

CLINICAL PRACTICE

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Bedbugs

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This Journal feature begins with a case vignette highlighting a common clinical problem. Evidence supporting various strategies is then presented, followed by a review of formal guidelines, when they exist. The article ends with the authors' clinical recommendations.

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A 35-year-old man presented to the clinic with pruritic maculopapular skin lesions on his neck, left arm, and trunk; no other abnormalities were noted. He described having had a similar rash a few months earlier for which he did not seek treatment and reported that his wife had similar skin lesions on her arms and neck. They had just returned to their house in Marseille, France, after traveling out of the country for 3 months. How should his case be evaluated and managed?

THE CLINICAL PROBLEM

BEDBUGS, INCLUDING *CIMEX LECTULARIUS*, THE COMMON BEDBUG, AND *C. hemipterus*, the tropical bedbug, are flat, brown insects that bite humans to obtain a blood meal.^{1,2} They have no wings and cannot fly or jump. They move fast, about 3 to 4 ft per minute. The life cycle of a bedbug comprises six stages: egg, four nymphal stages, and adult (Fig. 1).^{3,4} Adult bedbugs that have a food source live up to 4 to 5 months; on average, starved bedbugs (at any life stage) at room temperature will die within 70 days.^{3,4}

Between blood meals, bedbugs hide in dark places, such as household cracks and crevices, walls, luggage, bedclothes, mattresses, bedsprings, bed frames, spaces under baseboards, loose or peeling wallpaper, electrical switch plates, and conduits for electrical cables (Fig. 2 and Fig. S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org). They emerge from these hiding places primarily at night to feed on their sleeping human hosts.^{1,2} The introduction of several bedbugs into a new site leads to their exponential multiplication, with thousands of bugs after 2 or 3 months.

A global resurgence of bedbugs has been observed in the past 30 years. Reasons behind the resurgence are multifactorial and include resistance to insecticide products currently in use, ineffective pest-control-related practices, lack of knowledge about preventing infestations, and an increase until recently in domestic and international travel.^{1-3,5} Although data regarding bedbug infestations are lacking in peer-reviewed publications, quantitative information has been released by major pest-control companies.⁶ In Europe, the British Pest Control Association's Executive Summary of 2014 showed that bedbug treatments by local authorities increased by 21% between 2010–2011 and 2013–2014.⁶ A survey in Australia showed an overall rise of 4500% in the years 1999–2006, as compared with earlier years.⁶

Sites of infestations include hotels, bed-and-breakfasts, private homes, apartments and condominiums, public transport vehicles and crafts (trains, cruise ships, and airplanes), theaters, hospitals, and armed-forces buildings.^{3,7,8} In New York City, the most recent data (released in 2014) showed a prevalence of bedbug infestations as high as 12% in some neighborhoods.^{9,10} Data from large pest-control firms in the United States indicated that at least 80% of hotels had dealt with bedbugs in



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KEY CLINICAL POINTS

BEDBUGS

- Bedbugs are flat, brown insects that bite the exposed skin of sleeping humans to feed on their blood.
- Bedbug infestations have increased dramatically in recent years and are associated with substantial economic costs and psychological distress.
- Infestations are often recognized when patients present for medical care for skin lesions. Suggestive skin lesions should prompt advice to investigate the home for evidence of bedbugs, which may require professional assistance.
- Mechanical methods (including vacuuming and heating or freezing) are essential to eradicate bedbugs.
- Although commercial insecticides are frequently used, these are of limited effectiveness because of resistance. In settings where insecticides are used, they should be combined with mechanical methods.
- To date, bedbugs have not been implicated in transmission of infectious agents to humans.

2015, and 40% had managed infestations in the past month.^{6,11} For hotels, the total average cost of any bedbug incident has been estimated to be more than \$23,000, including replacement of soft goods, pest-control treatment, and litigation costs.¹¹ Costs are also incurred for surveillance, prevention programs, and reduced rental occupancy.¹¹

Hospitals, hospices, and elder care facilities lose access to beds because of bedbugs, and the economic effects on health care facilities are large.^{12,13} A total of 180 infestations were recorded in a 937-bed hospital in Cleveland for 1 year, with total costs of \$55,915.¹² In July 2019, a notice of public appeal to competition was published to provide products for the detection and control of bedbugs for the benefit of the French Ministry of Armed Forces.¹⁴

Physicians are increasingly confronted with bedbug problems as patients present with cutaneous lesions that appear to be bites. However, for patients and doctors, associating these lesions with bedbug bites may be difficult, because many people do not know that their house is infested by bedbugs. In the United Kingdom and Germany, surveys indicate that only 10 to 12.5% of respondents could recognize bedbugs when shown a specimen.^{15,16}

STRATEGIES AND EVIDENCE

DIAGNOSIS AND EVALUATION*Skin Lesions*

Bedbug bites are painless and may occur on any exposed part of the body. However, bites and lesions commonly occur on exposed areas that are not covered by sheets and blankets, such as the arms, legs, feet, face, and neck (Fig. 3 and Fig. S2).

Skin lesions can be noticeable immediately after the person wakes up but sometimes develop over the following days. Pruritic, maculopapular,

and erythematous lesions are the most common clinical presentation; the diameter is typically 2 to 5 mm but may be up to 2 cm. Other lesions include wheals, vesicles, and, less frequently, bullae and nodules. A central punctum at the bite site may be seen in some cases, but often this is not visible.³

It is difficult to clinically discriminate bedbug bites from other arthropod bites. Bites may present in cluster. Some authors have reported bedbug bites as occurring in a straight line or zigzag pattern in a row of at least three to five bites (termed “breakfast, lunch, and dinner”),¹⁷⁻¹⁹ although these patterns are not specific to bedbugs.

Isolated case reports have described systemic reactions, such as diffuse urticaria, asthma, and anaphylaxis. Scratching of pruritic lesions may lead to secondary infections such as impetigo, ecthyma, folliculitis, cellulitis, or lymphangitis; their frequency is unclear.^{1,3}

Psychological Issues

The psychological consequences of bedbug infestations are often underestimated.^{3,20} Sleep deprivation, insomnia, or sleeplessness are commonly associated with infestation.²⁰ Patients often are awakened by the itching due to bedbug bites; scratching then may exacerbate the itch sensation, further disturbing sleep (“itch-scratch cycle”).³

Bedbug infestations are also associated with psychological distress manifesting as nightmares, phobias, hypervigilance, insomnia, anxiety, avoidance behaviors, delusions of parasitosis, and personal dysfunction, with people worrying that they are being bitten at night. People living in an infested home may feel shame and social isolation. In rare cases, bedbugs may cause serious psychiatric consequences, with or without previous mental health conditions. Suicide after infestation has been even described.²¹

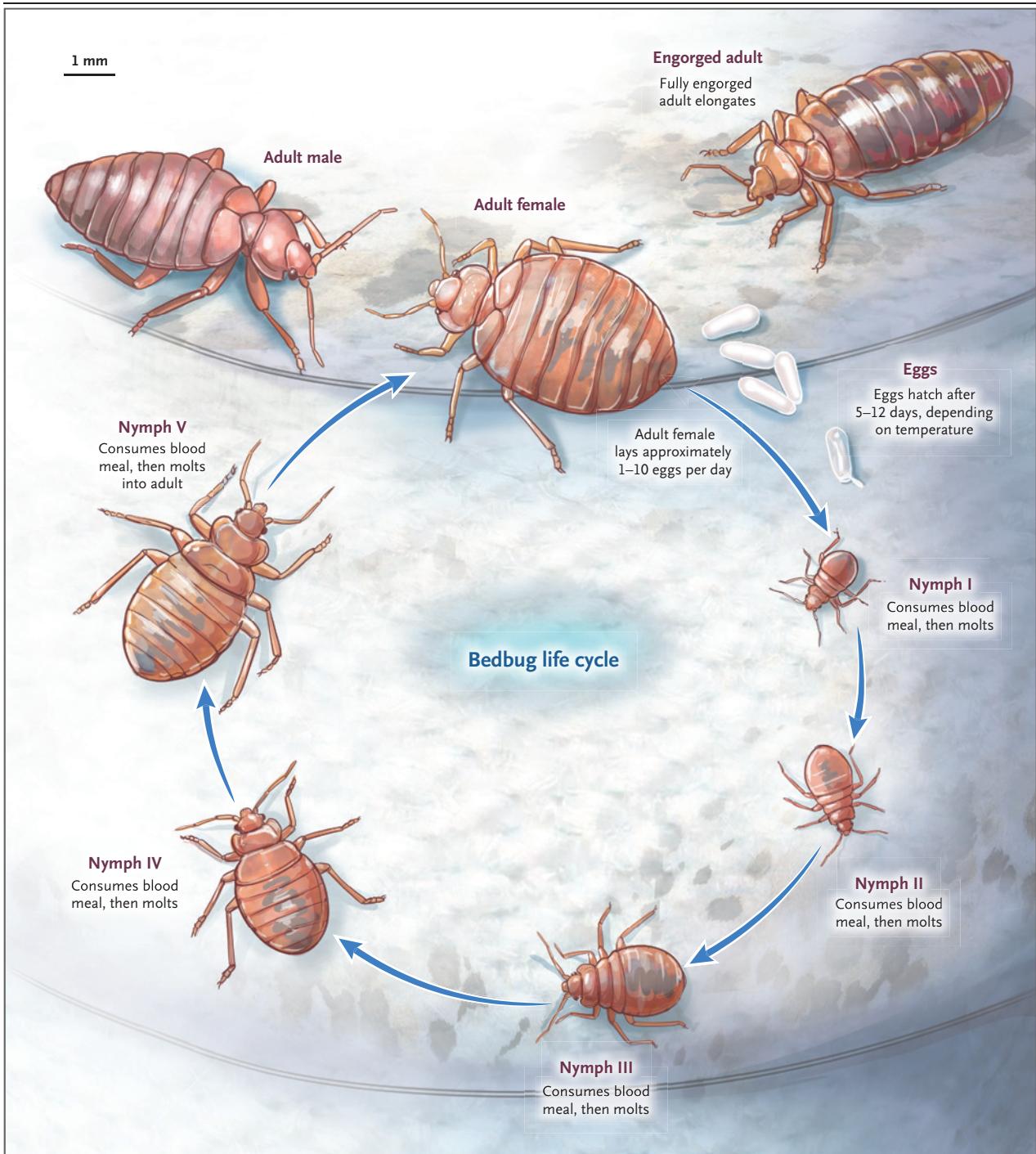


Figure 1. The Life Cycle of the Common Bedbug, *Cimex lectularius*.

After mating, *C. lectularius* females lay 1 to 10 cream-colored eggs, 1 mm long each, per day throughout their adult lives and approximately 200 (up to 500) eggs in a lifetime; *C. hemipterus* (tropical bedbugs) lay up to 50 eggs in a lifetime.^{3,4} Bedbugs are dependent on humans but may feed on a wide variety of other warm-blooded animals. At room temperatures of approximately 22°C (72°F), eggs hatch within 9 to 12 days into nymphs. Bedbugs of both sexes in all nymphal and adult stages require blood to accomplish their life cycle. Nymphs require at least one blood meal to molt to the next stage. Every 3 to 5 days, a bedbug must feed for 3 to 5 minutes to get a complete engorgement before molting to the next stage.^{3,4} This life cycle depends on the temperature and relative humidity. At 22°C, the life cycle requires approximately 2 months.^{3,4}

DIAGNOSIS OF A BEDBUG INFESTATION IN THE HOME

The inspection of rest areas, such as beds, sofas, and their surroundings, must be conducted meticulously, which often requires an experienced professional. The presence of exoskeletons or bedbug dark fecal spots on the mattress and bedding is a clear sign of infestation (Fig. 2 and Fig. S1).

Bedbugs emit a characteristic musty, sweet odor produced by specialized glands. People who can smell this odor often describe it as a berry scent. Trained sniffer dogs are efficient at detecting bedbugs and particularly useful for large-scale facilities, office buildings, retail stores, and theaters. However, their performance may vary under field conditions.²² In 2014, an evaluation of the accuracy of 11 canine detection teams in infested apartments showed that the mean detection rate was 44% (range, 10 to 100) and mean false positive rate was 15% (range, 0 to 57), with no significant relationship between the experience or certification status of the team and the detection rates.²²

Attractant-based bedbug traps (“monitors” or “interceptors”) are commercially available and may be useful for detecting low-level infestations.³ Bedbugs not found on inspection may show up in these traps. Some traps include attractants derived from human hosts, such as carbon dioxide or lactic acid, or bedbug pheromones as chemical lures. In 2016, bedbug prevalence was examined in 2372 low-income apartments within 43 buildings in New Jersey. Monitoring with interceptors detected 89% and brief visual inspections detected 72% of the infestations.²³ However, very few bedbug traps have been scientifically tested for efficacy under field conditions. Bedbug traps are not effective for eradication.

TREATMENT OF THE CONSEQUENCES OF BEDBUG BITES

Cutaneous symptoms are frequently self-limiting and typically resolve within 1 to 2 weeks. In the absence of randomized trials, management is based on expert opinion.¹⁻³ Bites should be washed with soap or antiseptic solutions. Topical glucocorticoids (e.g., hydrocortisone [1%]) once or twice a day for up to 7 days) and antihistamine medications may help for highly pruritic lesions. Systemic antibiotics may be indicated to treat secondary infections. Mental health effects may require additional supportive treatments and the advice of a psychiatrist.

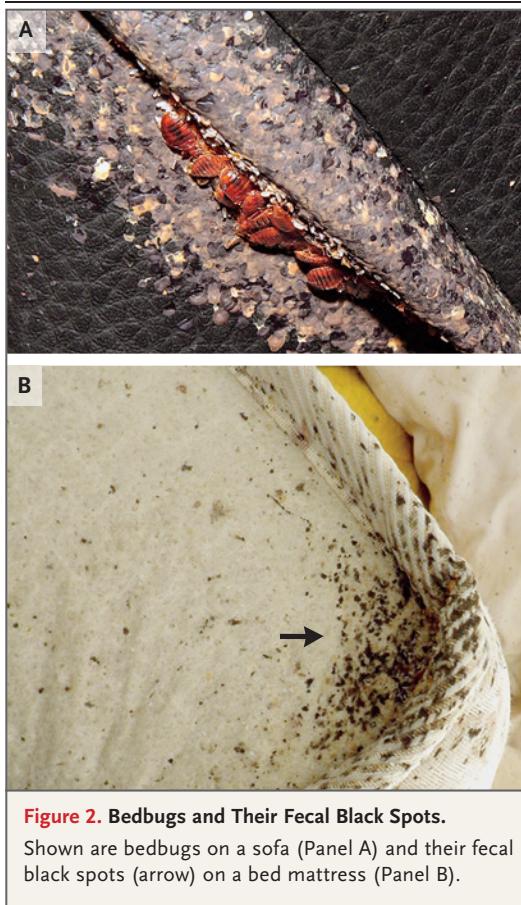


Figure 2. Bedbugs and Their Fecal Black Spots.

Shown are bedbugs on a sofa (Panel A) and their fecal black spots (arrow) on a bed mattress (Panel B).

CONTROL

Eradication is linked to early detection.³ Non-chemical control methods are essential¹⁻³ (Table 1). Vacuum cleaners can rapidly reduce the bedbug population in an infestation and even remove some eggs, particularly if there is associated scraping of the substrate. Vacuum cleaners need to have a disposable bag, which is immediately removed and sealed in plastic after use.

Textile materials must be removed from infested locations and washed at 60°C (140°F) or frozen. Placing items at –20°C (–4°F) for at least 2 hours kills all bedbugs and eggs; however, placement in most domestic-level freezers is generally insufficient.

By steaming mattresses and other furniture covered in unremovable textile at 60°C, all stages of bedbugs are also killed rapidly (in <1 minute).^{3,24} This can be performed with the use of affordable consumer-grade commercial steamers,^{25,26} with a speed of around 3 cm per second,²⁷ allowing lethal conditions above 50°C (122°F) to penetrate 1.1 to 1.8 cm into fabric.

Heating tents or portable heat chambers,



Figure 3 (facing page). Skin Lesions after Bedbug Bites.

Shown are erythematous and maculopapular lesions (Panels A and B) and vesicular lesions (Panel C). Bites in linear distribution (Panel B) are sometimes referred to as the “breakfast, lunch, and dinner” (unspecific) sign.

generally heated to 55°C (131°F), are an alternative means of killing bedbugs on clothes or furniture (within 1 hour).²⁷ Another thermal control method is to heat infested rooms to a minimum of 55°C with the use of professional heaters; 6 to 8 hours may be needed to achieve the required temperature everywhere. This “whole-room” heat treatment can be adopted for locations with limited accessibility or large-volume spaces, such as train cars or airplanes.

Bedbug populations are now largely resistant to conventional insecticides including pyrethroids,²⁸⁻³⁰

which are the most widely used compounds and are included in more than 90% of commercially available insecticides.³ Knowledge about mechanisms of resistance is incomplete.^{3,28} Insect foggers (bug bombs) do not control bedbugs; the aerosolized particles are unable to penetrate into bedbug harborages, and insect foggers may also have contributed to insecticide resistance. Moreover, there is concern about the health and environmental risks of insecticides. In houses or apartments with light infestations, nonchemical methods alone can eradicate bedbugs³¹; there is no evidence to indicate that the combination of nonchemical methods with insecticides is better than nonchemical methods alone.

Insecticides, however, remain part of many integrated pest-management programs, because some insecticides may provide some residual con-

Table 1. Steps Involved in Recognizing Bedbug Bites and Controlling Infestations.

Suspicion for possible bedbug bites

Recognize the suggestive localization of skin lesions on exposed areas of the body that are not covered by sheets and blankets, such as the neck, face, arms, legs, feet, and, less frequently, the trunk. Recognize that bedbug bites may result in a wide range of skin lesions.

Consider the psychological consequences of bedbugs, such as sleep deprivation.

Advice to patients to regarding searching for bugs or their traces

Meticulously inspect human rest areas and their surroundings to look for bedbugs, exoskeletons, or bedbug fecal material.

Inspect walls, wall cracks, tapestries, draperies, and conduits for electric cables.

Commercial traps may be helpful for the detection of bugs but not for their elimination.

Detection by trained sniffer dogs is efficiently used by many pest-control companies.

Advice to patients for control and elimination of bedbugs

Physically remove bedbugs with a typical vacuum cleaner, and seal the vacuum bag to prevent the infestation of neighboring locations. Dry brushing or surface cleaning is a complementary action for removing the eggs and nymphs that remain attached.

Wash textiles (e.g., bedsheets, clothes, and blankets) at 60°C (140°F).*

Directly kill bedbugs by heating and steaming with the help of experienced professionals from a pest-control company.†

Do not use insect foggers, also known as bug bombs.

Avoid the use of commercial insecticide.‡

Management of potential bedbug infestations in health care settings

Bedbugs may be in the luggage and bags carried with patients.

Where infestation is recognized, health care facilities treating a patient should be informed to ensure that the bedbugs do not spread.

Clothes, blankets, luggage, bags, and other possessions that are not essential during a patient's hospitalization or office visit should be left at home.

* A common misconception is to “wash all clothes,” which is not necessary if no signs of bedbugs have been found in or on the furniture. If an item (e.g., wool clothes, books, shoes, or children's toys) or material cannot be laundered, it can be placed at -20°C for 2 hours to kill all bedbugs and eggs. Placement in a domestic-level freezer will not kill all bugs because some bugs will tolerate these conditions.

† Collection with a vacuum cleaner is advised before steam cleaning because the pressure of the steam can disperse the bedbugs. However, if steam is hot enough, bugs would not have time to leave the area and the steam pressure is unlikely to blow them away. Steam is a slow process because it requires a speed of 3 cm per second. The steam emission tip must be about 2.5 to 3.8 cm from the surface being steamed.

‡ Insecticide treatments, even those performed by professionals, will not be effective because of insecticide resistance. By reducing the bedbug biomass and even if only partly efficient, insecticides remain part of integrated pest management in apartment complexes and multiunit buildings.

trol and reduce the bedbug biomass.²⁷ Eradication remains challenging for people living in apartment complexes and multiunit buildings, because reservoirs commonly remain from which the insects disperse.³² A report comparing bedbug control strategies used by three housing authorities showed that integrated pest-management programs (involving detection of bedbugs, non-chemical and chemical elimination strategies, education, and outreach) were associated with a significantly greater reduction in infestations than traditional pest-control services.³³

PREVENTION

Sealing cracks and crevices to discourage bedbug harborage, regularly inspecting furniture, checking a hotel room before sleeping, and examining the clothes of a patient before hospitalization can reduce the risk of bedbug infestation. Health care settings need policies and protocols for surveillance, preventive measures, and action. Where a bedbug infestation is known, a patient's items can be placed in sealed plastic bags and frozen until the next day, and steam cleaners can be used in the patient's room and on any material in contact with the patients, such as wheelchairs. Travelers who are exposed to bedbugs need to decontaminate luggage, clothes, and belongings on returning home, using mechanical methods (brushing, vacuuming, heating, washing, or freezing) rather than chemical methods to eliminate eggs or bugs that were brought back.⁵

AREAS OF UNCERTAINTY

There are limited data on the proportion of people reacting to bedbug bites, and the immune basis of the clinical reaction is poorly understood.³ Reactions may involve individual factors and may depend on previous exposures. Some persons may not have any reaction, as we have experienced when feeding *C. lectularius* on ourselves. In a review of human reactions to bedbug bites, the latency between the bite and cutaneous reactions decreased with repeated exposure, and 75% of 331 bitten persons overall had a reaction³⁴; however, conclusions are limited by the heterogeneity among reports.

Bedbugs have been shown to carry more than 45 infectious agents,^{35,36} and some experimental data have aroused concern that they might transmit disease. For example, laboratory experiments have shown the competence of *C. lectularius* as a

vector of *Trypanosoma cruzi*, the agent of Chagas' disease.³⁷ Studies have shown that *C. lectularius* can acquire, maintain, and excrete viable *Bartonella quintana*, the agent of louse-borne trench fever, and *Borrelia recurrentis*, the agent of louse-borne recurrent fever, which might infect humans through skin lesions similar to the mechanism of the transmission by body lice.^{38,39} However, bedbugs normally do not defecate while or immediately after feeding. There are currently no known cases of transmission of any infectious agents by bedbugs to humans.

There is no clinical test available for bedbug exposure. Research on the sialome⁴⁰ (the set of proteins of the salivary glands) of bedbugs has suggested the potential for determining whether a patient has been bitten by bedbugs through a bedbug salivary protein antibody test, but further research is needed.

The development of new products to detect or kill bedbugs is needed.²⁷ Desiccant dusts, such as insecticide-grade diatomaceous earth and other slow-acting silica gel dust, have been recently tested or are commercially available.²⁷ They may be used as part of a bedbug control or preventive program but need to be used with caution because some products may be harmful to human health by inhalation and may cause skin irritation.⁴¹

GUIDELINES

To our knowledge, there are no formal guidelines from professional medical societies on the management of bedbugs.

CONCLUSIONS AND RECOMMENDATIONS

The patient described in the vignette has skin lesions that are consistent with bedbug bites, including their reported appearance, location on uncovered areas of the body, occurrence also in his wife, and disappearance after the patient left the house for a protracted period. We would educate him about the likelihood of bedbugs in his home and advise him to inspect his mattress and bedding for evidence of infestation (including exoskeletons or bedbug dark fecal spots). A professional pest-control company is often needed to identify infestations and to provide appropriate intervention. Mechanical management methods (brushing, vacuuming, heating, washing, or freezing) are efficient at the individual house level to eradicate

the bugs. Web resources are available for health care professionals and patients as well as owners, tenants, and public schools (Table S1).

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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