection in the majority of these cases remains unclear.

Soft-tissue infections are most commonly caused by the "rapidly growing" nontuberculous mycobacteria (i.e., *M. fortuitum*, *M. chelonae*, and *M. abscessus*), so named because they grow in 7 days compared with 14 to 21 days for most mycobacteria. Rapid growers are usually associated with foreign material. Although they are not found as skin commensals, loss of skin integrity is historically linked to infection.[21] Recognition of this unusual infection is important, as delay in diagnosis may lead to lengthy courses of inadequate antibiotic regimens and additional surgery for the patient. Identification requires a positive mycobacterial culture, and treatment includes surgical debridement and directed antimicrobial coverage based on isolate sensitivities.

PATIENTS AND METHODS

Patients

Patients were identified using the electronic database of the Provincial Laboratory of Microbiology and Public Health of Northern Alberta and the Lab Information System of the British Columbia Center for Disease Control. All patients with mycobacterial isolates from a breast specimen following placement of a prosthesis submitted in Edmonton, Alberta, or Vancouver, British Columbia, between 1993 and 2003 were included for review.

Organisms

All specimens submitted for mycobacterial culture had direct smear examination for presence of acid-fast bacilli by auramine-rhodamine and Ziehl-Neelsen methods. Tissue and fluid specimens were inoculated onto BACTEC MGIT media, Lowenstein-Jensen media with pyruvate, and Middlebrook 7H10 media enriched with hemin. In addition, swabs were inoculated into modified selective Kirchner's media. Cultures were incubated 7 weeks before being considered negative. When necessary, the identification of isolates was confirmed by 16S rRNA sequencing at the National Reference Center for Mycobacteriology, Winnipeg, Manitoba, Canada. Susceptibility testing was performed by the E-test method.

Chart Review

A retrospective review of the clinical charts of all patients identified as having a periprosthetic nontuberculous mycobacterial infection was performed. Culture data including organism and antibiotic susceptibility profiles were recorded. Demographics included place of residence and age. Past health included any history of immunosuppression. Operative reports identified the location of the surgical facility, type of prosthesis, surgical plane, operative time, and administration of perioperative antibiotics. Clinical notes from both plastic surgery and infectious disease specialists were reviewed to determine the clinical presentation and treatment plan.

Statistical Analysis

Frequencies were used to describe categorical data. For continuous data, the median and interquartile range was used as a measure of central tendency in cases with extreme outliers; otherwise, the mean ± SD was used. All statistical analyses were performed using SPSS 12.0 for Windows software (SPSS, Inc., Chicago, Ill.).

RESULTS

Patients

Fourteen breast tissue specimens yielding nontuberculous mycobacteria were identified as being periprosthetic specimens. The 14 specimens represented 10 patient cases, as four patients had bilateral infections (Table 1). Nine patient cases were identified in Edmonton, Alberta, and one was identified in Vancouver, British Columbia. These cases occurred in the practices of seven different plastic surgeons and across five different surgical facilities. The median patient age was 36.0 years (interquartile range, 32.3 to 48.3 years). All of the women were previously healthy and on no antimicrobial or immunosuppressant medications at the time of surgery. Three patients had a history of breast carcinoma. No patient had received previous chemotherapy. Of the 10 patients, six underwent breast augmentation, one patient underwent bilateral capsulorrhaphy following augmentation, and three underwent either unilateral (one of three) or bilateral (two of three) postmastectomy prosthetic breast reconstruc-

Table 1. Summary of 12 Women with Periprosthetic Nontuberculous Mycobacterial Infection following Breast Augmentation or Breast Reconstruction Surgery

Patient	Age at Surgery (yr)	Date of Surgery	Type of Surgery	Location of Surgery	Surgeon	Unilateral/Bilateral Infection	Time to Onset Of Symptoms (wk)	Time to Culture (wk)	*Mycobacterium* Species Isolated
1	49	February 1997	BAM	Facility A	A	Bilateral	4 (L), 4 (R)	4.7 (L), 5 (R)	*M. fortuitum*
									M. fortuitum
2	33	December 1998	BAM	Facility A	A	Unilateral	1	9.7	*M. fortuitum*
3	33	November 2001	BAM	Facility B	A	Unilateral	1	5	*M. goodii*
4	34	September 2003	BAM	Facility B	B	Bilateral	8 (L), 8 (R)	5.4 (L), 4.8 (R)	*M. fortuitum*
									M. fortuitum
5	19	October 2003	BC	Facility B	B	Unilateral	6	7	*M. fortuitum*
6	32	June 1996	BAM	Facility A	C	Unilateral	5	4	*M. parafortuitum*
7	54	September 2001	DBRM	Facility C	D	Bilateral	6 (L), 16 (R)	5.3 (L), 6 (R)	*M. fortuitum*
									M. fortuitum
8	46	March 2002	DBRM	Facility D	E	Unilateral	4	6.4	*M. fortuitum*
9	25	September 2001	BAM	Facility B	F	Bilateral	10 (L), 6 (R)	4.7 (L), 5 (R)	*M. fortuitum*
									M. fortuitum
10	40	July 2000	IBRM	Facility E	G	Unilateral	4	6	*M. avium*
									M. smegmatis

BAM, bilateral augmentation mammaplasty; DBRM, delayed breast reconstructive mammaplasty; IBRM, immediate breast reconstructive mammaplasty; BC, bilateral capsulorrhaphy.

tion. Of the reconstructive cases, two were delayed reconstructions and one was immediate. Seven patients underwent surgery in one of two private surgical facilities. The remaining three had their surgery performed in one of three public hospitals.

Surgical Factors

Incision types varied and included previous mastectomy scar and periareolar and inframammary approaches. Eight patients had implants placed in the submuscular plane, and the remaining two patients had implants placed in the subglandular plane. Fifty percent of all infected prostheses were textured, with the other half being smooth. Thirteen infected prostheses (nine patient cases) were saline-filled, and one prosthesis was gel-filled (Table 2). All of the reconstructive cases presented with infection of the tissue expander.

Irrigation solutions also varied. A bacitracin solution was used to irrigate the breast pocket in two patient cases, a 10% povidone-iodine solution was used in two cases, and the remaining six patients had no irrigation of the breast pocket; however, the implants were soaked in a sterile 0.9% normal saline solution before insertion. Agents used for skin preparation included a 2% chlorhexidine gluconate solution in seven patient cases and a 10% povidone-iodine solution in the remaining three patients. Seven patients received an intraoperative dose of either a first-generation cephalosporin or clindamycin. The remaining three patients received no perioperative antibiotic prophylaxis. The mean ± SD operative time was 76 ± 22 minutes.

Clinical Disease Presentation

The median time between surgery and the development of a clinical infection was 4.5 weeks (interquartile range, 3.2 to 8.0 weeks). All patients presented with breast swelling, seven had erythema of the operative incision, four had spontaneous discharge from the incision, and two presented with fever. No patient had implant extrusion or exposure. Both breasts were infected in four patients (one case of breast reconstruction and three cases of breast augmentation). Two of these patients presented with symptoms in both breasts simultaneously. The remaining two patients noted symptoms first in one breast, requiring unilateral explantation. Each then had onset of symptoms in the contralateral breast at a later date necessitating

Table 2. Profile of Practices and Procedures

Variable	No. of Patients	No. of Infected Implants
Surgical approach		
Inframammary	6/10	
Periareolar	2/10	
Prior mastectomy scar	2/10	
Surgical plane		
Submuscular	8/10	
Subglandular	2/10	
Prosthesis type		
Saline-filled		13/14
Gel-filled		1/14
Smooth		7/14
Textured		7/14
Location of surgery		
Private cosmetic surgical facility	7/10	
Hospital operating room	3/10	
Other practices		
Irrigation of breast pocket before insertion of prosthesis	4/10	
Intraoperative antibiotics	7/10	

removal of the remaining prosthesis. In the cases where the operative findings were well described, a commonly reported finding was the presence of exuberant granulation tissue and odorless, seropurulent periprosthetic fluid.

Microbiological Characteristics

Identification of the mycobacterial pathogen required more than 1 month of incubation in all cases. Periprosthetic fluid usually revealed polymorphonuclear leukocytes with few or no organisms seen on Gram stain. The median time until definitive culture of the responsible organism was 5.4 weeks (interquartile range, 4.8 to 6.5 weeks).

Each periprosthetic specimen had at least one nontuberculous mycobacteria isolate. One specimen grew two different organisms, for a total of 15 identified organisms. Of these, there were five unique isolates identified (Table 1). These included *M. fortuitum* [$n = 11$ (73.3 percent)], *M. smegmatis* [$n = 1$ (6.7 percent)], *M. goodii* [$n = 1$ (6.7 percent)], *M. parafortuitum* [$n = 1$ (6.7 percent)], and *M. avium-intracellulare* [$n = 1$ (6.7 percent)]. On antimicrobial susceptibility testing of *M. fortuitum* (the most commonly identified isolate), 82 percent of isolates were sensitive to amikacin, 72 percent were sensitive to ciprofloxacin, 64 percent were sensitive to doxycycline, 55 percent were sensitive to imipenem, 55 percent were sensitive to clarithromycin, and 55 percent were sensitive to Septra.

Treatment

The median time that patients were on any antibiotic regimen was 22 weeks (interquartile range, 14 to 30 weeks). Initially, patients were treated with an empiric antibiotic regimen for a median of 4 weeks (interquartile range, 2.0 to 6.5 weeks). Nine of the 10 patients were referred to an infectious disease specialist once nontuberculous mycobacteria was cultured from the periprosthetic fluid.

The average number of additional operations required after diagnosis of periprosthetic infection was 2.7 ± 1.5. One patient required only aspiration of a periprosthetic collection under sterile conditions in the surgeon's office. This patient did not undergo explantation, and her infection cleared following aspiration and antibiotic therapy. The remaining nine patients underwent explantation. Of these, six ultimately had successful reimplantation. Reimplantation in these patients was performed a median of 11.5 months (interquartile range, 5.7 to 19.5 months) following explantation. Two patients had not reached the appropriate time interval following explantation for consideration of reimplantation at the study's completion, and one patient chose not to have her implants replaced.

DISCUSSION

The frequency of nontuberculous mycobacterial infection is increasing worldwide. This is attributable in part to improved culture methods, but the survival of these organisms is also enabled by host factors such as immunosuppression and alteration of host defenses by tissue damage or the presence of foreign material.[22] The primary source of nontuberculous mycobacteria is felt to

be the environment, as a large number of mycobacterial species have been recovered from natural water, soil, dust, and aerosol samples.[23] The nontuberculous mycobacteria's broad-spectrum resistance to antimicrobial agents, including chlorine and their low nutritional requirements, enable growth in water distribution systems.[22] These organisms possess a hydrophobic, lipid-rich cell wall that facilitates the formation of a biofilm on solid surfaces such as water pipes,[24] catheters[25] and, theoretically, breast implants.

The majority of skin and soft-tissue nontuberculous mycobacterial infections are thought to result from inoculation by means of direct contact with contaminated materials. Runyon postulated that mycobacteria may be skin commensals, but thus far this has not been demonstrated.[2] The infectious source has been hypothesized on a case-by-case basis and theories include contaminated instruments, skin disinfectant,[26] gentian violet used for skin marking,[8] and contaminated hospital water systems.[27] One study identified a species of *M. avium-intracellulare* that persisted in the water system of a hospital for over 18 months.[27]

The source of infection in this study population is unclear. It is theoretically possible that nontuberculous mycobacteria might gain access to the surgical wound from the public water system at the time of showering. It is equally possible that these organisms are present on the skin and are not eliminated by skin preparation preoperatively, thus gaining access to the periprosthetic space through the skin incision. Although the exact source of infection is unknown, it seems most likely that the transient presence of mycobacteria in the surgical environment is the source of the pathogens responsible for this periprosthetic infection.

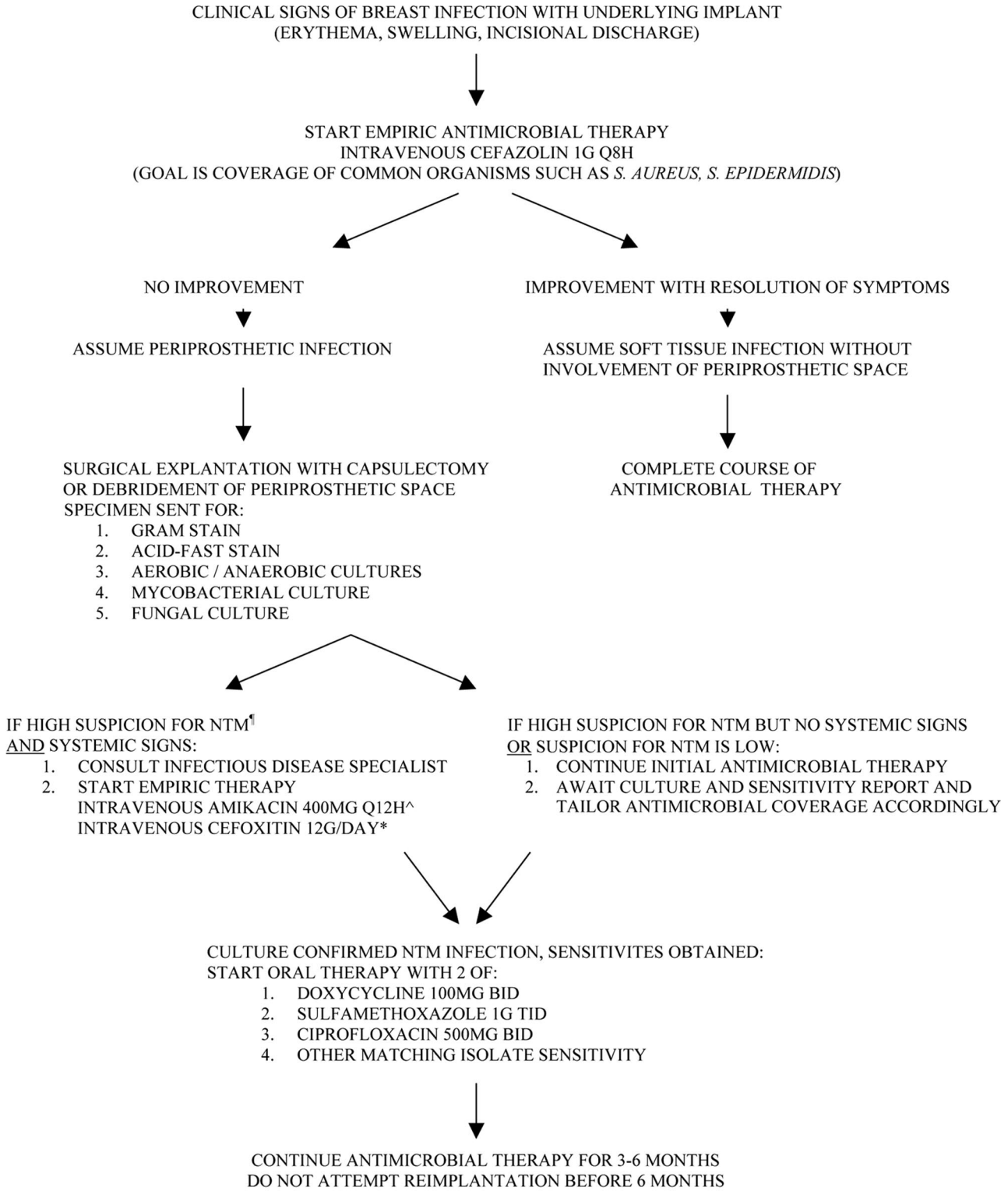
Without a control group, it is difficult to draw any meaningful conclusions as to which surgical, prosthetic, or patient factors predispose to this infection. The majority of patients in this study had smooth saline-filled implants placed in the submuscular plane; however, during the period of study, this was also by far the most common implant type and plane used at our institutions. No single irrigation solution was used on the implants before insertion. Seventy percent of patients received intraoperative antibiotics, but this was also a standard procedure during the study period. It is therefore difficult to determine a causative agent or a population at-risk.

In this study, all cases were healthy young women with local signs of infection and, in the majority of cases, absence of systemic illness. Breast swelling, erythema at the incision, and discharge of fluid through the incision site were the most common symptoms. The median time from surgery to symptoms was 4.5 weeks, which closely matches that reported in the literature.[15] This incubation time can range from 1 week to 4 months, as seen in this study. Patients waited a median of 5.4 weeks for definitive culture of the causative organism. During this time, patients were treated with a nonspecific antibiotic regimen for a median of 4.0 weeks. Definitive surgical management in all but one patient included implant removal and thorough debridement of the periprosthetic space by curettage or capsulectomy.

There are no controlled clinical trials of treatment for disease caused by the rapidly growing mycobacteria that have been performed comparing one form of treatment to another; however, susceptibility studies have demonstrated excellent in vitro activity of drugs such as amikacin, cefoxitin, ciprofloxacin, and doxycycline.[28] On the basis of these studies, guidelines have been suggested for drug therapy of nonpulmonary disease caused by rapidly growing nontuberculous mycobacteria.[29]

Initial treatment of any postoperative breast infection includes empiric antimicrobial coverage. If this does not lead to resolution of symptoms and a periprosthetic infection is suspected, removal of the prosthesis with debridement of the periprosthetic space is recommended. If the patient improves following removal of the prosthesis or does not go on to develop systemic symptoms, the initial empiric therapy may be continued while awaiting culture and sensitivity. However, if the patient becomes systemically ill and the suspicion for nontuberculous mycobacterial infection is high, recommended empiric therapy includes intravenous amikacin plus intravenous cefoxitin in standard doses (Fig. 1). Once susceptibilities are obtained, therapy can be tailored accordingly. A minimum of 3 to 6 months of therapy is recommended, and removal of the infected implants with debridement of the periprosthetic space is felt to be necessary for complete eradication of the infection.[30] As nontuberculous mycobacteria can cause clinically silent persistent infection in breast tissue, reimplantation should not be attempted before 6 months of appropriate therapy.

There has been only one study in the literature that has estimated the incidence of nontuberculous mycobacterial periprosthetic infection. Clegg et al.[16] conducted a retrospective mail survey of 2062 plastic surgeons in 1978 and identified 39,455 cases of augmentation mammaplasty performed that year. This study likely suffered from



¶ No organism seen on Gram stain, intraoperative findings include seropurulent fluid and exuberant granulation tissue, long course of conventional antimicrobial therapy with no resolution of symptoms.

* Monitor white blood cell counts for anemia, leukopenia.

^ Monitor renal function, eighth nerve function as risk of renal toxicity and vestibular/auditory toxicity.

Fig. 1. Algorithm for treatment of nontuberculous mycobacterial periprosthetic infection.

recall and diagnostic biases and the method of microbiologic diagnosis was not reported; however, the authors did report on five patient cases of nontuberculous mycobacterial infection, for an overall rate of 0.013 percent. Nontuberculous mycobacterial periprosthetic infections are rare, as demonstrated by this retrospective study. However, they may be underdiagnosed, as mycobacterial cultures are infrequently performed at the time of surgical exploration. A proportion of infections with negative routine cultures may represent undetected nontuberculous mycobacterial infections.

CONCLUSIONS

All patients undergoing breast surgery with placement of a prosthesis are at risk for nontuberculous mycobacterial infection. The clinical course is similar to postoperative bacterial soft-tissue infection. Systemic signs such as fever may be absent. Routine wound cultures are usually negative. Surgical exploration of the periprosthetic space generally yields clear to cloudy, odorless fluid in association with granulation tissue within the periprosthetic pocket. It is advisable that, whenever a periprosthetic infection is explored surgically, consideration be given to performing an acid-fast bacillus stain and mycobacterial cultures in addition to routine Gram stain, bacterial, and fungal cultures. Implant removal and surgical debridement of the periprosthetic space are necessary adjuncts to prolonged multiagent antimicrobial therapy. With this approach, eventual successful reimplantation may be achieved.

Sheina A. Macadam, M.D.
Division of Plastic Surgery and Burn Unit
University of British Columbia and Vancouver General Hospital
2nd Floor, JPP 2
855 West 12th Avenue
Vancouver, British Columbia V5Z 1M9, Canada
sheinam@shaw.ca

DISCLOSURE

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this article.

REFERENCES

1. Argenta, L. C. Reconstruction of the breast by tissue expansion. *Clin. Plast. Surg.* 11: 257, 1984.
2. Courtiss, E. H., Goldwyn, R. M., and Anastasi, G. W. The fate of breast implants with infections around them. *Plast. Reconstr. Surg.* 63: 812, 1979.
3. Perras, C. The prevention and treatment of infections following breast implants. *Plast. Reconstr. Surg.* 35: 649, 1965.
4. Gibney, J. The long term results of tissue expansion for breast reconstruction. *Clin. Plast. Surg.* 14: 509, 1987.
5. van Heerden, J. A., Jackson, I. T., Martin, J. K., et al. Surgical technique and pitfalls of breast reconstruction immediately after mastectomy for carcinoma: Initial experience. *Mayo Clin. Proc.* 62: 185, 1987.
6. Freedman, A. M., and Jackson, I. T. Infections in breast implants. *Infect. Dis. Clin. North Am.* 3: 275, 1989.
7. Thornton, J. W., Argenta, L. C., McClatchey, K. D., et al. Studies on the endogenous flora of the human breast. *Ann. Plast. Surg.* 20: 39, 1988.
8. Runyon, E. H. Identification of mycobacterial pathogens utilizing colony characteristics. *Am. J. Clin. Pathol.* 54: 578, 1970.
9. Timpe, A., and Runyon, E. H. Relationship of atypical acid-fast bacilli to human disease: A preliminary report. *J. Lab. Clin. Med.* 44: 202, 1954.
10. Safranek, T. J., Jarvis, W. R., Carson, L. A., et al. *Mycobacterium chelonae* wound infections after plastic surgery employing contaminated gentian violet skin-marking solution. *N. Engl. J. Med.* 317: 197, 1987.
11. Murillo, J., Torres, J., Bofill, L., et al. Skin and wound infection by rapidly growing mycobacteria: An unexpected complication of liposuction and liposculpture. *Arch. Dermatol.* 136: 1347, 2000.
12. Zimmerman, L. E., Turner, L., and McTigue, J. W. *Mycobacterium fortuitum* infection of the cornea: A report of two cases. *Arch. Ophthalmol.* 82: 596, 1969.
13. Smith, R. E., Salz, J. J., Moors, R., et al. *Mycobacterium chelonei* and orbital granuloma after tear duct probing. *Am. J. Ophthalmol.* 89: 139, 1980.
14. Foz, A., Roy, C., Jurado, J., et al. *Mycobacterium chelonei* iatrogenic infections. *J. Clin. Microbiol.* 7: 319, 1978.
15. Hoffman, P. C., Fraser, D. W., Robicsek, F., et al. Two outbreaks of sternal wound infections due to organisms of the *Mycobacterium fortuitum* complex. *J. Infect. Dis.* 143: 533, 1981.
16. Clegg, H. W., Bertagnoll, P., Hightower, H. W, et al. Mammaplasty-associated mycobacterial infections: A survey of plastic surgeons. *Plast. Reconstr. Surg.* 72: 165, 1983.
17. Clegg, H. W., Foster, M. T., Sanders, W. E., et al. Infection due to organisms of *Mycobacterium fortuitum* complex after augmentation mammaplasty: Clinical and epidemiologic features. *J. Infect. Dis.* 147: 427, 1983.
18. Wallace, R. J., Steele, L. C., Labidi, A., et al. Heterogeneity among isolates of rapidly growing mycobacteria responsible for infections following augmentation mammaplasty despite case clustering in Texas and other southern coastal states. *J. Infect. Dis.* 160: 281, 1989.
19. Haiavy, J., and Tobin, H. *Mycobacterium fortuitum* infection in prosthetic breast implants. *Plast. Reconstr. Surg.* 109: 2124, 2002.
20. Toranto, R., and Malow, J. B. Atypical mycobacteria periprosthetic infections: Diagnosis and treatment. *Plast. Reconstr. Surg.* 66: 226, 1986.
21. Runyon, E. H. Whence mycobacteria and mycobacterioses? *Ann. Intern. Med.* 75: 467, 1971.
22. Falkinham, J. O., III. The changing pattern of nontuberculous mycobacterial disease. *Can. J. Infect. Dis.* 14: 281, 2003.
23. Falkinham, J. O., III. The epidemiology of infection by nontuberculous mycobacteria. *Clin. Microbiol. Rev.* 9: 177, 1996.
24. Falkinham, J. O., III, Norton, C. D., and Le Chevallier, M. W. Factors influencing numbers of *Mycobacterium avium*, *Mycobacterium intracellulare*, and other mycobacteria in drinking water distribution systems. *Appl. Environ. Microbiol.* 67: 1225, 2001.

25. Schelonka, R. L., Ascher, P., McMahon, D. P., et al. Catheter-related sepsis caused by *Mycobacterium avium* complex. *Pediatr. Infect. Dis.* 13: 235, 1994.
26. Foz, A., Roy, C., Juardo, J., et al. *Mycobacterium chelonei* iatrogenic infections. *J. Clin. Microbiol.* 7: 319, 1978.
27. von Reyn, C. F., Maslow, J. N., Barber, T. W., et al. Persistent colonization of potable water as a source of *Mycobacterium avium* infection in AIDS. *Lancet* 343: 1137, 1994.
28. Swenson, J. M., Wallace, R. J., Jr., Silcox, V. A., et al. Antimicrobial susceptibility testing of 5 subgroups of *Mycobacterium fortuitum* and *Mycobacterium chelonae*. *Antimicrob. Agents Chemother.* 28: 807, 1985.
29. Wallace, R. J., Jr. The clinical presentation, diagnosis and therapy of cutaneous and pulmonary infections due to the rapidly growing mycobacteria, *M. fortuitum and M. chelonae*. *Clin. Chest Med.* 10: 419, 1989.
30. Wallace, R. J., O'Brien, R., Glassroth, J., et al. Diagnosis and treatment of disease caused by nontuberculous mycobacteria. Official Statement of the American Thoracic Society. March, 1990.