

Bed Bugs (*Cimex lectularius*) and Clinical Consequences of Their Bites

Jerome Goddard, PhD

Richard deShazo, MD

CIMEX LECTULARIUS HAS BEEN known as a human parasite for thousands of years, but scientific studies of this insect are recent and limited.^{1,2} International travel, immigration, changes in pest control practices, and insecticide resistance may have contributed to a recent resurgence of this blood-sucking insect in developed countries.^{1,3} Bed bug infestations have been reported increasingly in homes, apartments, hotel rooms, hospitals, and dormitories in the United States since 1980 (TABLE 1).^{1,21,22} For example, reports of bed bug infestations in San Francisco doubled between 2004 and 2006.²³ The resurgence affects other countries as well. Public health experts in Toronto, Ontario, Canada, reported a 100% increase in telephone complaints about bed bugs during a 6-month period in 2002.⁴ In Germany, bed bug infestations increased from 5 reported cases in 1992 to 76 cases in 2004.²⁴ In Australia, bed bug samples submitted to a government public agency increased by 400% during the period of 2001-2004 compared with 1997-2000.²⁵

The insect family Cimicidae contains species commonly called bed bugs,

Context Bed bug (*Cimex lectularius*) infestations are rapidly increasing worldwide. Health consequences include nuisance biting and cutaneous and systemic reactions. The potential for bed bugs to serve as disease vectors and optimal methods for bed bug pest control and eradication are unclear.

Objectives To present current knowledge of the health and medical effects of bed bugs and to explore key issues in pest control and eradication efforts.

Data Sources A search of MEDLINE and EMBASE databases (1960-October 2008) for articles using the keywords *bed bugs*, *Cimex lectularius*, *humans*, *parasitology*, *pathogenicity*, and *drug effects*. For pest control, PubMed and Toxline searches (1960-October 2008) were performed using the keywords *bed bugs*, *Cimex*, *control*, *prevention*, and *eradication*. Manual searches of older journals, textbooks, pest control trade journals, and newspapers (1892-October 2008) were also performed.

Study Selection Original accounts or investigations of bed bugs, clinical responses with sufficient detail of cause and effect between the bed bug bite and clinical response, and convincing evidence of substantiated presence of bed bug exposure. For pest control, documentation that an eradication measure quantitatively decreased bed bugs.

Data Extraction A trained medical reference librarian assisted with the literature search. Two authors with expertise in the diagnosis, treatment, and eradication of bed bugs reviewed the clinical articles. One author evaluated the pest control articles.

Data Synthesis Fifty-three articles met inclusion criteria and were summarized. Only 2 clinical trials concerning bed bugs were identified and tested the ability of pest control interventions to eradicate bed bugs. Although transmission of more than 40 human diseases has been attributed to bed bugs, there is little evidence that they are vectors of communicable disease. A variety of clinical reactions to bed bugs have been reported, including cutaneous and rarely systemic reactions. A wide range of empirical treatments, including antibiotics, antihistamines, topical and oral corticosteroids, and epinephrine, have been used for bite reactions with varying results. No evidence-based interventions to eradicate bed bugs or prevent bites were identified.

Conclusions Treatment options for cutaneous and systemic reactions from bed bug bites have not been evaluated in clinical trials and there is no evidence that outcomes differ significantly from those receiving no treatment. Evidence for disease transmission by bed bugs is lacking. Pest control and eradication is challenging due to insecticide resistance, lack of effective products, and health concerns about spraying mattresses with pesticides.

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and questions on p 1391.

Author Affiliations: Department of Entomology and Plant Pathology, Mississippi State University, Mississippi State (Dr Goddard), and Department of Medicine, University of Mississippi Medical Center, Jackson (Drs Goddard and deShazo).

Corresponding Author: Jerome Goddard, PhD, Department of Entomology and Plant Pathology, Mississippi

State University, Box 9775, Mississippi State, MS 39762 (jgoddard@entomology.msstate.edu).

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bat bugs, and swallow bugs. Bed bugs are found in temperate and tropical regions worldwide.^{26,27} The 91 species in this family are wingless, obligate hematophagous ectoparasites that feed on bats, birds, and mammals.^{26,27} The word *Cimex* is derived from the Roman designation for bug and *lectularius* from the Latin name for couch or bed. Only 2

species, *Cimex lectularius* and *Cimex hemipterus*, readily feed on humans but others may rarely do so as well.

Adult bed bugs are oval shaped, flat, and approximately 5 mm long (FIGURE 1A). They resemble unfed ticks or small cockroaches and are easily visible, even to the untrained eye. Adults are reddish brown (chestnut) in color,

whereas immatures are much smaller and may be light yellow. They have a pyramid-shaped head with prominent compound eyes, slender antennae, and a long proboscis tucked underneath the head and thorax. After a blood meal, the bugs may increase in length by 30% to 50% and in weight by 150% to 200% (Figure 1B).²⁷

Table 1. Bed Bug Infestations and Reported Reactions to Their Bites

Source	Site of Infestation	No. of Participants or Places	Area(s) of Body Affected	Type of Reaction and/or Severity of Infestation
Cutaneous Reactions				
Hwang et al, ⁴ 2005	Homeless shelters	243 Residents	Skin	9/243 Residents (4%) had a skin condition consistent with bed bug bites
Gbakima et al, ⁵ 2002	Refugee camp	221 Refugees	NR	196/221 Refugees (86%) who were bitten by bed bugs had wheals; others reported irritation, lack of sleep
Bartley and Harlan, ⁶ 1974	Military barracks	39 Soldiers	Arms, legs, trunk/back/chest	14/39 Soldiers (36%) complained of bites; only 2 sought medical aid; bite effects varied from none to elongate, swollen, pruritic reddish wheals
Mouchtouri et al, ⁷ 2008	Ships	21 Ferries	NR	3/21 Ferries (14%) were infested with bed bugs
Hwang et al, ⁴ 2005	Homeless shelters	17 Shelters	NR	15/17 Shelters (88%) had bed bugs in mattress or bed frames
Ryckman, ⁸ 1985	Experimental feeding	14 Volunteers	Forearm	3/14 Volunteers (21%) had swelling, pruritus, erythema
Masetti and Bruschi, ⁹ 2007	Single-family dwelling	2 Patients	Arms, legs	First patient had erythema, swelling, pruritic maculae, papulae Second patient had bullae
Sansom et al, ¹⁰ 1992	Hotel	2 Patients	Face, trunk/back/chest/legs	First patient developed a delayed reaction and pruritic papular lesions with central puncta 60 h after bite; 4 days later, this developed into a hemorrhagic bullous rash Second patient had no reaction until 9 d later when a papular rash appeared
Tharakaram, ¹¹ 1999	Hostel	1 Person	Trunk/back/chest, legs, arms	Erythematous pruritic rash, central puncta, bullae
Leverkus et al, ¹² 2006	Hotel	1 Person	Arms, legs	First exposure resulted in pruritic macules; subsequent exposure resulted in macules evolving into erythematous nodules with blisters
Goddard and deShazo, ¹³ 2008	Hotel	1 Person	Arms, legs, trunk/back/chest	Local cutaneous reaction with erythema, pruritus, papules, puncta visible
Liebold et al, ¹⁴ 2003	Hotel	1 Person	Arms, trunk/back/chest	First exposure resulted in pruritic papulonodular reaction with bullae that became secondarily infected (impetiginization); subsequent exposure resulted in bullous eruption and fever
Stucki and Ludwig, ¹⁵ 2008	Hotel	1 Person	Arms and breasts	Pruritic papules
Brasch and Schwarz, ¹⁶ 2006	Single-family dwelling	1 Person	Arm, neck	Intensely pruritic papules
Ter Poorten and Prose, ¹⁷ 2005	Single-family dwelling	1 Person	Arms, legs, trunk/back/chest	Erythematous papules; urticarial papules ^a ; macules, intensely pruritic
Mumcuoglu, ¹⁸ 2008	Apartment	1 Person	Hands, legs, neck	Pruritic, erythematous macules
Fletcher et al, ¹⁹ 2002	NR	1 Person	Hands, arms	Widespread, extremely pruritic, bullous eruptions; urticarial papules ^a ; and plaques
Systemic Reactions				
Abou Gamra et al, ²⁰ 1991	NR	54 Patients with asthma and 11 controls	Skin tests	First <i>Cimex</i> antigen skin test induced pruritic reactions in 37.1% patients with asthma vs 9.1% controls; second <i>Cimex</i> antigen skin test induced 50.1% positive test results in patients with asthma vs 18.2% controls

Abbreviation: NR, not reported.

^aThe term *urticarial papules* is used by the authors.

Figure 1. Adult Bed Bug Before and After a Human Blood Meal Feeding

An adult bed bug before (A) and after (B) a human blood meal feeding. The bed bug is shown on a scale of 1 mm per interval.

Bed bugs sense and seek warmth, a trait that helps them locate warm-blooded hosts.²⁷ They generally avoid light, hide during the day, and feed at night. Hiding places are usually within 1 to 2 meters of suitable hosts and include seams in mattresses, crevices in box springs, backsides of headboards, spaces under baseboards or loose wallpaper, and even behind hanging pictures. Adult bed bugs have an average life span of 6 to 12 months and can survive up to a year without feeding.

Dispersal of human-associated bed bugs generally depends on their human hosts for movement from one location to another.²⁸ This may occur by way of furniture, clothing, suitcases, used mattresses, and other personal possessions. Bugs may also migrate from one apartment or hotel room to another through holes in walls, water pipes, or gutters.^{29,30}

We present current knowledge of the health and medical effects of bed bugs, explore key issues in eradication efforts, and identify areas where further research is needed. Furthermore, we summarize evidence regarding whether bed bugs can serve as vectors of human disease and delineate clinical manifestations associated with bed bug bites in humans. Existing data regarding

treatment of bed bug bites, prevention of bed bug bites, and bed bug eradication are also described.

METHODS

We focused our computer-assisted literature search on (1) the medical and health effects of bed bugs, and (2) pest control and eradication aspects of the bed bugs. We searched MEDLINE and EMBASE (European) databases for the period between 1960 and October 2008. Our search strategy was limited to English language papers and used the Medical Subject Heading (MeSH) term *bed bugs*. Additional keywords included *Cimex lectularius*, *humans*, *parasitology*, *pathogenicity*, *bite reactions*, *hypersensitivity*, *skin*, *cutaneous*, and *drug effects*. We also searched for publication types, including *clinical trial* or *randomized controlled trial*. For bed bug pest control and eradication information, we accessed PubMed and Toxline databases using the keywords *bed bugs*, *Cimex*, *pest control*, *prevention*, and *eradication* between 1960 through October 2008.

We sought information using manual searches to identify pertinent articles in sources frequently not included in computer databases. These included older journals, textbooks, pest control trade journals, and newspapers from 1892 to

October 2008 in the entomology reference collection of the Mississippi Entomological Museum at Mississippi State University, Mississippi State. We also reviewed reference lists from retrieved articles and textbooks to identify additional articles of interest. During this manual search of reference lists, we found (and included) 6 key medical articles written in German and Portuguese.

The criteria used to select studies of the health and medical effects of bed bug bites were (1) accounts or investigations that were original, (2) clinical responses with sufficient detail to allow for a reasonable conclusion of cause and effect between the bed bug bite and clinical response, and (3) convincing evidence that the reactions described were unlikely to have resulted from other insects. Specifically, we looked for information that substantiated the presence of bed bug exposure by identifying insects or their cast skins in the environment where the patient noted a clinical reaction. We also required that the description of the clinical reaction had to be sufficiently detailed (ie, dermal vs systemic, characteristics of the dermatological response, or symptoms from the systemic response) to establish that an untoward event actually occurred. Studies failing to document the presence of bed bugs, cast skins, or bed bug excreta in the environment where the reaction occurred and studies failing to identify the clinical characteristics of the reaction were excluded.

Criteria used to select studies about bed bug prevention, control, and eradication were (1) documentation of bed bugs in the environment, and (2) documentation that a prevention or eradication measure quantitatively decreased or prevented bed bugs in a specific environment. Studies primarily concerned with controlling other insects in the home environment, but which peripherally mentioned bed bugs, were excluded. Papers that reported only laboratory assays of pesticides were excluded.

A trained medical reference librarian assisted us with the literature search. Two medical entomologists (J.G. and

R.D.) with expertise in the diagnosis, treatment, and eradication of bed bugs reviewed the clinical articles selected. For pest control and eradication information, 1 author (J.G.) evaluated the articles.

RESULTS

Evidence Synthesis

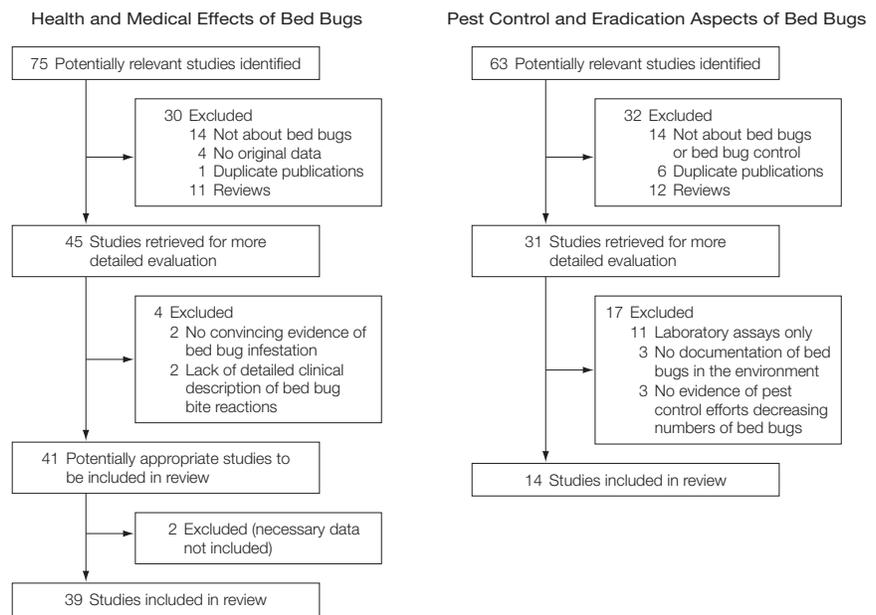
Seventy-five citations were identified regarding the health and medical effects of bed bugs and 39 articles met inclusion criteria and were included in the review (FIGURE 2). Sixty-three articles on pest control and eradication of bed bugs were identified and 14 of them met inclusion criteria and were included in the review. Only 2 clinical trials concerning bed bugs were identified, but they involved pest control interventions and not the health and medical effects. Almost all articles concerning the health and medical effects from bed bugs were case reports of 1 person or a few persons bitten, descriptions of the bite reactions, and treatments given.

Bed Bugs as Vectors of Human Disease

Transmission of more than 40 human diseases has been attributed to bed bugs, but there is little evidence that such transmission has ever occurred (TABLE 2).^{47,48} Older scientific literature postulated that bed bugs may be vectors of plague, yellow fever, tuberculosis,⁴⁹ relapsing fever, leprosy, filariasis,³¹ *kala azar* (leishmaniasis),⁵⁰ cancer,⁵¹ smallpox,⁵² yellow fever, and Chagas disease (*Trypanosoma cruzi*).^{41,53} Recently, the possibility of human immunodeficiency virus and hepatitis B virus (HBV) transmission by bed bugs has been investigated.

Human immunodeficiency virus can be detected in bed bugs up to 8 days after ingestion of highly concentrated virus in experimental blood meals. However, no viral replication has been observed within the insects and no virus has been detected in bed bug feces.^{32,33} Mechanical transmission of human immunodeficiency virus has not been demonstrated using an artificial system of feeding bed bugs through membranes.³³

Figure 2. Study Selection Diagram



The best candidate for human disease transmission by bed bugs is HBV. Bed bugs collected from huts in an HBV endemic area in northern Transvaal, South Africa, were hepatitis B surface antigen positive,⁴³ as were samples collected from Senegal,⁴² Egypt,⁴⁵ the Ivory Coast,⁵⁴ and China.⁴⁴ Hepatitis B surface antigen has also been shown to persist in bed bugs for more than 7 weeks after experimental feeding, but no replication of HBV was detected in the insects.^{34,36} Polymerase chain reaction assays have detected HBV DNA in bed bugs and their excrement up to 6 weeks after feeding on infected blood.^{38,39} Despite these findings, a 2-year bed bug eradication project in Gambia had no effect on rates of HBV infection, despite 100% reduction of bed bug numbers.⁵⁵

To our knowledge, no study to date has demonstrated bed bug “vector competence” (the ability to acquire, maintain, and transmit an infectious agent), and an attempt to demonstrate vector competence for HBV failed in an experiment with chimpanzees.⁴⁰ In that experiment, bed bugs were fed HBV-infected blood through an apparatus containing artificial skin-like mem-

branes. Two weeks later, approximately 50% of the insects contained virus. These insects then took blood meals from chimpanzees, but no infections or seroconversions resulted in the primates. When the same blood used to infect the insects was injected into the chimpanzees, they rapidly developed HBV infection.⁴⁰

Although evidence for disease transmission by bed bugs is equivocal, issues of vector competence, reactions to insect bites, embarrassment, and mental anguish have been the basis for lawsuits against landlords and lodging corporations.⁴⁸

Reactions to Bed Bug Bites in Humans

Cutaneous Reactions. Our review of case reports revealed that the usual response to a bed bug bite appears to be no reaction with a barely visible punctum at the location of the bite (Table 1). The most common reactions for which medical attention is sought are 2- to 5-mm pruritic maculopapular, erythematous lesions at bed bug feeding sites, one per insect (FIGURE 3). These usually itch and, if not abraded, resolve within a week.^{8,9,56} The size and pruritus

Table 2. Studies of Potential Disease Transmission by Bed Bugs

Source	Potential Disease Agent	No. of Bed Bugs, Animals, or Individuals	Data/Findings
Studies With Bed Bugs Only			
Nelson, ³¹ 1963	Filariasis	300 Bed bugs	Bed bugs fed on a man with infection (<i>Wuchereria bancrofti</i>); almost all bugs ingested microfilariae but most worms died within 3 d; a few microfilariae survived in bugs 20 d but showed no signs of development to infective third stage
Jupp and Lyons, ³² 1987	HIV	100 Bed bugs	4 In vitro attempts failed to transmit HIV from blood-virus mixture to uninfected blood by interrupted feeding of bed bugs via artificial membranes ^a
Webb et al, ³³ 1989	HIV	115 Bed bugs	No viral replication in bed bugs after feeding on HIV-infected blood; no mechanical transmission in vitro occurred during feeding through artificial membranes
Ogston et al, ³⁴ 1979	HBV	Approximately 100 third and fourth instar nymphs divided into experimental and control groups; 10 samples of several bugs each tested over 9 wk	HBsAg persisted in most bed bugs 4 wk after infected blood meal; 1 bug was HBsAg-positive 6 wk after initial feeding; all control bugs were negative; no evidence of HBV replication in bed bugs
Ogston and London, ³⁵ 1980	HBV	100 Bed bugs in treatment group and 100 in control group	After feeding on infected blood via artificial feeder, HBsAg appeared in bed bug feces collected during second week of experiment and present until eighth week; all bed bugs in control group were HBsAg-negative
Jupp and McElligott, ³⁶ 1979	HBV	136 Adult and 109 nymphal bed bugs	HBsAg persisted in bed bugs for >7 wk after experimental feeding, but no viral replication; all control bugs fed on HBsAg-negative blood were negative
Taylor and Morrison, ³⁷ 1980	HBV	288 Adult bed bugs, 80 third to fifth instar nymphs, and large number of first and second instar nymphs	3/23 HBsAg-positive nymphs in 1 batch were positive after 122 d; persistence of viral antigen and indications of increasing proportion positive at 2-3 mo suggested HBV replication in bed bugs; no transovarial transmission of HBV to bed bug offspring
Blow et al, ³⁸ 2001	HBV	100 Bed bugs fed on HBV-infected blood and 100 bed bugs fed on HBV-negative blood	Detection of HBV nucleic acids by PCR assays in bed bugs and their excrement up to 35 d after feeding on infected blood meal; HBV DNA was detected in bed bugs 21 and 28 d after infectious blood meal
Silverman et al, ³⁹ 2001	HBV	55 Bed bugs fed on HBV-positive human blood; control bed bugs fed on HBV-negative human blood (controls)	HBV DNA was detected by PCR assays in bed bugs and their excrement up to 6 wk after feeding on infected blood; HBV DNA was detected as early as day 1; excrement tested positive within 7 d after feeding
Studies With Bed Bugs and Laboratory Animals			
Jupp et al, ⁴⁰ 1991	HBV	200 Bed bugs and 3 chimpanzees	53%-85% Of bed bugs were HBsAg-positive after feeding on infected blood via artificial membrane; infected bed bugs were placed on 3 chimpanzees, who did not develop HBV infection up to 11 mo; attempt to artificially transmit HBV to chimpanzees failed
Jörg, ⁴¹ 1992	Chagas disease	1 Azara's grass mouse and 30 white laboratory mice	125 Bed bugs acquired infection with <i>Trypanosoma cruzi</i> after feeding on infected Azara's grass mouse and 96.6% of white mice were infected with <i>T. cruzi</i> 15 d after bug bites; infection maintained in bed bugs for 320 d
Studies of Bed Bugs and Disease in Human Settings			
Wills et al, ⁴² 1977	HBV	161 Bed bugs	23/161 Bed bugs (14.2%) collected from bedding in huts in Senegal, West Africa, were HBsAg-positive
Jupp et al, ⁴³ 1978	HBV	1368 Bed bugs from 6 localities	30.6/1000 Bed bugs collected from huts in HBV endemic areas in Africa were HBsAg positive
Hu et al, ⁴⁴ 1984	HBV	401 Bed bugs collected from beds	HBsAg positivity of bed bugs (n = 32) from HBsAg-positive carrier's beds in China was 56.2%; for HBsAg-negative (n = 140 bugs), 33.5%; and for HBsAg unknown status (n = 229 bugs), 24.4%
El-Masry and Kotkat, ⁴⁵ 1990	HBV	276 Soldiers; 1800 bed bugs from army barracks, 300 bed bugs from uninfected colony	10/276 Military recruits (3.6%) were HBsAg-positive; 300/1800 bed bugs (16%) collected from barracks were HBsAg-positive; all controls were negative
Rothberg and Pick, ⁴⁶ 1994	HBV	641 Children divided into treatment (n = 320) and control (n = 321) groups	Treatment group had insecticide sprayed to kill bed bugs in homes over 2 y. At end of intervention, 526 children retested and homes evaluated. No children in sprayed homes had bed bug bites; 69/160 children (28%) in treatment group were HBV-positive and 91/160 (33%) in control group had HBV infection. Bed bug eradication had no effect on HBV infection rates, despite reduction in bed bugs

Abbreviations: HBsAg, hepatitis B surface antigen; HBV, hepatitis B virus; HIV, human immunodeficiency virus; PCR, polymerase chain reaction.

^aTightly-stretched Parafilm membrane, a thermoplastic, self-sealing film (Pechiney Plastic Packaging Co, Chicago, Illinois).

associated with these common reactions may increase in some individuals who experience repeated bites.^{6,14,57} There are no data to establish how frequently common reactions occur.

Some patients experience complex cutaneous reactions. Reports of these include pruritic wheals (local urticaria) around a central punctum, papular urticaria, and diffuse urticaria at bite sites usually noted on arising.^{5,16,58-60} Bullous rashes may occur subsequent to biting events days later.⁶¹⁻⁶⁵ In some cases, these reactions evolve into pruritic papules or nodules that may become superinfected (impetiginous) after scratching and persist for weeks.^{9,14,58,66-68} Secondary infection also may result in folliculitis, cellulitis, or an eczematoid dermatitis.^{67,69}

The timing of cutaneous reactions to bed bugs may change with multiple exposures. This appears to reflect host immunological responses to salivary proteins.^{8,61,70-74} Usinger²⁷ fed a colony of bed bugs on himself weekly for 7 years and noted that his reactions progressed from delayed to immediate, with no evidence of desensitization. Three salivary proteins have been identified that may play a role in host immunological responses (a nitric oxide-liberating heme protein [nitrophorin],⁷⁵ a 17-kDa anticoagulant [Factor X],⁷⁶ and a 40-kDa apyrase-like nucleotide-binding enzyme⁷⁷). One article¹² provides evidence for an immunological response to salivary proteins as the basis for some cutaneous reactions to bed bug bites. A hotel guest noticed isolated macules after her first visit to a hotel. After a second stay at the same hotel 1 year later, macules again appeared but this time evolved over 3 days into crops of erythematous nodules with blisters.¹² She was skin tested with a *C lectularius* salivary gland extract a year after the second hotel stay. Dermal injection of increasing concentrations of the extract resulted in a dose-related increase in the size of wheal and flare reactions that occurred within 20 minutes of injection. These wheal and flare reactions developed into papular reactions over 24 hours. The most concentrated salivary solution caused a

Figure 3. Lesions on a Human Leg 30 Minutes After Bed Bug Bites



Reproduced with permission from Harold Harlan, PhD. Not all persons bitten by bed bugs display cutaneous lesions.

papule with a blister. In vitro studies demonstrated that the patient had IgE specific to the nitrophorin but not the apyrase protein component of unfractionated salivary extract. This article suggests that some responses to bed bug bites are the same IgE-mediated biphasic (late-phase) reactions we have previously described to insect stings.⁷⁸

Systemic Reactions. There are a few studies of systemic reactions from bed bug bites, including asthma, generalized urticaria, and anaphylaxis.^{63,79-81} One study⁸² suggested that generalized urticaria from bed bug bites is not unusual. However, the descriptions of the “urticaria” in 1 study suggests erythema multiforme.⁸³ In another study, a man staying in a hotel awakened during the night with severe itching and urticaria on his arm and neck; bed bugs were found in the room.⁸⁴ He developed angioedema and hypotension, was hospitalized, and his electrocardiogram showed transient anterolateral ischemia. Eight months later, after an experimental bed bug bite, he developed a wheal at the bite site with generalized itching that required epinephrine administration to resolve his symptoms. A home evaluation of another man who had asthma revealed bed bugs in his bedding and an intradermal allergy skin test

with an extract of bed bugs was positive.⁸¹ When his bedding was changed, the asthma symptoms ceased.

Treatment of Bed Bug Bite Reactions

Treatments of common and complex cutaneous reactions are usually symptomatic and not evidence based (TABLE 3). If lesions are pruritic, topical application of over-the-counter or prescription antipruritic agents (paroxime, doxepin) or intermediate potency corticosteroids (triamcinolone) may be helpful. Sites that are superinfected may benefit from topical mupirocin or systemic antibiotics. Systemic reactions to bed bug bites are treated as insect-induced anaphylaxis,^{70,84,85} with treatment including intramuscular epinephrine, antihistamines, and corticosteroids.

Issues in Prevention, Pest Control, and Eradication

Steps necessary for bed bug eradication include (1) proper identification of the bed bug species present, because some bat-infesting species may be found inside homes; (2) education of persons involved; (3) thorough inspection of infested and adjacent areas; (4) implementation of chemical and nonchemical control measures; and (5) follow-up to evaluate the success of

Table 3. Reported Treatments and Outcomes for Dermatitis From Bed Bug Bites^a

Source	No. of Patients	Treatment(s)	No. Improved	Remarks
Scarupa and Economides, ⁸³ 2006	17 ^b	Antihistamines and topical and/or systemic corticosteroids	17	Antihistamines minimize itch in some patients, although appearance and duration of dermatitis was not affected; lesions in most patients were poorly responsive to relatively high-dose oral corticosteroids
Masetti and Bruschi, ⁹ 2007	2	Oral antibiotics, oral antihistamines, and topical corticosteroids	2	Remission in 2 wk
Sansom et al, ¹⁰ 1992	2	Prednisolone	2	Both patients had resolution of dermatitis over a 2-wk period, but only one was treated
Goddard and deShazo, ¹³ 2008	1	Diphenhydramine, injection of 80-mg depomedrol; another injection 12 d later	1	Completely resolved in 2 wk
Mumcuoglu, ¹⁸ 2008	1	Systemic corticosteroids	0	Little improvement in clinical symptoms
Stucki and Ludwig, ¹⁵ 2008	1	Topical corticosteroids	1	Symptoms completely resolved within 2 d
Ter Poorten and Prose, ¹⁷ 2005	1	Oral corticosteroids, oral antihistamines, oral antibiotics, topical permethrin, antibiotic ointments, mid-potency corticosteroid creams	0	"Unsuccessful"
Fletcher et al, ¹⁹ 2002	1	Oral prednisolone and flucloxacillin	1	"Rapid response"
Liebold et al, ¹⁴ 2003	1	100-mg prednisolone and 4-mg dimethindene maleate intravenously; 2-g/d erythromycin for 5 d; topical ointments containing betamethasone	1	Remission in 1 wk
Brasch and Schwarz, ¹⁶ 2006	1	Topical corticosteroids	1	"Sting" reactions became short-term with corticosteroid treatments

^aNo study designs were reported in these treatment regimes.

^bNot 17 patients at once; these patients were observed over a 7-month period.

Figure 4. Bed Bug and Bed Bug Excreta on a Mattress

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eradication.^{86,87} Prevention of bed bug bites is best achieved with avoidance, because no repellents for the insects have been demonstrated conclusively to be effective. The mosquito repellent, oil of lemon eucalyptus, may help.⁸⁸ Bed bugs and their fecal matter are easily visible (FIGURE 4). When sleeping in hotels or other unfamiliar

environments, a prudent approach for preventing bites is to check the premises for bed bugs or their excreta. Important sites to inspect include mattress cords, cracks and crevices in box springs, and the back of headboards. Items purchased at garage sales and resale shops, especially mattresses, box springs, and bedding, should be care-

fully inspected for bed bugs before they are brought into homes because they may initiate an infestation.

Bed bugs are extremely difficult to eradicate^{1,86,89} and pest control issues relating to bed bugs and eradication procedures have been recently reviewed in detail.^{1,86,90} Pesticides are typically evaluated in the laboratory and less commonly in the field with demonstration-type studies, a common practice in University Extension Services. Currently, a variety of pesticides are undergoing evaluation for control of bed bugs. In general, the products have not performed as well as against other pests and eradication often requires non-chemical tactics as well. In 1 trial,⁵⁵ insecticide spraying of children's dwellings effectively reduced exposure to bed bugs and, in another trial,⁹¹ insecticide-treated bed nets for malaria control helped eliminate bed bugs from infested homes. There is evidence that pyrethroid-impregnated bed nets used in many tropical countries for malaria control may be moderately effective against bed bugs.⁹²⁻⁹⁴ However, these bed nets may be contributing to insecticide resistance in bed bugs.^{92,93}

Pesticide control of bed bugs is complicated by insecticide resistance, lack of effective products, and health concerns about spraying mattresses with pesticides.^{1,3,88} Nonchemical methods for bed bug control include vacuuming, heat or steam treatments, mattress and box spring encasements, and discarding furnishings such as mattresses and box springs. Discarding mattresses and box springs is sometimes recommended by pest control personnel or public health authorities, but is financially burdensome.⁸⁶⁻⁸⁸ Others recommend that mattresses and box springs be covered with encasements (similar to those used for dust mite allergies) that will not allow any remaining bugs to feed through the material or escape its confines.

COMMENT

No randomized controlled trials on bite reactions, risk factors for outbreaks, or treatment modalities were identified during this review. Two identified clinical trials involved pest control interventions. Most articles concerning health and medical effects of bed bugs consisted of case reports of 1 to 2 persons bitten and their treatment. No study designs were described in the treatment approaches.

Detailed accounts of bed bug biting incidents⁴⁻⁶ demonstrate that not everyone bitten by bed bugs develops a clinical reaction, a finding supported by experimental work with volunteers that reported that only approximately 30% of patients react to bites.⁸ A variety of clinical reactions to bed bugs have been reported but these have not been placed into a clinically useful classification. Our review of the medical literature on this topic along with our clinical experience suggests that a useful classification of reactions should be based on local cutaneous vs systemic symptoms. Local cutaneous reactions have been reported to be uniphasic or multiphasic in timing and are similar to those reactions we have previously described for other insect bites and stings.⁷⁸

There are few data to support bed bugs as vectors for transmission of hu-

man disease agents. After feeding on an infectious blood meal, bed bugs excrete hepatitis B surface antigen in their feces and could be a possible source of HBV infection by contamination of skin lesions or mucosal surfaces, or by inhalation of dust. However, their transmission of a human disease is yet to be firmly established.

The use of any treatment strategy for symptomatic bed bug bites has not been established. The largest series described an experience with only 17 patients. Although patients often improve after therapy with oral or topical corticosteroids and antihistamines, there are reports in which these treatments are unsuccessful.^{17,18} In 1 article of 2 patients with dermal reactions to bed bug bites, one was treated with prednisolone and the other was not treated.¹⁰ Reactions subsided within 2 weeks in both patients.

Bed bugs are likely to be more problematic in the future due to travel, immigration, and insecticide resistance. The most crucial need for research is in determining its vector competence.^{1,2,48} Development of effective repellents and public education about bed bugs are also important goals. Research is needed to elucidate the pathogenesis of clinical reactions to bed bug bites so that optimal therapy may be identified.

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Study concept and design, acquisition of data, analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, and administrative, technical, or material support: Goddard, deShazo.

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