

# Bedbugs (*Cimicidae* infestation): the worldwide renaissance of an old partner of human kind

## Authors

Paulo Ricardo Criado<sup>1</sup>  
Walter Belda Junior<sup>2</sup>  
Roberta Fachini Jardim  
Criado<sup>3</sup>  
Roberta Vasconcelos  
e Silva<sup>4</sup>  
Cidia Vasconcelos<sup>5</sup>

<sup>1</sup>PhD, Dermatology;  
School of Medicine,  
Universidade de São Paulo  
- USP; Assistant professor,  
Dermatology, HC-FMUSP  
<sup>2</sup>Professor, UNICAMP;  
Assistant Professor,  
Department of  
Dermatology, FMUSP

<sup>3</sup>Master's Degree, IAMSPE;  
Allergist, Dermatology,  
Faculdade de Medicina  
do ABC

<sup>4</sup>Dermatology; Post-  
Graduation, Department of  
Dermatology, FMUSP

<sup>5</sup>Post-Doctorate,  
Department of Pathology,  
FMUSP; Professor at  
the Post-Graduation  
Programme, IAMSPE e  
UNICID

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## Correspondence to:

Paulo Ricardo Criado  
Hospital das Clínicas da  
Faculdade de Medicina  
da USP  
Instituto Central, 3º andar,  
Av. Dr. Enéas de Carvalho  
Aguiar, 255  
05403-000, São Paulo  
Brazil  
Phone: 55 11 30698001  
prcriado@uol.com.br

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## ABSTRACT

Bedbugs have been known as a human parasite for thousands of years, but scientific studies about this insect are recent and limited. *Cimex lectularius*, the common bedbug, was a well-known parasite in human dwellings until the end of the Second World War. Nowadays, bedbugs are considered uncommon in the industrialized world. Anecdotal reports suggest that bedbugs are getting more common in the United States, Canada, and United Kingdom. In Brazil, there are few reports about bedbug infestations in the literature. The aim of this article was to alert physicians, especially in Brazil, about this ectoparasitosis, including aspects of the bedbug biology, their parasitism in human host, treatment and prophylaxis.

**Keywords:** hemiptera; bedbugs; *Cimex lectularius*; pyrethrins; DDT.

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## INTRODUCTION

The common bedbug (*Cimex lectularius*) was a well-known parasite in human dwellings until the end of the Second World War.<sup>1</sup> With the introduction of modern insecticides, especially DDT, and improved hygiene in developed countries, the prevalence of bedbug infestation decreased dramatically.<sup>1</sup>

Nowadays, bedbug infestations are common in the developing world, occurring in settings of unsanitary living conditions and overcrowding. Bedbug infestations became rare during the second half of the 20<sup>th</sup> century and have been considered a condition that occurs in travelers returning from developing countries.<sup>2</sup> However, an increasing incidence of bedbug infestations has been widely reported in the recent medical literature, for example, in Korea,<sup>3</sup> France,<sup>4</sup> Germany,<sup>5</sup> USA,<sup>6-9</sup> Canada,<sup>10</sup> Italy,<sup>11</sup> and Australia.<sup>12</sup> International trips, immigration, changes in pest control practices, and insecticide resistance may have contributed to a recent resurgence of this blood-sucking insect in developed countries.<sup>13</sup> *Cimex lectularius* is a wingless, redbrown, nocturnal hematophagous insect that grows to an adult length of 5 - 6 mm.<sup>14</sup>

Bedbugs hide during the day in cracks and crevices in beds, furniture, floors and walls.<sup>14</sup> They emerge at night to feed.<sup>14</sup> Only in cases of severe infestation they are found on individuals

or in their clothes during the day.<sup>14</sup> In Brazil, the prevalence of bedbugs is uncertain. However, there are some reports of bedbug infestations after Second World War in this country.<sup>15-17</sup>

## EPIDEMIOLOGY AND AGENT FEATURES

The bedbug belongs to the phylum *Arthropoda*, the class *Hexapoda* (*Insecta*), the order *Hemiptera* (which represents 'true bugs'), the family *Cimicidae*, and the genus *Cimex*. Bedbugs belong to the same order of insects (*Hemiptera*) that includes common garden plant pests such as aphids and cicadas.<sup>18</sup> The difference between the garden bugs and the bedbugs is that the family *Cimicidae*, that covers bedbugs, has evolved to become exclusively haematophagous, ie., blood feeders.<sup>18</sup> The word *Cimex* is derived from the Roman designation for bug and *lectularius* from the Latin name for couch or bed.<sup>13</sup> Only two species, *Cimex lectularius* and *Cimex hemipterus* (native from tropical areas), usually feed on humans, but others may rarely do so as well.<sup>13</sup> *Cimex hemipterus* is the temperate bedbug's tropical cousin, although the species overlap in distribution around the world, and hybrid forms occur.<sup>13</sup> The female bug is longer than the male bug and *C. hemipterus* is about 25% longer than *C. lectularius*.

Adult bedbugs are wingless, roughly oval in shape, flattened, and approximately 5 mm long (Figure 1).<sup>13,18</sup> They resemble unfed ticks or small cockroaches and are easily visible, even to the untrained eye.<sup>13</sup> Adults are reddish brown (chestnut) in color, whereas immature may be light yellow and are much smaller.<sup>13</sup> They have a pyramid-shaped head with prominent compound eyes, slender antennae, and a long proboscis tucked underneath the head and thorax.<sup>13</sup> After a blood meal, the bugs may increase in length by 30% to 50% and in weight by 150% to 200%.<sup>13</sup> The common bedbug, *Cimex lectularius*, has a remarkable ability to survive four months to two years without feeding, a feature that presumably accounts for their incredible capacity to persist for long periods in human bedding and other locations.<sup>19</sup> It tolerates a loss of up to a third of their total body water volume,<sup>19</sup> an impressive statistic even among arthropods. Finally, bedbugs can also enter a stupor-like state of quiescence, when they retract their paws and completely cease the activity of enhancing nutrients and stocking water.<sup>19</sup>

Epidemiologically, *C. lectularius* is a nuisance pest to humans, causing loss of sleep due to annoying bites.<sup>19</sup> Bedbug infestation has been associated with iron deficiency, secondary bacterial infection from bite sores, and allergic hypersensitivity.<sup>19</sup> This species is broadly distributed, occurring throughout a large part of the temperate zone, and is most well succeeded in cosmopolitan areas with high human density.<sup>19</sup>

Although bedbugs could theoretically act as a disease vector, as body lice, which transmits *Bartonella quintana* (the causal agent of trench fever) among homeless persons,<sup>10</sup> they have never been shown to transmit disease *in vivo*. Hepatitis B viral DNA can be detected in bedbugs up to six

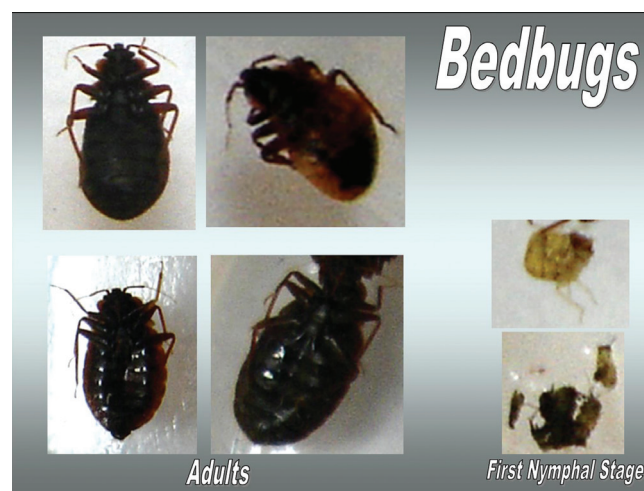
weeks after they feed on infectious blood, but no transmission of hepatitis B infection was found in a chimpanzee model.<sup>20-23</sup> Transmission of hepatitis C is unlikely, since hepatitis C viral RNA is not detectable in bedbugs after an infectious blood meal.<sup>24</sup> Live HIV can be recovered from bedbugs up to one hour after they feed on infected blood, but no epidemiological evidence for HIV transmission by this route exists.<sup>25-27</sup>

The cimicid life cycle is composed primarily of five nymphal stages followed by adulthood.<sup>27</sup> All five nymphal (juvenile) stages and adults are mobile and require a blood meal to molt, and the adult requires an additional blood meal to reproduce.<sup>19</sup> Overall, the nymphal stages last about 6-8 weeks, and the adult bedbug can typically live for 6-12 months.<sup>28</sup> Each adult female lays two to four eggs a day until death; a typical female can lay 200-500 eggs throughout life.<sup>28</sup> During nymphal stages the youngest being around 1 mm and having a light cream appearance, but progressively becoming darker and larger as they develop.<sup>18</sup> The eggs are cemented to solid surfaces where they are refuged and hatched within 6-10 days at room temperature.<sup>28</sup> As bedbugs that do not feed within days of emerging from the egg die,<sup>28,29</sup> the bedbug usually resides in areas where such blood meals are easily obtained.<sup>28</sup> Bedbugs can remain active in environments as cold as 7°C, and their upper thermal death point is as high as 45°C.<sup>28</sup>

Bedbugs have been present throughout recorded history, and are mentioned in ancient Greek and Roman writings as well as early Jewish and Christian documents; early North American colonial records also include mention to bedbugs.<sup>28</sup> Nowadays, bedbugs infestation has been a real problem in some countries. In Australia, infestations have risen by an incredible 4,500% between 2000 and 2006.<sup>18</sup> In Brazil, the literature about this infestation is scanty. Studying pemphigus foliaceus (Fogo Selvagem, FS) epidemiology in Terena reservation in Limão Verde (Mato Grosso), Aoki *et al.*<sup>15</sup> concluded that there was a high frequency of hematophagous insects (bedbugs and kissing bugs) in the houses of FS patients. There are few reports in urban areas of Northeast and Southeast Brazil.<sup>16</sup> Probably, in our country there is under notification of bedbugs occurrence in medical literature. Brazilian Sanitary Authorities must be alert due to the great income of tourists in the next years to Brazil, during Football World Cup and Olympic Games. Some people and supply materials will come to the country and maybe can introduce imported bedbugs via luggage, as well return to their original countries with bedbugs in luggage.

In the early part of the current resurgence, bedbugs were most likely to be encountered in commercial accommodation with high guest turnover, such as at popular tourism destinations, with people often transferring the insects' home via luggage.<sup>18</sup> However, since then, bedbugs have spread to the wider community and infestations have occurred in such diverse locations as trains, charter boats, cinemas, hospital wards and clinic waiting rooms, staff and student accommodations, and brothels.<sup>18</sup>

**Figure 1:** Adult and nymphal stages of the bedbug. Left: adult bedbugs are oval shaped, flat, and approximately 5 mm long, whereas immature ones are much smaller and may be light yellow (right). Bedbugs have a pyramid-shaped head with prominent compound eyes, slender antennae, and a long proboscis tucked underneath the head and thorax.



In homes, bedbugs hide in the dark crevices of walls, furniture, picture frames, and peeling wallpaper.<sup>28</sup> Bedbugs may also nest in the folds of clothing and linens, or in the corners of suitcases.<sup>28</sup> Dispersal of human-associated bed-bugs generally depends on their human hosts to move from one location to another.<sup>20</sup> This may occur through furniture, clothing, suitcases, used mattresses, and other personal possessions.<sup>20</sup> Bugs may also migrate from one apartment or hotel room to another through holes in walls, water pipes, or gutters.<sup>20</sup> Bedbugs often inhabit bat or bird roosts, including those in homes.<sup>28</sup> In fact, there are two separate bat bug species, *Cimex adjunctus* and *Cimex pilosellus*, which also bite humans when their hosts are absent.<sup>28</sup> Over the past three years, there has been a large rise in bedbug infestations in low income housing, often involving thousands to tens of thousands of bedbugs in a single infestation.<sup>18</sup> Indications of an infestation include unexplained bite reactions, dark spotting on the bed from fecal deposition, and presence of the insects themselves.<sup>18</sup>

### INTERACTIONS WITH THE HOST

The mouthparts of bedbugs are especially adapted for piercing skin and sucking blood.<sup>13</sup> Bedbugs nearly always feed at night, although they may bite during the day when ravenous.<sup>28</sup> Following emergence from a refuge, bedbugs may travel 5-20 feet (1.524 - 6.096 meters) to reach a victim.<sup>28</sup> The cimicid is attracted to a victim chiefly through the perception of body temperature and by detection of carbon dioxide production.<sup>28</sup> Bedbugs usually feed about every 3-5 days for 4-10 minutes.<sup>28</sup> After feeding, bedbugs find their way back to the refuge via an airborne aggregation pheromone secreted by other bedbugs ensconced within the refuge.<sup>28</sup> This complex aggregation pheromone contains 10 essential components, and it may attract adult males, virgin adult females, and juvenile bedbugs to the lair.<sup>28</sup>

Multiple physiological components of bedbug saliva contribute to the efficacy of its bite.<sup>28</sup> During feeding they inject saliva, which has anticoagulant properties and contains protein fractions that can produce various allergic reactions in humans.<sup>18</sup> Blood feeding typically occurs at night and often the bites are not noticed until the appearance of a clinical reaction, which can occur some days later.<sup>18</sup> Three salivary proteins that have been identified may play a role in host immunological responses (a nitric oxide-liberating heme protein [nitrophorin], a 17-kDa anticoagulant [Factor X], and a 40-kDa apyrase-like nucleotide-binding enzyme).<sup>20</sup> Nitrophorin is a heme protein that transports nitric oxide and functions as a vasodilator.<sup>30</sup>

The timing of cutaneous reactions to bedbugs may change with multiple exposures.<sup>20</sup> This appears to reflect host immunological responses to salivary proteins. Usinger<sup>31</sup> himself fed on a colony of bedbugs weekly for seven years and noted that his reactions progressed from delayed to immediate, with no evidence of desensitization. Leverkus *et al.*<sup>32</sup> suggested that some responses to bedbug bites are the

same IgE-mediated biphasic (late-phase) reactions that have been previously described to insect stings (such as sustained edema, erythema, vesicles, bullae and pruritus).

### CLINICAL PRESENTATION AND DIAGNOSIS

The clinical picture of bug bites substantially varies between individuals, depending on previous exposure and the degree of an immune response.<sup>31</sup> It has often been quoted that around 20% of people will show no clinical reaction to the bite,<sup>18</sup> however, such figures have been based on limited data.<sup>18</sup> In a recent study by Reinhardt *et al.*,<sup>32</sup> it was found that 11 out of 24 people had no dermatological reaction to a bedbug bite on first exposure. With further bites, most (18/19) developed an obvious clinical skin reaction and the latency period for those that previously reacted decreased substantially. This particular research focused on acute exposure, yet investigations on chronic exposure are virtually non-existent.<sup>18</sup>

The morphology of skin lesions resulting from bedbug bites is diverse, including macules, papules and papulevesicles, wheals, bullae and nodules.<sup>30</sup> Several conditions can be included in the clinical differential diagnosis (Table 1).<sup>30</sup>

Table 1. Clinical differential diagnosis from bedbug bites

Cutaneous lesions	Differential diagnosis
Macules	Arthropod bite reaction Trauma Drug reaction Erythema multiforme
Papules and papulovesicles	Atopic dermatitis Flea bites Scabies Lice infestation Prurigo simplex Polymorphous light eruption Papular urticaria Dermatitis herpeti formis Linear IgA bullous der matosis Bullous pemphigoid
Bullae	Flea bites Other arthropod bite reaction Bullous pemphigoid Ecthyma Erythema multiforme Fixed drug eruption Porphyria cutanea tarda
Wheals	Angioedema Urticaria Chagas' disease (Romaña's sign) Papular urticaria



The most commonly affected areas of the body are the face, arms, shoulders and legs, i.e., those that tend to be not covered while sleeping.<sup>18</sup> Often the first sign of bedbug bites are small indistinct red macular spots, which may later develop into the classic bedbug wheal.<sup>18</sup> These wheals are usually greater than 1 cm (up to 20 cm) across, and are accompanied by itching and inflammation; they usually subside to red spots and can last for several days.<sup>18</sup> Papules grow as large as 3 cm in diameter.<sup>28</sup> Pruritus is usually present.<sup>30</sup> Uncommonly, a prolonged delay (until nine days) has been observed between the time of exposure to the bedbug bites and the development of the cutaneous reaction.<sup>33</sup> The lesions have been described as “breakfast, lunch, and dinner”, when the cutaneous reaction from the bites presents in a linear array of three papules (Figure 2).<sup>30</sup> However, bedbugs have also been observed to dine at sites where clothes are tightly held against the skin, such as beneath the waistband of pajamas or underwear.<sup>30</sup> Bedbug bites rarely occur in the axillae or popliteal fossae, in contrast to the bites of many other insects and arthropods.<sup>28</sup>

Patients presenting with papular urticaria often have IgG antibodies to specific bedbug proteins.<sup>28</sup> Bullae may form as a response to bedbug bites,<sup>28</sup> and this phenomenon is mediated by the presence of IgE antibodies against salivary nitrophenol.<sup>32</sup> Anaphylaxis to bedbug bites is rare, but the occurrence has been documented in the literature, and may even lead to death on rare occasions.<sup>33</sup>

There are a few studies about systemic reactions from bedbug bites, including asthma, generalized urticaria, and anaphylaxis.<sup>34-36</sup> One study<sup>37</sup> suggested that generalized

urticaria from bedbug bites is not unusual. However, the description of the “urticaria” in one study suggests erythema multiforme.<sup>38</sup> In another study, a man staying in a hotel awakened during the night with severe itching and urticaria on his arm and neck; bedbugs were found in the room.<sup>39</sup> He developed angioedema and hypotension, was hospitalized, and his electrocardiogram showed transient anterolateral ischemia. Eight months later, after an experimental bedbug 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 bedbugs in his bedding and an intradermal allergy skin test with an extract of bedbugs was positive.<sup>36</sup> When his bedding was changed, the asthma symptoms ceased.

The diagnosis was usually considered on the basis of the clinical history and occasionally established when the insect was found and its identity confirmed.<sup>30,40</sup> The most locations where bedbugs are found are listed in Table 2. However, there are a few recent publications in which the pathology findings of bedbug bite skin lesions are described.<sup>30</sup>

The histopathological findings of bedbug bites is similar to that of many other insect and arthropod bite reactions.<sup>28</sup> Typically, there is a perivascular infiltrate of lymphocytes, histiocytes, eosinophils, and mast cells within the upper dermis.<sup>40</sup> One report,<sup>6</sup> from a child, described the histopathology examination of a biopsy of an “urticarial papule” from the left arm of a 10-year-old girl in whom the bugs that were subsequently found at night on her bed were identified as *C. lectularius* by ‘the local university extension service;’ there

**Figure 2:** A. Patient presents with multiple pruritic erythematous papules on her forearm. Bedbug bites on the arm. Bites typically occur in clusters or in a linear distribution referred to as the “breakfast, lunch, and dinner” sign. B. Detail of the erythematous macules and papules in linear distribution. C. Male patient with vesicle-papules lesions and purpuric papules in linear distribution in lumbar area and abdomen.



**Table 2. Locations where bedbugs can be found**

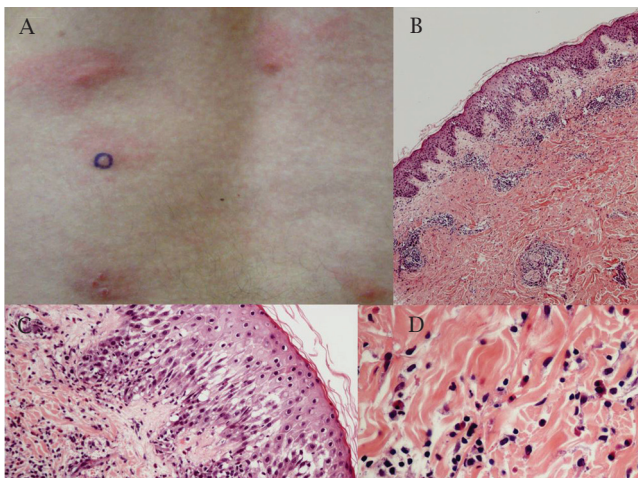
Furniture
Electrical boxes
Draperies
Baseboards
Wall and floor cracks and crevices
Carpet
Luggage and corners of suitcases
Bed frames and headboards
Dark protected places
Picture frames
Wall hangings
Mattress and box spring seams
Peeling wall paper
Clothes and linens
Bats or birds roosts

was "... a mildly hyperkeratotic epidermis with minimal spongiosis and a prominent, dense, mixed superficial and deep perivascular and interstitial infiltrate (composed predominantly of eosinophils) within the dermis." The authors commented that "... this pattern was felt to be most consistent with papular urticaria secondary to arthropod bites."<sup>6</sup>

In summary, the findings in skin biopsy are not pathognomonic from bedbug bite; however may be helpful in patients with an atypical clinical presentation or in whom positive identification of the suspected bedbug is not possible and other conditions are being considered.<sup>30</sup> For papular lesions, dermal edema and a perivascular infiltrate in the superficial and deep dermis, composed predominantly of lymphocytes with frequent eosinophils, are often observed (Figure 3).<sup>30</sup> Neutrophils are not a prominent finding.<sup>30</sup> In contrast to other conditions characterized by a dermal infiltrate of eosinophils, the inflammatory reaction caused by bug bites is usually denser and deeper than those observed following bites from other common arthropods, with the exception of ticks.<sup>30</sup>

Suspected diagnosis of bedbug bites can be confirmed when the causative culprit is captured for macroscopic evaluation;<sup>30</sup> they may be located under folds or along seams in the mattress, in the cracks and crevices of the bed frame, or behind the headboard.<sup>30</sup> Suggestive evidence of a bedbug infestation includes blood spots on the sheets or dark fecal spots on linen or near cracks.<sup>30</sup> In addition, when there is a large infestation, a distinctive pungent odor may be noticed since the bedbugs have special glands that secrete an oily, malodorous substance.<sup>30</sup>

**Figure 3:** A. Vesicle-papule lesion on lumbar area was selected to cutaneous biopsy. B. Histopathological exam showed epidermal intense spongiosis and inflammatory infiltrate in upper and lower dermis around vessels and epidermal adnexal structures (HE, OM 40x). C. This skin section demonstrated epidermal spongiosis and perivascular inflammatory infiltrate in papillary dermis (HE, 100x). D. Detail of the dermal inflammatory infiltrate showed lymphomononuclear cells and numerous eosinophils around the vessels and between collagen fiber bundles (HE, OM 400x).



## TREATMENT AND PROPHYLAXIS

Bedbug bites are self-limited and usually resolve within 1-2 weeks without treatment.<sup>28</sup> Moreover, consequences of bedbug infestation include anxiety, nervousness, stress, and exhaustion from lack of sleep.<sup>41</sup> Prevention and avoidance of secondary infection is an important factor to hasten resolution, and this is generally achieved with simple hygiene alone.<sup>28</sup>

The dermatologic management of bedbug bites is straightforward;<sup>42</sup> but the elimination of bedbugs from an infested environment is a challenge.<sup>42</sup> Pruritic lesions themselves may be treated with topical corticosteroids and antihistamines.<sup>42</sup>

Today, bedbugs have been found in hotels, hospitals, laboratories, airports, cruise ships, homes, schools and homeless shelters.<sup>41</sup>

Steps necessary for bedbug eradication include:<sup>20</sup> (I) proper identification of the bedbug species present, because some bat-infesting species may be found inside homes; (II) education of persons involved; (III) inspection of infested and adjacent areas; (IV) implementation of chemical and nonchemical control measures; and (V) follow-up to evaluate the success of eradication.

To detect a bedbug infestation, a flashlight should be available in the bed and turned on approximately an hour before dawn when bedbugs are most active.<sup>41</sup> Care should be taken by the host to remain in bed and not move suddenly because movement will cause the bugs to scatter.<sup>41</sup> A flashlight should be used to inspect all areas of the mattress.<sup>41</sup> The bedbugs' speed is similar to ants.<sup>41</sup> However, at this time of the morning, they have just ingested a meal which will make them larger in appearance and slower in movement. This combination provides a greater chance of visualization of the bedbugs, although it may take several seconds of looking at the mattress to notice them.<sup>41</sup>

Once bedbugs have been confirmed in the home or school environment, it is necessary to treat the infestation. Each infestation is different, and there are different treatment options available. Insecticides are available to assist in bug control.<sup>41</sup> In persistent bedbug infestations, trained canines can be used to detect common hiding places as crevices in the walls and floors, headboards, mattresses, and bed frames.<sup>41</sup> The dogs use their olfactory glands to seek out the bug's sweet and musty scent.<sup>41</sup> However, this service is used only in difficult cases as it is costly.<sup>41</sup>

Some steps must be adopted to bedbugs prophylaxis. These steps include procedures at home, school and during trips. Along the school year, children and their families may travel during holidays and school recesses.<sup>41</sup> Many families stay in hotels, children may attend sleep-over camps during the summer months, and some children may sleep over at friends' houses during the school

year.<sup>41</sup> The seams of the mattress should be examined carefully; also check behind the wall decor and headboard as these are common areas for bedbugs to hide.<sup>41</sup>

Bedbugs can survive for up to a year between meals, necessitating the use of insecticides in their elimination;<sup>43</sup> professional extermination services should be consulted.<sup>43</sup> Further, a thorough cleaning of the bedroom should take place in order to remove any traces of the bugs and their dung.<sup>43</sup> Clutter should be removed and any crevices in which the bugs might hide or lay eggs should be filled.<sup>43</sup> Steps should be taken to minimize the amount of skin exposed at night, such as wearing long sleeved nightclothes and applying insect repellent (eg, DEET [diethyltoluamide]) to uncovered skin.<sup>43</sup> Appropriate chemicals (malathion, pyrethrin, dichlorvos, permethrin, and diethyltoluamide) must make direct contact with all affected surfaces.<sup>1</sup> The discovery of live bedbugs two weeks after appropriate treatment measures is indicative of continued infestation.<sup>1</sup> The services of a professional exterminator may be required.<sup>1</sup> It should be noted that high levels of resistance to pyrethroid insecticides were detected in populations collected from homes in Kentucky and Ohio in the United States.<sup>1</sup>

Patients should be informed that multiple applications of pesticide might be required before the problem is eliminated and that they should continue with symptomatic management of any further lesions.<sup>43</sup> Patients living in apartments or multi-unit housing should notify their landlords or superintendents of the problem.<sup>43</sup>

## CONCLUSIONS

Bedbugs are likely to be more problematic in the future due to travelling, immigration, and insecticide resistance.<sup>20</sup> All socioeconomic groups are subject to being bitten by *Cimex lectularius*, the common bedbug. The most crucial need for research is in determining its vector competence.<sup>20</sup> To Brazilian biologists and physicians remains the challenge to identify and qualify the real extension of this ectoparasitosis in our country and to alert the sanitary authorities to the bedbug combat. We agree that for this to have a positive effect, the measures must include physicians and population education, implement of mechanisms of adequate sanitary inspections in airports, ports, hotels and hostels.

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