Epidemiol. Infect. (2017), **145**, 1292–1303. © Cambridge University Press 2017
doi:10.1017/S0950268816003411

REVIEW ARTICLE
Wohlfahrtiimonas chitiniclastica: current insights into an emerging human pathogen

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Received 18 August 2016; Final revision 26 October 2016; Accepted 21 December 2016; first published online 6 February 2017

SUMMARY

Since the first description of *Wohlfahrtiimonas chitiniclastica* in 2008, a number of well described case reports demonstrating its pathogenic role in humans have been published. Infections may be closely linked to flies, such as *Wohlfahrtia magnifica, Lucilia sericata, Chrysomya megacephala* or *Musca domestica*. These insects are potent vectors for the distribution of *W. chitiniclastica* causing local or systemic infections originating from wounds infested with fly larvae. However, other potential sources of transmission of *W. chitiniclastica* have been described such as soil or chicken meat. Infections in humans reported to date comprise wound infections, cellulitis, osteomyelitis and sepsis. This review summarizes all the literature available up to now and gives the current knowledge about this emerging human pathogen. Additionally, four patients with proven *W. chitiniclastica* infections treated at Dresden University Hospital between 2013 and 2015, are included. Special focus was placed on microbiological identification and antibiotic susceptibility testing of the pathogen.

Key words: Antibiotic treatment, diagnostics, epidemiology, MALDI-TOF MS, resistance testing, *Wohlfahrtiimonas chitiniclastica*.

INTRODUCTION

Wohlfahrtiimonas (W.) chitiniclastica was first described by Tóth *et al*. in 2008. The strain was isolated from a homogenate of larvae of the fly *Wohlfahrtia (Woh.) magnifica* [1]. These flies are ectoparasites, which are fully dependent on the host to complete their life cycle (obligate parasites). They are an important cause of myiasis in both animals and humans [2]. For the bacterial isolate Tóth and co-workers proposed the name *Wohlfahrtiimonas* gen.nov. and defined *W. chitiniclastica* as the first species [1]. In 2014 Lee *et al*. described an additional species named *W. larvae* [3].

W. chitiniclastica are Gram-negative, strictly aerobic and non-motile rods, which lack the ability to form endospores [1]. The optimal growth temperature is between 28 °C and 37 °C [1]. Both catalase and oxidase reaction are positive while tests for urease, indole and H_2S are negative [1]. A strong chitinase activity is an important characteristic. This enzyme may play a

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role in the metamorphosis of the fly suggesting a symbiotic relationship between the insect and the bacterium [1, 4]. Additionally, there is a close relationship between *W. chitiniclastica* and *Ignatzschineria larvae* (bacteria which also express chitinase and are linked to larvae as well) [5]. Up to now a few case reports have been published suggesting that *W. chitiniclastica* itself is pathogenic for humans and may be the cause of severe diseases such as bloodstream infections or osteomyelitis [4, 6, 7]. Bacteria are thought to be transmitted through fly larvae in traumatic skin lesions and/or mucosal surfaces of the host [2, 8]. In this review, we summarize the current reports on human infections caused by *W. chitiniclastica*. All available literature is included and furthermore, we present four of our own cases of human *W. chitiniclastica* infections from patients treated at Dresden University Hospital between 2013 and 2015.

SEARCH STRATEGY

Search

A literature search in PubMed, using the following key words, was performed: '*Wohlfahrtiimonas chitiniclastica*', '*Wohlfahrtiimonas chitiniclastica* AND infection', '*Wohlfahrtiimonas chitiniclastica* AND human', 'myiasis AND *Wohlfahrtia magnifica*'. All studies published since the first description of *W. chitiniclastica* in 2008 were included up to August 2016. All references cited in the relevant articles were evaluated according to their relevance for the topic of this review.

Selection

All case reports describing human infections caused or associated with *W. chitiniclastica* were included together with the first description of the bacterial strain. Furthermore, relevant articles about *Woh. magnifica* and myiasis were selected.

Inclusion of own data

In addition to the results obtained from the literature search we included data from four patients treated at the Dresden University Hospital between 2013 and 2015. In all these cases *W. chitiniclastica* was confirmed using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS; Bruker Daltonics, Germany) and sequencing of the 16S rRNA gene. It transpired that the VITEK 2 system (bioMérieux, Germany), also used in our laboratory, constantly misidentified the investigated strains, assigning different and false species names to them.

RESULTS

Cases

Eight case reports dealing with *W. chitiniclastica* infections in humans were identified by PubMed search using the search term '*Wohlfahrtiimonas chitiniclastica* AND human'. One of the reports, however, describes a fatal outcome of a *W. chitiniclastica* infection in a deer [8] in the USA, and another publication reports on a dolphin suffering from endocarditis [9]. Additionally, in a recently published case report hoof cellulitis of a cow is presented [10]. These three reports on veterinary cases did not meet our search criteria since we wanted to include only human infections. In contrast, the search criterion '*Wohlfahrtiimonas chitiniclastica* AND infections' revealed only seven cases including the above-mentioned two zoonotic cases. Using '*Wohlfahrtiimonas chitiniclastica*' as a search criterion alone, produced 12 results, including the initial description by Tóth *et al*. [1]. Furthermore, another publication about the pathogen's occurrence in the insect species *Hermetia illucens* [3] and a report on a whole genome sequence of a *W. chitiniclastica* strain [11] appeared. To date, seven case reports and in total eight cases have been published on *W. chitiniclastica* infections in humans (case numbers: 1 [4], 2 [6], 3 [12], 4 [7], 5 [13], 6 [14], 7, 8 [15]). Additionally, we report on the outcome of four patients treated at Dresden University Hospital during the last three years (cases 9–12).

Patients' characteristics

Age and gender

Five patients were female (cases 1, 3, 5, 8, 12) and seven were male (cases 2, 4, 5, 6, 8, 10, 11). The medium age was 63·75 years with a range from 26 years (case 6) to 82 years (case 3). These data are summarized in Table 1.

Social history/living conditions

Information about the patient`s social situation and living conditions were not provided for four of the 12 cases (cases 3, 4, 6, 9). Five patients were reported

https://doi.org/10.1017/S0950268816003411 Published online by Cambridge University Press

Table 1. Wohlfahrtiimonas chitiniclastica *cases reported in the literature and own patient reports*

Case no.	Age, years	Gender	Region	Underlying disease (s)/reasons for hospital admission	Social conditions	Insect larvae/ infested wounds	Reference
1	60	Female	Marseille, France	Alcoholism/fatigue	Homeless, bad hygienic state, history of alcoholism	Positive	[4]
2	70	Male	Buenos Aires, Argentina	Occlusive peripheral arteriopathy of the lower limbs/sensory impairment	Homeless, history of alcoholism and smoking	Negative	[6]
3	82	Female	Guildford, UK	Recurrent falls, hypertension, chronic kidney disease, ischemic heart disease, hypercholesteraemia, osteoarthritis/found unconscious	NP	Positive	[12]
4	64	Male	Tartu, Estonia	Gangrene in distal parts of the legs and amputation of the feet/ admission due to an accident	Alcoholism	NP	[7]
5	43	Male	Trivandrum, India	Diabetes, deep ulcer, cellulitis, gangrene/progressing gangrenous changes	Alcoholism and smoking	NP	[13]
6	26	Male	Salt Lake City, USA	Morbid obesity, lymphoedema, cellulitis/progressive ulceral disease	NP	NP	[14]
7	72	Male	Hawaii, USA	Stroke and deafness/found unconscious	Poor hygienic conditions	Positive	[15]
8	69	Female	Hawaii, USA	Ruptured cerebral aneurysm and right hemiparesis/sacral pain and painful urination	Homeless, poor hygienic conditions	Negative	[15]
9	79	Male	Dresden, Germany	Diabetes mellitus, coronary heart disease, chronic renal failure, venous insufficiency/progressive ulceral disease	Normal social conditions	Negative	This publication (DSM 100375)
10	43	Male	Dresden, Germany	Alcoholism/treatment of alcohol withdrawal syndrome, exclusion of tuberculosis	Homeless, alcoholism, ulceral disease	Negative	This publication (DSM 100374)
11	78	Female	Dresden, Germany	Severe obesity, chronic venous insufficiency, arterial hypertension, chronic heart failure NYHA II/progressive ulceral disease	Difficult social conditions	Negative	This publication (DSM 100676)
12	71	Male	Dresden, Germany	Deep vein thrombosis, leg ulcers/ speech disorder as consequence of a tablet and alcohol intoxication in suicidal intent	NP	Negative	This publication (DSM 100917)

NP, Not provided.

to be homeless (cases 1, 2, 5, 8, 10), one patient (case 11) was living alone under difficult social conditions (not further specified), one patient (case 9) lived under normal social conditions (not further specified) and one patient (case 11) lived under poor hygienic conditions (not further specified). Alcohol abuse was reported in four of the 12 cases (cases 1, 2, 5, 10). Two patients were smokers (cases 2 and 5). No information was given in six cases (cases 3, 4, 6–8, 12). These data are summarized in Table 1.

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Underlying diseases

No information about a basic disease was provided for three patients (cases 1, 4, 10). Five patients (cases 2, 3, 9, 11, 12) had circulatory diseases such as chronic venous insufficiency, ischaemic heart disease, arteriopathy including coronary artery disease or arterial hypertension. Two patients (cases 6 and 11) were reported to be obese and two patients (cases 5 and 9) were known to suffer from diabetes. Two patients (cases 3 and 9) additionally had renal dysfunction. One patient (case 7) was reported with a stroke and one patient (case 8) with a hemiparesis due to a ruptured cerebral aneurysm. A comprehensive summary is given in Table 1.

Infections reported in association with W. chitiniclastica

In four cases bloodstream infections caused by *W. chitiniclastica* were reported (cases 1–3, 7). In case 7 *E. coli* was detected in addition to *W. chitiniclastica*. One patient (case 4) was admitted to hospital due to a necrotizing skin infection. Two patients (cases 5 and 6) suffered from cellulitis. Case 5 additionally suffered from a deep ulcer which progressed to osteomyelitis. Five patients (cases 8–12) suffered from infected ulcers. These data are summarized in Table 2.

Monomicrobial vs. *polymicrobial infection*

In four cases *W. chitiniclastica* was the only bacterium which could be identified and in eight cases at least one additional bacterium could be identified or *W. chitiniclastica* was part of a polymicrobial spectrum. In four cases, *W. chitiniclastica* was isolated from blood cultures, in one case the samples were taken during surgery and seven samples were taken from skin-related diseases (e.g. ulcers). In cases 1, 2 and 5 *W. chitiniclastica* was the only bacterium isolated and in case 3 the organism was isolated from primary blood cultures taken upon the patient's admission to hospital. However, further cultures grew in this patient: *Proteus mirabilis, Providencia rettgeri* and *Staphylococcus aureus*. Eight cases (4, 6–12) suffered from a polymicrobial infection where *W. chitiniclastica* was isolated together with other sepsis-causing pathogens. In case 4 *Myroides odoratimimus* was additionally detected, in case 6 *P. vulgaris, Klebsiella pneumoniae, Acinetobacter lwoffii* and *S. aureus* were identified, in case 7 both *W. chitiniclastica* and *Escherichia coli* were detected in the blood culture, in case 8 *W. chitiniclastica* was detected together with *S. aureus, Aeromonas* spp., *Streptococcus simulans* and *Bacteroides fragilis*. In case 9, *E. coli* and bacteria of the anaerobic skin flora (without further characterization) were detected. Blood cultures of case 10 grew skin flora together with *P. mirabilis*. In case 11 normal aerobic skin flora, *Proteus vulgaris, S. aureus, Morganella morganii, Serratia marcescens* and *W. chitiniclastica* were detected, and in case 12 normal aerobic skin flora, *P. mirabilis, Pseudomonas aeruginosa* and *Providencia stuartii* were identified (Table 2).

Antibiotic treatment and patient outcome

Nine of 12 patients received antibiotic treatment, mostly β-lactams (e.g. penicillins and cephalosporins) and quinolones. Treatment strategy was changed in five patients (second-line antibiotics). Two out of 12 patients died. Case 1 was effectively treated with 2 g/d ceftriaxone. Case 2 received a combination of 400 mg ciprofloxacin every 12 h and 1·5 g ampicillin/sulbactam every 6 h. For case 3, 750 mg cefuroxime and 500 mg metronidazole were administered 3 times a day and 500 mg clarithromycin twice a day. The therapy was changed to 500 mg flucloxacillin four times a day. The patient did not survive. Case 4 received amoxicillin/clavulanate for 8 days and the outcome was positive. There is no information about antibiotic treatment for case 5. Case 6 received a 10-day course of cefpodoxime. Case 7 was given piperacillin/tazobactam, clindamycin and vancomycin. This patient died 1 day after admission. Case 8 initially received ceftaroline which was changed later to meropenem. For case 9 a 4-day antibiotic treatment with 500 mg levofloxacin twice a day and 600 mg clindamycin three times a day was performed. Cases 10–12 did not receive any antibiotic treatment. These data are summarized in Table 2.

Geographical distribution and epidemiological aspects

Cases 1 (Marseille, France), 3 (Guilford, UK), 4 (Tartu, Estonia), 9–12 (Dresden, Germany) were reported from European countries. Case 2 was reported from Argentina (Buenos Aires) and case 5 from India (Trivandrum). Three cases were reported form North America (cases 6–8). Table 1 summarizes the geographical distribution of *W. chitiniclastica* isolates presented in this review.

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Table 2. *Overview of strain sampling, methods of identification, antimicrobial treatment, patients' outcome and case rating*

Case no. [ref.]	Source	Bacteria identified	Methods of identification	Antibiotics, 1st line	Antibiotics, 2nd line	Outcome	Rating
1 [4]	Blood culture	*W. chitiniclastica*	16S rRNA gene sequencing (homology: NP)	Ceftriaxone 2 g/d	NA	Survived	Invasive infection caused by *W. chitiniclastica*
2 [6]	Blood culture	*W. chitiniclastica*	API 20 NE misidentification of *W. chitiniclastica* as *B. diminuta* or *O. urethralis* 16S rRNA gene sequencing (homology: 99%)	Ciprofloxacin (400 mg, 2 x/d) and ampicillin (1·5 g, 4 x/d)	Ceftazidime and amikacin	Fatal	Invasive infection caused by *W. chitiniclastica*
3 [12]	Blood culture	*W. chitiniclastica*	MALDI-TOF MS (scores: 2·264, 2·200) 16S rRNA gene sequencing (homology: NP)	Cefuroxime (750 mg, 3 x/d) metronidazole (500 mg, 2 x/d) clarithromycin (500 mg, 2 x/d, for 7 days), topical fusidic acid and chloramphenicol	Flucoxacillin (500 mg, 4 x/d, p.o.)	Surived	Invasive infection caused by *W. chitiniclastica*
4 [7]	Bone samples collected during surgery (resection site)	*W. chitiniclastica* *M. odoratimimus*	VITEK 2 misidentification of *W. chitiniclastica* as *C. testosteroni* (96%) MALDI-TOF MS (scores: 2·350, 2·389, 2·259) 16S rRNA gene sequencing (homology: 99%)	Amoxicillin/clavulanate for 8 days	NA	Survived	Polymicrobial infection, (unclear if *W. chitiniclastica* was really the causative agent)
5 [13]	Swabs from deep site of ulcer	*W. chitiniclastica*	MALDI-TOF MS (score: NP) 16S rRNA gene sequencing (homology: ND)	Cefoperaxone/sulbactam (1·5 g, 2 x/d)	Cefpodoxime (2 x/d, p.o. for 2 weeks)	Survived	Infection caused by *W. chitiniclastica*
6 [14]	Swab from the right leg	*W. chitiniclastica* *P. vulgaris* *K. pneumoniae* *S. aureus*	VITEK 2 misidentification of *W. chitiniclastica* as *A. lwoffii* (96%) MALDI-TOF MS (scores: 2·253, 2·296, 2·229) 16S rRNA gene sequencing (homology: NP)	Cefpodoxime (for 10 days)	NA	Survived	It was unresolved if *W. chitiniclastica* was the causative agent of the disease

Table 2 (*cont.*)

Case no. [ref.]	Source	Bacteria identified	Methods of identification	Antibiotics, 1st line	Antibiotics, 2nd line	Outcome	Rating
7 [15]	Blood culture	*W. chitiniclastica* *E. coli*	16S rRNA gene sequencing (homology: 100%)	Piperacillin/tazobactam, clindamycin, vancomycin	NA	Fatal	Blood culture proved *W. chitiniclastica* to be relevant
8 [15]	Swabs from deep wound	*W. chitiniclastica* *S. aureus* *Aeromonas* spp. *S. simulans,* *B. fragilis*	16S rRNA gene sequencing (homology: 100%)	Ceftaroline fosamil	Meropenem	Survived	Clinical relevance of *W. chitiniclastica* could not be determined
9 This publication (DSM 100375)	Swabs from ulcer of the left leg	*W. chitiniclastica* *E. coli*	VITEK 2 misidentification of *W. chitiniclastica* as *A. lwoffii* (96%) MALDI-TOF MS (score: 2·262) 16S rRNA gene sequencing (homology: 100%)	Cefuroxime (500 mg, 2 x/d for 5 days)	Levofloxacin (500 mg, 2 x/d for 9 days), clindamycin (600 mg, 3 x/d for 4 days)	Survived	Colonization, no signs of infection or inflammation
10 This publication (DSM 100374)	Swabs from ulcers	*W. chitiniclastica* *P. mirabilis*	VITEK 2 misidentification of *W. chitiniclastica* as *A. Iwoffii* (96%) MALDI-TOF MS (score: 2·441) 16S rRNA gene sequencing (homology: 100%)	No antibiotic treatment	NA	Survived	Colonization, no signs of infection or inflammation
11 This publication (DSM 100676)	Swabs from ulcers	*W. chitiniclastica* *P. mirabilis* *S. aureus* *S. marcescens* *M. morganii*	VITEK 2 misidentification of *W. chitiniclastica* as *R. radiobacter* (99%) MALDI-TOF MS (score: 2·019) 16S rRNA gene sequencing (homology: 100%)	No antibiotic treatment	NA	Survived	Colonization, no signs of infection or inflammation

Table 2 (*cont.*)

Case no. [ref.]	Source	Bacteria identified	Methods of identification	Antibiotics, 1st line	Antibiotics, 2nd line	Outcome	Rating
12 This publication (DSM 100917)	Swabs from leg ulcers	*W. chitiniclastica* *P. mirabilis* *P. stuartii* *P. aeruginosa*	VITEK 2 misidentification of *W. chitiniclastica* as *A. lwoffii* (96%) or *C. testosteroni* (97%) MALDI-TOF MS (score: 2·396) 16S rRNA gene sequencing (homology: 100%)	No antibiotic treatment	NA	Survived	It was unresolved if *W. chitiniclastica* was the causative agent of the disease

NP, Not provided; NA, not administered.

Methods of identification

MALDI-TOF MS

W. chitiniclastica was successfully identified by MALDI-TOF MS [16] in cases 3 (scores 2·264 and 2·200), 4 (scores 2·350, 2·389 and 2·259), 5 (score not provided), 6 (scores 2·253, 2·296 and 2·229), 9 (score 2·262), 10 (2·441), 11 (score 2·019) and 12 (score 2·396). Figure 1 shows the spectra of the *W. chitiniclastica*-type strain (DSM 18708) and of the four strains isolated at our hospital (DSM 100375, DSM 100374, DSM 100676, DSM 100917). The MALDI-TOF MS scores of all strains are summarized in Table 2. Scores show the reliability of the species identification. Scores above 2·300 represent a highly probable species identification, a score between 2·000 and 2·300 indicates a secure species identification, a score between 1·700 and 2·000 represents a probable species identification and a score below 1·700 is not reliable [16].

16S rDNA sequencing

W. chitiniclastica was correctly identified by 16S rRNA gene sequencing in cases 1 (homology data not provided), 2 (99% homology), 3 (homology data not provided), 4 (99% homology), 5 (homology data not provided), 6 (homology data not provided), 7 (100% homology), 8 (100% homology), 9 (100% homology), 10 (100% homology), 11 (100% homology) and 12 (100% homology). The data are summarized in Table 2.

Biochemical testing using VITEK 2

In cases 1 and 5 phenotypic analysis failed to identify the bacteria. However, the tests applied were not further described. In case 2 API 20 NE identified the strain as *Brevundimonas diminuta* or *Oligella urethralis* with a low probability of 88·5%. In case 4 the identification utilizing VITEK 2 revealed *Comamonas testosteroni* with a probability of 99%. However, 16S rDNA sequencing showed a homology to *C. testosterone*-type strain DSM 50244 with only 82%. In the following three cases, using VITEK 2, *W. chitiniclastica* was misidentified as *A. lwoffii*, i.e. cases 6 (probability 96%), 9 (probability 99%) and 10 (probability 96%). The biochemical reactions detected by VITEK 2, using the GN card, are presented in Supplementary Table S1. The substrates on the GN card are listed in table 7 of the *Encyclopedia of Rapid Microbiological Methods* [17]. In addition to the *W. chitiniclastica*-type strain

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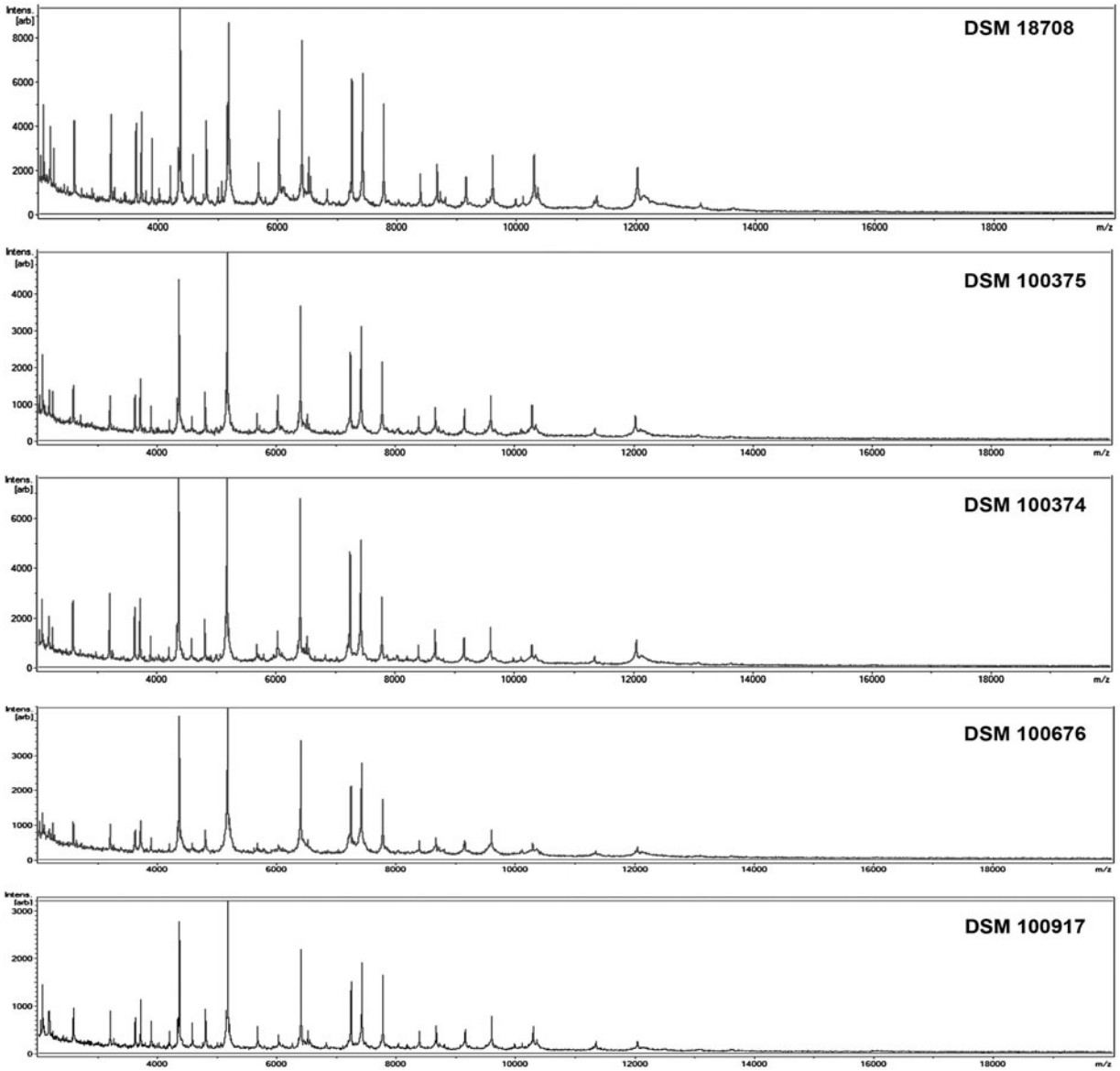

Fig. 1. MALDI-TOF MS spectra of the *W. chitiniclastica*-type strain and our isolates. Shown are the mass spectra of the *W. chitiniclastica*-type strain (DSM 18708) and the four strains isolated at Dresden University Hospital: DSM 100375 (case 9); DSM 100374 (case 10); DSM 100676 (case 11); DSM 100917 (case 12).

(DSM 18708), results from the four isolates collected at Dresden University Hospital (DSM 100374, DSM 100375, DSM 100676, DSM 100917) are included.

Antimicrobial susceptibility testing

Among the group of β-lactam antibiotics, *W. chitiniclastica* was susceptible to penicillins, cephalosporins and carbapenems (cases 1, 2, 4–12), to quinolones (cases 1, 2, 5–12), aminoglycosides (cases 1, 2, 4–12), trimethoprim/sulfamethoxazole (cases 1, 2, 4–10), colistin (case 4) or tetracycline (cases 2, 7, 8). No resistance data were provided for case 3. Testing was performed using E-test strips (BESTBION, Germany) according to the EUCAST guidelines for 2016.

In agreement with published data the type strain DSM 18708 and our isolates were also susceptible to β-lactam antibiotics, to quinolones and to tigecycline. The minimum inhibitory concentration (MIC) values are given in Table 3. Testing was performed according the guidelines using non-species-related breakpoints of the European Committee on Antimicrobial Susceptibility Testing (EUCAST; http://www.eucast.org/). Additionally, we tested our strains against trimethoprim/sulfamethoxazole,

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fosfomycin, colistin, gentamicin, amikacin, erythromycin and azithromycin (Table 3). However, EUCAST non-species-related breakpoints are not available for these antibiotics. MIC values ranged from 0·032 μg/ml to 4 μg/ml, except for fosfomycin, which revealed MIC values >1024 μg/ml in all isolates presented in Table 3.

DISCUSSION

W. chitiniclastica was first isolated from samples of the obligate parasitic fly *Woh. magnifica* in 2008 [1, 2, 11]. The sequenced *W. chitiniclastica* strain SH04 has a genome size of 2·12 Mb, with an average G/C content of 43·48%. It contains 2006 open reading frames [11]. Further investigations revealed a high similarity to *I. larvae*, another bacterial species which is also commonly found in flies [1, 5]. The transmission of these bacteria therefore seems to be closely linked to these insects. Female flies of the species *Woh. magnifica* deposit eggs in traumatic skin lesions or on mucosal surfaces of the affected host [18]. The developed larvae feed within the tissue leading to significant destruction which may even result in a fatal outcome [19]. After 5–7 days the larvae fall to the ground and pupate. At this stage of the insect's life cycle the enzyme chitinase may play an important role by supporting the insects in their pupation [20].

In addition to the close link of *W. chitiniclastica* to certain flies, the bacteria have recently been detected in arsenic-affected soils from Bangladesh [21]. Furthermore, Matos and co-workers found *W. chitiniclastica* in multiple samples of chicken meat purchased in Brazilian supermarkets [22]. The occurrence of this bacterium indicates poor sanitary conditions and is contrary to good manufacturing practice [22]. Because the fly *Woh. magnifica* does not occur in South America another route of infection via *C. megacephala* as depositor of *W. chitiniclastica* was suggested.

To date, four well documented cases (cases 1–4) of invasive/bloodstream infections caused by *W. chitiniclastica* have been reported [4, 6, 7, 12]. It is probable that the bacteria are transmitted to the tissue of the host by larvae and may reach the bloodstream while being distributed in the tissue. In these case descriptions, *W. chitiniclastica* was the only bacterium isolated. One patient died due to septic shock caused by *W. chitiniclastica* [6].

However, in cases 5, 6 and 9–12 *W. chitiniclastica* was part of a polymicrobial spectrum and therefore it is impossible to clarify if *W. chitiniclastica* was the sole cause of infection (see references in Table 2). Mouse infection experiments published recently by Qi *et al*. revealed *W. chitiniclastica* being pathogenic to mice only at large doses, i.e. 10^9–10^{10} colony-forming units per intraperitoneal injection [10]. In cases 7 and 8, published recently by Nogi *et al*., the authors report on two patients with soft tissue infection and sepsis [15]. In both cases *W. chitiniclastica* was not the sole cause of the disease [15]. In case 7 *E. coli* was additionally identified and in case 8 *W. chitiniclastica* was part of a large polymicrobial spectrum consisting of aerobic and anaerobic pathogens [15].

W. chitiniclastica patients, their underlying diseases and cause of hospitalization are listed in Table 1. Most patients suffered from diseases affecting the skin such as ulcers (cases 9–11 [13–15]), wounds (cases 7 and 8 [15]), gangrene (cases 4 and 5 [7, 13]) or cellulitis (case 5 [13]). Patients suffered also from impairments of the cardiovascular system such as occlusive arteriopathy (case 2 [6]), hypertension (cases 3 [12] and 11), different heart diseases (cases 3 [12], 9 and 11), chronic venous insufficiency (cases 9 and 11) or deep vein thrombosis (case 12). The two patients reported by Nogi *et al*. (cases 7 and 8) suffered from neurological disorders, stroke and ruptured cerebral aneurysm [15]. Conditions leading to an increased probability of maggot infestation can be considered a risk factor for *W. chitiniclastica* infections. Cases 1, 2, 8 [4, 6, 15] and 10 were reported to be homeless, thus being at higher risk of being affected by myiasis. Case 3, who exhibited multiple maggots and insect larvae, was found unconscious in her garden after collapsing 72–96 h earlier [12]. Since many (especially vascular) diseases are typical for older patients it is not surprising that the mean age of *W. chitiniclastica* patients was found to be 63·75 years. Gender, however, does not seem to play a role.

The cases described here are reports from different parts of the world. At the time of writing the fly *Woh. magnifica* is found in continental Europe and the Middle East [2] but is unknown in the UK [4, 12], South America [6], North America [14] and Asia [13]. However, it is likely that the bacteria can be transmitted by different insects. For instance, as described in case 3, the common green bottle fly *Lucilia sericata* was identified as source of a *W. chitiniclastica* infection [12]. Furthermore, *W. chitiniclastica* could be isolated from the flies *Chrysomya megacephala* and *Musca domestica* [7, 23].

https://doi.org/10.1017/S0950268816003411 Published online by Cambridge University Press

Table 3. *Antibiotic susceptibility of the* Wohlfahrtiimonas chitiniclastica*-type strain DSM 18708 and the isolates from Dresden University Hospital*

Antibiotic	MIC DSM 18708	Interpretation EUCAST	MIC DSM 100374	Interpretation EUCAST	MIC DSM 100375	Interpretation EUCAST	MIC DSM 100676	Interpretation EUCAST	MIC DSM 100917	Interpretation EUCAST
Ampicillin	0·032	S	0·064	S	0·064	S	0·064	S	0·064	S
Piperacillin/ tazobactam	0·032	S	0·125	S	0·064	S	0·032	S	0·125	S
Ceftazidime	0·016	S	0·032	S	0·064	S	0·064	S	0·064	S
Cefepime	0·064	S	0·016	S	0·032	S	0·064	S	0·016	S
Aztreonam	0·016	S	0·016	S	0·016	S	0·032	S	0·016	S
Imipenem	0·125	S	0·125	S	0·125	S	0·016	S	0·125	S
Meropenem	0·004	S	0·008	S	0·004	S	0·125	S	0·004	S
Ciprofloxacin	0·032	S	0·016	S	0·016	S	0·016	S	0·004	S
Moxifloxacin	0·125	S	0·008	S	0·125	S	0·032	S	0·032	S
Tigecycline	0·032	S	0·125	S	0·125	S	0·125	S	0·125	S
Trimethoprim/ sulfamethozxazole	0·125	IE	0·125	IE	0·125	IE	0·25	IE	0·125	IE
Fosfomycin	1024	IE	1024	IE	1024	IE	1024	IE	1024	IE
Colistin	1	IE	1	IE	1	IE	1	IE	1	IE
Gentamicin	0·5	IE	1	IE	0·5	IE	1	IE	1	IE
Amikacin	0·5	IE	1	IE	1	IE	1	IE	1	IE
Erythromycin	2	IE	2	IE	4	IE	2	IE	2	IE
Azithromycin	0·5	IE	1	IE	0·5	IE	0·5	IE	1	IE

MIC, Minimum inhibitory concentration; S, susceptible; IE, insufficient evidence; EUCAST, European Committee on Antimicrobial Susceptibility Testing [breakpoint tables for interpretation of MICs and zone diameters, version 6.0, 2016 (http://www.eucast.org/fileadmin/src/media/PDFs/EUCAST_files/Breakpoint_tables/v_6.0_Breakpoint_table.pdf)].

Based on the current literature and our own experience biochemical approaches such as API (Analyical Profile Index, bioMérieux, Germany) or VITEK 2 (bioMérieux) to identify *W. chitiniclastica* lead to wrong and misleading results. The biochemical profiles, obtained by VITEK 2, of the four isolates from Dresden University Hospital and two type strains are given in Supplementary Table S1. Almuzara *et al.* used the API 20 NE system which resulted in *B. diminuta* or *O. urethralis* [6]. Analyses using the VITEK 2 system identified the bacterium as *C. testosteroni* with an excellent result (99% identitiy) or as *A. lwoffii* (96–99% identity) (cases 6–8) [14, 15]. De Dios *et al.* compared the biochemical profiles of *A. lwoffii* and *W. chitiniclastica* using both VITEK 2 and API 20 NE. They revealed that both bacteria showed an identical profile except for oxidase activity (*A. lwoffii* is oxidase negative *and W. chitiniclastica* is oxidase positive) [14]. 16S rRNA gene sequencing and MALDI-TOF MS, however, gave reproducible and reliable identification of *W. chitiniclastica* [7, 12–15]. We have described and compared both methods in detail recently [16]. MALDI-TOF MS, however, has the advantage of speed.

Antimicrobial susceptibility testing was performed in 11 out of the 12 cases and revealed that *W. chitiniclastica* is susceptible to β-lactam antibiotics, quinolones, aminoglycosides, colistin, trimethoprim/sulfamethoxazole and tetracyclin as reported in the literature [4, 6, 7, 13–15] and measured in our isolates given in Table 3. According to our investigations the MIC value determined for fosfomycin is very high (Table 3). This observation is in accord with results from Matos and co-workers who also found MIC values of >32 μg/ml in the samples they investigated [22]. These results suggest that *W. chitiniclastica* is intrinsically resistant to fosfomycin. In the same way it can be assumed that *W. chitiniclastica* is (due to the low MIC values determined *in vitro*) susceptible to tigecycline (Table 3). Most patients received an antimicrobial treatment using β-lactam antibiotics with a combination of quinolones or aminoglycosides. All patients except two [6, 15] survived. The fatal outcomes, however, may be explained by these patients poor condition upon admission to the hospital. Additionally, for case 7, described by Nogi *et al.*, it remains unclear if *W. chitiniclastica* or *E. coli* were responsible for the patient's septic condition [15]. Table 3 shows the antimicrobial profiles measured for the *W. chitiniclastica*-type strain (DSM 18708) and the four isolates from our hospital (DSM 100374, DSM 100375, DSM 100676, DSM 100917).

In conclusion, *W. chitiniclastica* is a recently described bacterial pathogen whose appearance is linked to certain flies. These insects carry and distribute this bacterium to a host. Since biochemistry-based approaches fail to correctly identify this bacterium MALDI-TOF MS or 16S rRNA gene sequencing are required for confirmation. Since *W. chitiniclastica* is susceptible to a wide range of antibiotics, treatment with β-lactam antibiotics alone or combined with quinolones or aminoglycosides may successfully be administered. Due to the few data currently available, more epidemiological research and an awareness that this bacterium can cause serious infections is needed. For rapid, economic and reliable detection MALDI-TOF MS will be the right diagnostic tool [16].

SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper visit https://doi.org/10.1017/S0950268816003411.

ACKNOWLEDGEMENTS

The authors did not receive funding for this work. We thank Dr. Bärbel Fösel and PD Dr. Sabine Gronow for including our strains in the DSMZ Open collection.

DECLARATION OF INTEREST

None.

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