International Journal of Infectious Diseases 17 (2013) e802–e805

Contents lists available at SciVerse ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Perspective

Reservoirs of *Acinetobacter baumannii* outside the hospital and potential involvement in emerging human community-acquired infections

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ARTICLE INFO

Article history:
Received 19 September 2012
Received in revised form 8 March 2013
Accepted 19 March 2013

Corresponding Editor: Eskild Petersen, Aarhus, Denmark

Keywords:
Acinetobacter baumannii
Reservoirs
Environment
Animals
Community-acquired infections

SUMMARY

The objective of the present report was to review briefly the potentially community-acquired *Acinetobacter baumannii* infections, to update information on the reservoirs of *A. baumannii* outside the hospital, and to consider their potential interactions with human infections. Most reports on potentially community-acquired *A. baumannii* have been published during the last 15 years. They concern community-acquired pneumonia, infections in survivors from natural disasters, and infected war wounds in troops from Iraq and Afghanistan. Although the existence of extra-hospital reservoirs of *A. baumannii* has long been disputed, the recent implementation of molecular methods has allowed the demonstration of the actual presence of this organism in various environmental locations, in human carriage, in pets, slaughter animals, and human lice. Although the origin of the *A. baumannii* infections in soldiers injured in Southwestern Asia is difficult to determine, there are some arguments to support the involvement of extra-hospital reservoirs in the occurrence of community-acquired infections. Overall, the emergence of community-acquired *A. baumannii* infections could be associated with interactions between animals, environment, and humans that are considered to be potentially involved in the emergence or re-emergence of some infectious diseases.

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1. Introduction

Acinetobacter baumannii has emerged as an important nosocomial pathogen, and nosocomial infection with this organism has been associated with increased patient morbidity, mortality, and health care costs.[1–3] Recent studies have improved our knowledge about the virulence of *A. baumannii* by using animal models, adherence to cell cultures, and phenotypic and molecular studies of the bacteria.[4–10] This organism has been responsible for numerous hospital outbreaks, presents a remarkable ability to upregulate or acquire resistance determinants,[11] and has a remarkable ability to survive for prolonged periods throughout the hospital environment,[12–14] which can be involved in the duration of certain outbreaks,[15] some of them lasting several years.[16] The cross-transmission of this organism from patient to patient and the possibility of outbreak extension by patient transfer has been demonstrated.[17] In contrast, the existence of an extra-hospital reservoir of *A. baumannii* and the implication of this potential reservoir in the occurrence of certain infections due to this organism are still controversial.[12,18] It is well established that the members of the genus *Acinetobacter* are considered ubiquitous microorganisms. However, according to most authors, *A. baumannii* being considered ubiquitous or highly prevalent in nature is an important misconception due to the difficulties encountered in accurately identifying this organism.[12,18]

The implementation of molecular methods (e.g. identification of the *bla*OXA-51-like gene by PCR, or the *rpo*B gene by sequencing) has recently improved the identification of *A. baumannii*.[19,20]

The objective of the present report was to review briefly the potentially community-acquired *A. baumannii* infections, to update information on the reservoirs of *A. baumannii* outside the hospital, and to consider their potential interactions with human infections.

2. Potentially community-acquired *A. baumannii* infections

Although the first reports of respiratory community-acquired Acinetobacter infections were published in 1977 in two alcoholic

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http://dx.doi.org/10.1016/j.ijid.2013.03.021

patients[21] and in 1981 in three foundry workers,[22] most reports concerning potentially community-acquired *A. baumannii* infections have been published during the last 15 years.

A. baumannii is increasingly recognized as an uncommon but important cause of community-acquired pneumonia.[23–26] In addition, most of these infections have occurred during the warmest and wettest seasons.[26] This strongly marked seasonal and geographical distribution could be related to some climatic or environmental features involved in the acquisition of these bacteria by patients. Other studies have demonstrated summer peaks and temperature-associated increases in Gram-negative infections among hospitalized patients.[27,28] According to a time-series analysis reported in a study conducted at the University of Maryland Medical Center, the increase in the monthly *A. baumannii* infection rate was 17% for each 10 °F increase in outdoor temperatures.[27] According to Anstey et al.,[23] community-acquired pneumonia could occur following microaspiration of *A. baumannii* in patients with preceding throat colonization with this species.

A. baumannii is one of the microorganisms that are most commonly isolated in wound cultures from survivors of natural disasters. It has been demonstrated in earthquakes[29,30] and a tsunami.[31] In the Wenchuan (China) earthquake that occurred in 2008, *A. baumannii* was isolated from wounds, sputum, and blood of some injured persons.[30]

Since 2003 the incidence of *A. baumannii* infection in US military hospitals has increased, primarily among wounded troops from Southwest Asia.[32] A microbiological study concerning war wounds in US troops from Iraq and Afghanistan upon arrival at the National Naval Medical Center (USA) demonstrated that *A. baumannii* was the most prevalent organism isolated, representing 63.0% of all isolates.[33] Similarly, bacteria belonging to the *A. calcoaceticus–baumannii* complex (ABC) were the most prevalent microorganisms isolated in the cultures obtained from casualties coming from Iraq and Afghanistan who had open tibial fractures that were complicated by infection.[34]

Overall, studies reporting community-acquired *A. baumannii* infections are based on single events or case series. It is noticeable that, to the best of our knowledge, no study estimating the evolution of the incidence of community-acquired *A. baumannii* infections has been published. Moreover, in most published studies, details concerning the methods used for bacterial identification are limited. Considering the difficulties encountered in the identification of *A. baumannii*, this lack of information is an important limitation for the interpretation of those study results.

3. Extra-hospital reservoirs of *A. baumannii*

A. baumannii has been isolated from various environmental locations. Indeed, it has been recovered from soil contaminated with petroleum hydrocarbons in countries presenting different climatic conditions, like India[35] and France.[36] A lot of *Acinetobacter* species, including *A. baumannii*, are able to degrade diesel fuel.[37] Among 66 soil samples analyzed in Hong Kong, more than a third contained *Acinetobacter sp*, with *A. baumannii* representing 23% of these bacteria.[38] *A. baumannii* has also been isolated from vegetables collected in supermarkets, greengrocers, and private gardens.[39] Lastly, a recent study conducted in South Korea recorded the presence of *A. baumannii* on inanimate surfaces that are often in contact with humans, like tables in parks and a game console.[40] *A. baumannii* was also recovered from manured agricultural soil and pig slurry in the UK,[41] and in aquaculture environments (fish and shrimp farms) in Southeast Asia.[42] It is noticeable that for all these environmental studies, molecular techniques for identification (amplified ribosomal DNA restriction analysis and analysis of the 16S rRNA gene) were used.

Data concerning human community carriage of *A. baumannii* are scarce. A study performed in New York City reported that 10.4% of community residents carried *A. baumannii* on their hands.[43] A prevalence study conducted among 102 healthy nondeployed US Army soldiers in training reported that 17 individuals (17%) carried ABC on their skin (forehead or feet).[44] Concurrently, a study performed by the same authors among US Army soldiers stationed in Iraq failed to find any skin carrier.[45] Previous surveys in Europe have also found the rates of *A. baumannii* skin carriage to be very low (<1%).[46,47]

During the last decade, *A. baumannii* strains have been isolated from animals. Most of the studies reporting animal cases have been conducted in veterinary clinics or hospitals.[48–51] Nosocomial spread has been described.[49] The *A. baumannii* infections were reported in horses and pets, with a slight predominance in wound infections and abscesses. For those studies performed in animal health care settings, it is difficult to demonstrate the extra-hospital origin of *A. baumannii*. However animals can still be colonized after discharge, then constituting a reservoir for potential transmissions to the environment, other animals, or humans.

In a study conducted in Scotland,[52] pigs and cattle slaughtered for human consumption and coming from different farms were sampled (feces, skin, nostril, ear) for *A. baumannii* isolation. The prevalence of *A. baumannii* carriage was 1.2%. The 16 *A. baumannii* isolated were grouped into three different clusters, but had different pulsed-field gel electrophoresis (PFGE) patterns compared with human isolates of the three major European clones ECI, ECII, and ECIII. Multi-resistant strains have been identified in other studies. Zordan et al.[53] reported that the 56 *A. baumannii* isolates obtained from several German veterinary clinics were highly resistant to antibiotics, a large proportion of them were genetically congruent with the European clones I, II, or III, and most of them belonged to the same cluster. These findings indicate that, as in human medicine, *A. baumannii* is also an emerging opportunistic pathogen in veterinary medicine, especially in hospitalized animals. However, no cohort or case–control study has investigated if contact of humans with animals increases the risk of acquiring *A. baumannii* infections.

Apart from vertebrate animals, *A. baumannii* strains have also been identified in human lice. La Scola and Raoult[54] demonstrated that the average prevalence of *A. baumannii* DNA among 622 body lice sampled from various continents (Europe, Africa, and South America) varied with a range from 3% to 58%. A recent study conducted in Ethiopia showed the presence of *A. baumannii* in human body lice and also head lice.[55] In another recent study conducted in Paris,[56] *A. baumannii* was isolated in 33% of head lice from elementary schoolchildren. However, whether lice could be a preferential host for *A. baumannii* has not been established.

4. Potential interactions between extra-hospital reservoirs and infections

According to a study recorded in Singapore, *A. baumannii* was found to colonize burns very early in the course of the infected patient's hospital stay (median 2 days).[57] Therefore, the importation from the community of some *A. baumannii* strains by the patient is a possibility not to be overlooked. This hypothesis is also supported by the small size of the outbreaks that occurred in this unit during the study. Indeed, the largest one included only five patients, indicating a low level of cross-transmission. Moreover, this outbreak could be traced to a patient following the Jakarta Marriott terrorist bombing, underscoring its community origin.[57]

The origin of the *A. baumannii* infections in soldiers injured in Afghanistan and Iraq is difficult to determine. The infections may have been acquired from environmental sources in the field, during evacuation from the operating theatres to the military field

hospitals, within these military field hospitals, or during treatment at hospitals after evacuation outside of the conflict area. In a study of skin and soft tissue infections due to *A. baumannii* identified among American soldiers and Iraqi nationals in a hospital ship, the mean time to diagnosis of the infection was 12.8 days, a duration that is more consistent with nosocomial acquisition.[58] Based on the absence of a correlation between the geographic location of the traumatic injury and the genotype of *A. baumannii*, Petersen et al. suggested that the environment at the time of wounding was an unlikely source of infection.[59] Concurrently, several studies showed that at the time of presentation to the hospital, higher rates of multi-resistant ABC infections or colonizations were observed in the Iraqi non-US patient population than in US patients.[60–62] The observations of Ake et al., which were recorded at the beginning of the casualty evacuation chain, suggest that multi-resistant ABC colonization or infection of host nation patients exists before their entry into deployed US military facilities. Therefore, this could at least partially reflect community carriage of these organisms.[60]

The role of a previous colonization with *A. baumannii* in the development of community-acquired infections is supported by the difference in rates of *A. baumannii* carriage identified in non-hospitalized patients (some high rates of skin carriage (4%) during the wet and warm season in Hong Kong[63] as compared to the low rates (<1%) of skin or fecal colonization described in Europe), which is consistent with the seasonal differences recorded for community-acquired *A. baumannii* pneumonia in Southeast Asia and their scarcity or their absence in Europe. Further studies are needed to determine whether lice can act as a hidden extra-human reservoir for bacteria and can promote the spread of *A. baumannii* among humans. In a broader perspective, it would be useful to study the potential role of other vectors (cockroaches, flies, etc.) in *A. baumannii* transmission.

The presence of strains belonging to the European clones I–III in animals raises concerns about the possibility of spread from humans to animals and vice versa. In addition, PCR and DNA sequencing for various genes of resistance to antibiotics demonstrated that the molecular backgrounds of resistance to aminoglycosides and quinolones and the hyperproduction of chromosomal beta-lactamases had patterns common to those described in *A. baumannii* of human origin.[52]

In conclusion, it has been demonstrated by molecular identification that *A. baumannii* is actually present outside the hospital. Several arguments are consistent with the involvement of extra-hospital reservoirs of *A. baumannii* in the occurrence of community-acquired infections. However additional studies are needed for a better estimation of the incidence of community-acquired *A. baumannii* infections and a better understanding of the mechanisms of interactions between the different potential reservoirs and humans.

Conflict of interest: No conflict of interest.

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