CONTAMINATION OF BURN WOUNDS BY ACHROMOBACTER XYLOSOXIDANS FOLLOWED BY SEVERE INFECTION: 10-YEAR ANALYSIS OF A BURN UNIT POPULATION

CONTAMINATION DES ZONES BRÛLÉES PAR ACHROMOBACTER XYLOSOXIDANS, ENTRAÎNANT UNE INFECTION SÉVÈRE: ANALYSE SUR 10 ANS

Schulz A.,✉ Perbix W., Fuchs P.C., Seyhan H., Schiefer J.L.

Department of Plastic Surgery, Hand Surgery, Burn Center, University of Witten/Herdecke, Cologne-Merheim Medical Center (CMMC), Cologne, Germany

SUMMARY. Gram-negative infections predominate in burn surgery. Until recently, *Achromobacter* species were described as sepsis-causing bacteria in immunocompromised patients only. Severe infections associated with *Achromobacter* species in burn patients have been rarely reported. We retrospectively analyzed all burn patients in our database, who were treated at the Intensive Care Burn Unit (ICBU) of the Cologne Merheim Burn Centre from January 2006 to December 2015, focusing on contamination and infection by *Achromobacter* species. We identified 20 patients with burns contaminated by *Achromobacter* species within the 10-year study period. Four of these patients showed signs of infection concomitant with detection of *Achromobacter* species. Despite receiving complex antibiotic therapy based on antibiogram and resistogram typing, 3 of these patients, who had extensive burns, developed severe sepsis. Two patients ultimately died of multiple organ failure. In 1 case, *Achromobacter xylosoxidans* was the only isolate detected from the swabs and blood samples taken during the last stage of sepsis. *Achromobacter xylosoxidans* contamination of wounds of severely burned immunocompromised patients can lead to systemic lethal infection. Close monitoring of burn wounds for contamination by *Achromobacter xylosoxidans* is essential, and appropriate therapy must be administered as soon as possible.

Keywords: Achromobacter species, severe burn injury, sepsis, gram-negative infections

RÉSUMÉ. *Les infections à Gram négatif prédominent chez les brûlés. Jusqu'à une période récente, Achromobacter xylosoxidans (Ax) n'était décrit comme pathogène que chez les patients immunodéprimés. Les infections sévères à Achromobacter n'ont été que rarement décrites chez les brûlés. Nous avons rétrospectivement revu tous les patients hospitalisés dans l'unité de réanimation du centre de traitement des brûlés Merheim de Cologne entre janvier 2006 et décembre 2015, à la recherche d'une infection ou d'une contamination à Achromobacter et avons trouvé 20 patients. Quatre d'entre eux présentaient des signes de sepsis dont trois, sévèrement brûlés, un sepsis sévère malgré une antibiothérapie adaptée à l'antibiogramme, deux en étant décédés dans un tableau de défaillance multiviscérale. Dans un cas, Ax était la seule bactérie isolée de prélèvements cutané et sanguins, prélevés en phase tardive du sepsis. La contamination cutanée par Ax, chez des patients immuodéprimés car sévèrement brûlés, peut conduire à un sepsis létal. La surveillance rapprochée de l'écologie de la brûlure et une antibiothérapie adaptée précoce sont donc essentielles.*

Mots-clés*: Achromobacter, brûlure sévère, sepsis, infection à gram négatif*

Introduction

Gram-negative infections predominate in burn surgery, and it is widely accepted that gram-negative bacteria may cause severe and life-threatening infections in hospitalized immunocompromised patients.[1-4] The gram-negative bacterium, *Achromobacter xylosoxidans*, belonging to the family *Alcaligenaceae* in the order Burkholderiales, is an aerobic, non-fermenting, rod-shaped bacterium that is found in soil and water.[5] Yabuuchi and Ohyama first described a case of chronic otitis media caused by *Achromobacter xylosoxidans* in 1971.[6] According to the classification by Euzéby, the genus contains 6 species.[5,7-9] *Achromobacter xylosoxidans* is generally known to be of low intrinsic pathogenicity for humans. Reports on infections with *Achromobacte*r species mainly describe seriously ill immunocompromised patients with malignancy, recipients of liver and bone marrow transplants, and patients with neutropenia, diabetes mellitus, renal failure, cystic fibrosis, HIV infection and IgM deficiency.[1-4] Life-threatening septic clinical courses have also been reported for nonbacteremic patients with wounds contaminated by *Achromobacter xylosoxidans*.[10]

In hospitals, *Achromobacter* species are common contaminants of "wet" environmental areas in the surgical ward.[11] They have been mainly isolated from respirators, incubators and disinfectants.[12,13] Because strains are commonly multidrug resistant, rigorous cleaning and disinfection measures are essential for pre-

✉Corresponding author: Alexandra Schulz MD, Department of Plastic Surgery, Hand Surgery, Burn Center, University of Witten/Herdecke, Cologne-Merheim Medical Center (CMMC), Ostmerheimer Strasse 200, 51109 Cologne, Germany. Tel.: +49 211 8907 18519; fax: +49 211 8907 8314; email: schulza@kliniken-koeln.de
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Author	Year	Title	Type of study	Cases	Location
Azzopardi EA et al.	2014	Gram negative wound infection in hospitalised adult burn patients	systematic review and meta-analysis		UK
Azzopardi EA et al.	2011	Emerging gram-negative infections in burn wounds	systematic review and meta-analysis		UK
Fujioka M et al.	2008	Alcaligenes xylosoxidans cholecystitis and meningitis acquired during bathing procedures in a burn unit	case report	2	Japan
Lin Y-H et al.	1997	Comparison of polymerase chain reaction and pulsed-field gel electrophoresis for the epidemiological typing of Alcaligenes xylosoxidans subsp. xylosoxidans in a burn unit	retrospective clinical study	15	Taiwan
Ng ZY et al.	2014	Resolution of concomitant Achromobacter xylosoxidans burn wound infection without adjustment of antimicrobial therapy	case report	1	Singapore
Vu-Thien H et al.	1998	Investigation of an outbreak of wound infections due to Alcaligenes xylosoxidans transmitted by chlorhexidine in a burns unit	observational study	6	France
Hummel RP et al.	1977	Antibiotic resistance transfer from nonpathogenic to pathogenic bacteria	animal model		USA

Fig. 1 - Current clinical publications on *Achromobacter* species in burn patients.

venting infections.[3,4] Reports of burn patients with wounds contaminated or infected by *Achromobacter xylosoxidans* are rare in the literature (*Fig. 1*).[12,14-17] The key aim of this study was to identify characteristics of burn injuries that supported contamination or infection by *Achromobacter* species in burn patients.

Materials and methods

We retrospectively analyzed all patients with thermal, chemical or electrical burns or scalding, who were treated at the intensive care burn unit (ICBU) of the Cologne-Merheim Medical Center, University of Witten/Herdecke between 2006 and 2015, for contamination with *Achromobacter* species. Data on demographics, burn injury pattern, course of disease and further treatment were compared to data from our general burn patient population.

Methodology

Comprehensive data on the cause of the burn, medical history, and treatment before and during hospitalization were routinely recorded for each patient. The course of contamination and infection with *Achromobacter* species and treatments of affected patients were analyzed in detail, based on these data. Findings from the following examinations were collected from the database: (a) swab cultures of the perineal, urethral, tracheal and nasal areas and from burn wounds on the day of ICBU admission and at short, regular intervals during the patient's stay; (b) swab cultures of superficial and deep wounds taken at each surgical procedure; (c) vital parameters; (d) results of routine laboratory examinations, (e) cultures of blood specimens obtained when there were signs of infection, including fever. Vital parameters were monitored and recorded by electronic devices. Laboratory biochemical testing that included markers of inflammation and coagulation status were performed and electronically recorded several times daily.

Surgical treatment

Burned tissue was surgically removed during the early stages of the injury, and defects were covered in accordance with the standard-of-care (SOC) protocols of the Cologne Merheim Burn Centre, which are based on international practice guidelines of burn care.[18,19] Once the patient was admitted, burn wounds were mechanically cleaned by removing blisters, superficial keratin layers and eschar. The depth of the burn was then assessed visually. For patients with a circumferential deep dermal burn injury we immediately performed escharotomy. Deep dermal and full thickness burns were treated by tangential excision and grafting, either on the day of admission or starting on the third day after burn injury.

Microbiology

Achromobacter species were identified using standard laboratory procedures. Swab cultures of the following areas were performed routinely on the day of admission and 3 times a week at regular intervals during each patient's stay in the ICBU: perineal, urethral, tracheal and nasal areas, and from burn wounds. Furthermore, swab cultures from superficial and deep wounds were performed at each surgical procedure. Cultures were examined by a clinical microbiologist. According to standard practice, antibiotic therapy was adjusted according to antibiogram and resistogram typing.

Definition of clinical terms

In this study, a patient was considered contaminated by *Achromobacter* species if 2 or more swab cultures or 2 blood cultures were positive for *Achromobacter* species. Nosocomial bloodstream infection, which was based on the criteria of the Centers for Disease Control and Prevention (CDC), was considered to be an infection occurring 48 hours or longer post hospitalization.[20] The definition of *Achromobacter* infection was based on the detection of a threshold number of organisms.[21,22] *Achromobacter* infection of a burn wound was identified based on the criteria of the CDC. *Achromobacter* infection of a burn wound manifested with a change in the appearance or character of the burn wound and was based on the identification of an *Achromobacter* isolate from a blood culture or the result of a

nonculture-based microbiological testing method (CDC/NHSN Surveillance Definitions for Specific Types of Infections 2016). Infection with sepsis was characterized by systemic inflammatory response syndrome associated with a documented infection. Sepsis may lead to organ dysfunction or hypotension.[23] In this study, sepsis and organ failure were identified based on the consensus definitions from the Society of Critical Care Medicine.[23,24]

Disinfection measures

The identification of *Achromobacter* species from any routine swab or blood culture was reported to our hospital's department of infection control. The methods used for disinfection were those of the standard hygiene protocol of the ICBU. Large surface areas (e.g. floor, bed, wall) were disinfected by exposure to Incidin® Plus (26 g glucoprotamin per 100 g solution; Ecolab Deutschland GmbH, Monheim am Rhein, Germany) for 60 min. Small surface areas (e.g. dressing trolley, bedside cabinet) were disinfected by exposure to Teralin® liquid (25 g ethanol [94%] and 35 g 1-propanol per 100 g solution; Schülke&Mayr GmbH, Norderstedt, Germany) for 5 min. Staff members' hands and skin were disinfected with Sterillium® classic pure (45 g 2-propanol, 30 g 1-propanol, 0.2 g mecetronium ethylsulfate per 100 g solution; BODE Chemie GmbH, Hamburg, Germany). Wound surfaces were routinely cleaned with Braunol (7.5 g povidone iodine per 100 g solution; B. Braun Melsungen AG, Melsungen, Germany). Octenidol mouthwash (Octenidin; Schülke&Mayr GmbH, Germany) was used for oral care. Kodan® spray was used for disinfection (10 g 1-propanol, 45 g 2-propanol, 0.2 g 2-phenylphenol per 100 g solution; Schülke&Mayr GmbH, Norderstedt, Germany) during minor procedures such as changing a catheter or sampling blood.

Statistical analysis

All data were collected retrospectively from our database. Microsoft Excel (2013, Microsoft, USA) and SPSS (IBM, USA) Version 21 were used to manage data, design the tables and perform calculations. Data from previous analyses were checked for completeness and accuracy. Nonparametric data comparisons were subjected to the Mann-Whitney U test. Frequencies were analyzed by the chi-square test.

Results

This study identified 685 patients with major chemical, electrical or thermal burns or scalding, who were admitted to our ICBU from January 2006 until December 2015 and had complete data. All major and minor burn wounds were classified according to the guidelines of the German Society for Medical Treatment of Burns.[25,26] Patients with minor burn injuries, who were admitted to our peripheral ward, were not considered in our study.

Of the 685 patients, 20 had burn wound contamination by *Achromobacter* species identified from at least two swab cultures. Furthermore, four cases of infection and three cases of sepsis associated with *Achromobacter* species were identified (*Table I*). Two of the four infected patients showed pure *Achromobacter* infections. The other two patients had coinfections with *Achromobacter* species and *Pseudomonas aeruginosa*.

Achromobacter–contaminated patients compared with the remaining patient population without Achromobacter contamination

From January 2006 until December 2015, 20 patients (14 males, 6 females) were found to be colonized with *Achromobacter* species (*Table I*). *Achromobacter* species were mainly initially identified from wound swab cultures (70% of all cases) on a mean of 22 days after admission. *Achromobacter* contamination was identified initially in tracheal secretions (10% of all cases) and nasopharyngeal (5% of all cases), ure-

Table I - Characteristics of patients: total body surface area (TBSA), time of contamination, contaminating species, infection and septic course of burn patients contaminated with *Achromobacter* species, who were treated at the burn unit from 2006 until 2015

		Contamination		Infection			
#	TBSA	Detection after admission (days)	Region	Detection after admission (days)	Region	A. Species	
1	34	17	urethral				
2	70	13	tracheal				
3	24	28	wound				
4	28	0	tracheal				
5	15	27	wound				
6	32	19	wound				
7	9	21	wound				
8	13	22	wound				
9	15	29	wound	**39**	**blood stream**	**AX**	**Sepsis**
10	35	40	wound				
11	33	30	wound				
12	30	63	wound				
13	7	6	wound				
14	10	40	wound				
15	22	19	wound				
16	36	7	wound				
17	75	18	wound				
18	35	9	wound	**28**	**blood stream**	**AX+AD**	**Sepsis**
19	45	12	blood	12	blood stream	AX	
20	62	29	wound	**70**	**blood stream**	**AX+AD**	**Sepsis**

AX = Achromobacter xylosoxidans, AI = Achromobacter insolutus, AD = Achromobacter denitrificans

Table II - Burn patients contaminated with *Achromobacter* species versus burn patients without *Achromobacter* species treated at the burn unit from 2006 until 2015

	A + contamination					Patients in total			
	N			%	p-value	N			%
Patients total	20					665			
Accident					**<0,001**				
Burn				68,5					71,5
scald				26,2					18,3
chemical burn				0,0					3,0
electricity burn				5,3					7,2
Suicide					0,362				
yes				5,0					7,4
no				95,0					92,6
Gender					0,707				
female				25,0					26,2
male				75,0					73,8
	mean	min	max	SD	p-value	mean	min	max	SD
Age (years)	44,2	17	74	16,31	0,546	39,6			19,16
BMI (kg/m^2)	25,1	20	34	3,88	0,090	26,1	14	70	5,68
ABSI score	7,4	3	12	2,18	**0,001**	5,7	2	16	2,62
% TBSA burn	31,2	7	75	16,9	**<0,001**	14,7	0	97	17,71
% 2a degree	13,4	1	42	10,85	**0,025**	7,6	0	82	9,40
% 2b degree	10,7	0	37	11,35	**0,020**	2,9	0	60	7,04
% 3 degree	16,3	2	67	16,73	**<0,001**	4,1	0	100	12,66
% 4 degree	2,3	0	6	3,21	**0,001**	0,1	0	30	1,20
GCS	12,4	6	15	3,62	0,220	13,1	1	15	3,68
ICU stay (days)	43,8	2	100	28,25	**<0,001**	16,1	0	202	24,52
				%	p-value				%
Escharotomy				35,0	**0,003**				13,3
Fasciotomy				10,0	0,142				4,1
Inhalation injury				20,0	0,676				19,2
Chatecholamin required first 24 hours				60,0	**<0,001**				21,2
Haemofiltration required				20,0	**0,010**				4,7
Mechanical ventilation required				80,0	0,763				50,0
Infection rate				20,0	**<0,001**				20,8
Sepsis rate				15,0	0,701				15,8
Organ system failure				45,0	**<0,001**				22,8
Mortality rate				20,0	0,576				9,9

thral (10% of all cases), and blood cultures (5% of all cases). There was no evidence of transmission from *Achromobacter*-contaminated patients to other patients.

Table II shows the data on demographics, burn injury pattern, course of disease and additional treatment of the 20 patients with *Achromobacter* contamination and the other 665 patients (without *Achromobacter* contamination). There was a significant difference ($p<0.001$) in the type of accident causing the burn; more of the patients with *Achromobacter* contamination were injured by scalding than the other patients. There were no significant differences between the groups in rates of burns associated with gender, age, body mass index (BMI), Glasgow coma scale (GCS), inhalation trauma, and the need for fasciotomy. The respective differences between the patients with *Achromobacter* contamination and the other patients were significant for Abbreviated Burn Severity Index (ABSI) (mean 7.44 versus 5.70, $p=0.001$), burned mean total body surface areas (TBSAs) (mean 31.2% versus 14.7%, $p<0.001$), burn depth (mean percentage, 2nd a degree 13.4% versus 7.6%, $p=0,025$; 2nd b degree 10.7% versus 2.9%, $p=0.020$; 3rd degree 16.3% versus 4.1%, $p<0.001$; 4th degree 2.3% versus 0.1%, $p=0.001$) and length of ICU stay (mean, 43.8 versus 16.1 days, $p<0.001$).

The ICBU medical procedures and treatments for the patients with *Achromobacter* contamination were more extensive and invasive. Patients with *Achromobacter* contamination needed significantly more escharotomy procedures ($p=0.003$), administration of catecholamines during the first 24 hours of their ICBU stay ($p<0.001$), and haemofiltration ($p=0.01$) than the other patients. Surprisingly, infection rates with various types of bacterial strains were lower in patients with *Achromobacter* contamination than in the other patients ($p<0.001$). Rate of organ failure was higher in patients with *Achromobacter* contamination than in the other patients ($p<0.001$).

Achromobacter-associated septic patients compared with the other septic burn patients

Among the 665 patients without any evidence of *Achromobacter* contamination, there were 103 patients with sepsis associated with infections with a variety of other bacterial strains. Sepsis in those patients was commonly caused by coagulase-negative *Staphylococcus* species, followed by *Staphylococcus aureus*, *Enterococcus faecalis*, *Enterococcus faecium*, *Pseudomonas aeruginosa*, *Acinetobacter baumanii*, *Enterobacteriaceae* and *Escherichia coli*. Among the 20 patients

Table III - Septic patients with *Achromobacter* species versus septic burn patients without *Achromobacter* species who were treated at the burn unit from 2006 until 2015

	A + sepsis				Patients in total + sepsis			
	N			%	N			%
Patients total	3				103			
Accident								
Burn				33,3				82,7
Scald				33,3				5,1
chemical burn				0,0				3,1
electricity burn				33,3				9,2
Suicide								
yes				0,0				5,1
no				100,0				94,9
Gender								
female				33,3				24,3
male				66,7				75,7
	mean	min	max	SD	mean	min	max	SD
Age (years)	41,0	27	49	12,17	47,2	9	85	17,92
BMI (kg/m^2)	23,3	20	28	4,16	26,0	18	35	3,82
ABSI score	8,7	7	10	1,53	5,4	0	14	2,90
% TBSA burn	43,5	35	61	14,72	15,6	1	90	16,73
% 2a degree	11,5	1	24	11,33	6,2	0	82	9,78
% 2b degree	10,9	5	23	10,02	4,5	0	40	7,90
% 3 degree	19,1	15	23	4,18	3,8	0	57	8,06
% 4 degree	6,0	6	6	0,00	0,0	0	2	0,20
GCS	12,0	10	13	1,53	13,6	3	15	3,25
ICU stay (days)	75,0	29	100	39,89	19,6	1	202	40,20
				%				%
Escharotomy				66,7				13,00
Fasciotomy				33,3				6,50
Inhalation injury				33,3				35,20
Chatecholamin required first 24 hours				100				29,70
Haemofiltration required				66,7				3,00
Mechanical ventilation required				100				49,04
Infection rate				100				100,00
Sepsis rate				100				100,00
Organ system failure				100				36,00
Mortality rate				66,7				7,53

with *Achromobacter* colonization, three patients (two males, one female) had a septic course. All three septic patients with *Achromobacter* infection had coinfections with *Pseudomonas aeruginosa* (multiresistant in two cases) and *Achromobacter xylosoxidans*, which was found initially in swab cultures of their wounds. One patient also had *Serratia marcescens* in wound swab. These three patients had sustained severe burn injuries as follows: 1 had sustained electrical burns (35% TBSA: 28% deep dermal and full thickness burn), 1 had sustained thermal burns (35% TBSA: 25% deep dermal and full thickness burn), and 1 had sustained severe scalding (60.6% TBSA: 37% deep dermal and full thickness burn). The patient with thermal burn injury also had chronic hepatitis C infection.

Table III shows the data on demographics, burn injury pattern, course of disease and additional treatment of the septic burn patients with *Achromobacter* contamination and the 103 septic patients (without *Achromobacter* contamination). There were no significant differences in the demographics, BMI, mean TBSA, need for fasciotomy, need for mechanical ventilation and inhalation injury between the septic burn patients with and without associated *Achromobacter* infection. Length of ICBU stay was longer for the septic burn patients than for those without associated *Achromobacter* infection (75.0 days versus 19.6 days, p=0.018). TBSA and burn depth were significantly greater for the septic burn patients with than for those without associated *Achromobacter* infection (mean TBSA 43.5% versus 15.6%, p=0.014; mean percentage: 3rd degree 19.1% versus 3.8%, p=0.04; 4th degree 6.0% versus 0.0%, p=0.001). Escharotomy (p=0.021), catecholamine administration (p<0.001) and haemofiltration (p<0.001) were performed more often for the septic burn patients with *Achromobacter* infection, and there were higher rates of organ failure (p<0.001) and mortality (p=0.001). ABSI score was higher (mean 8.7 versus 5.4, p=0.042) and GCS was lower (mean 12.0 versus 13.6, p=0.014) for the septic burn patients with than for those without associated *Achromobacter* infection.

In the 3 septic patients with associated *Achromobacter* infection, *Achromobacter xylosoxidans* was detected in blood culture, consistent with our criteria for sepsis. Only one of the three patients responded well to antibiotic treatment and recovered completely from sepsis. Both *Achromobacter denitrificans* and *Achromobacter xylosoxidans* were detected in the other two patients, and the isolates from these patients showed increased resistance to antibiotics and changes in patterns of

resistance. These two patients did not respond to a complex regimen of antibiotic therapy and died of multiple organ failure. During the final course of the septic illness of one of these patients, *Achromobacter xylosoxidans* was the only isolate found in the swab cultures.

Typical clinical course of Achromobacter infection in 1 patient

A 29-year-old man was admitted to the ICBU after a fall at a construction site from a height of 3 meters subsequent to a high-voltage injury. The patient's ABSI score and GCS in the emergency room were 7 and 10, respectively. After admission and initial cleaning of the wound, estimated TBSA was 35%. Additional findings included extensive muscle necrosis and compartment syndrome involving all 4 extremities, a non-dislocated fracture of the sixth cervical vertebra, and a dislocated left elbow.

Surgical treatment was performed starting the day of admission. Epifascial necrotic tissue was removed from both lower extremities, along with splitting of the fascia. During the first few days after admission, the patient underwent extensive excision of necrotic muscle and dermal tissue. The defects were then covered with free grafts, pedicle flaps and Meek grafts. Fractures were treated conservatively. The patient received complex intensive care therapy following the standard of care (SOC) of the Cologne Merheim Burn Centre, which included long-term mechanical ventilation. Haemofiltration was started on day 10. Details of bacterial strains detected and antibiotic therapy (administered following swab cultures, as described in the Methods section) are shown in *Figs. 2 and 3*, respectively. On day 6, the patient was isolated because of detection of multidrug-resistant *Pseudomonas aeruginosa* (resistant to 3 antibiotic groups) in the wounds. On day 10, *Achromobacter xylosoxidans* was detected in cultures of wound swabs. Laboratory parameters and vital signs indicated sepsis simultaneously with the isolation of *Achromobacter xylosoxidans*. *Achromobacter denitrificans* was subsequently isolated from a culture of a wound swab. Despite escalation of antibiotic therapy, there were signs of progression of the infection; the last cultures yielded *Achromobacter xylosoxidans* and *Achromobacter denitrificans* from cultures of blood and tracheal, burn wound, perineal and nasopharyngeal swabs. *Achromobacter* organisms were the only bacterial species isolated from these samples. The patient's septic course manifested clinically as extensive tissue infection, loss of skin transplants and pneumonia. On day 30 after admission, the patient died of multiple organ failure.

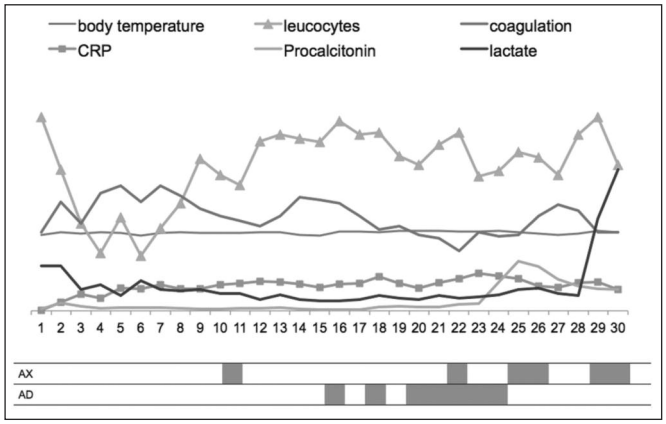

Fig. 2 - Typical clinical course of burn patient with *Achromobacter* infection: obvious increase in infectious disease markers after detection of microbial colonization with *Achromobacter* species (new detection of *Achromobacter* species marked).

Discussion

Fig. 1 provides an overview of the small number of current published reports on burn patients, with regard to wound contamination and infection by gram-negative *Achromobacter* species. The systematic review of Azzopardi et al. on emerging gram-negative infections in burn wounds reported that *Achro-*

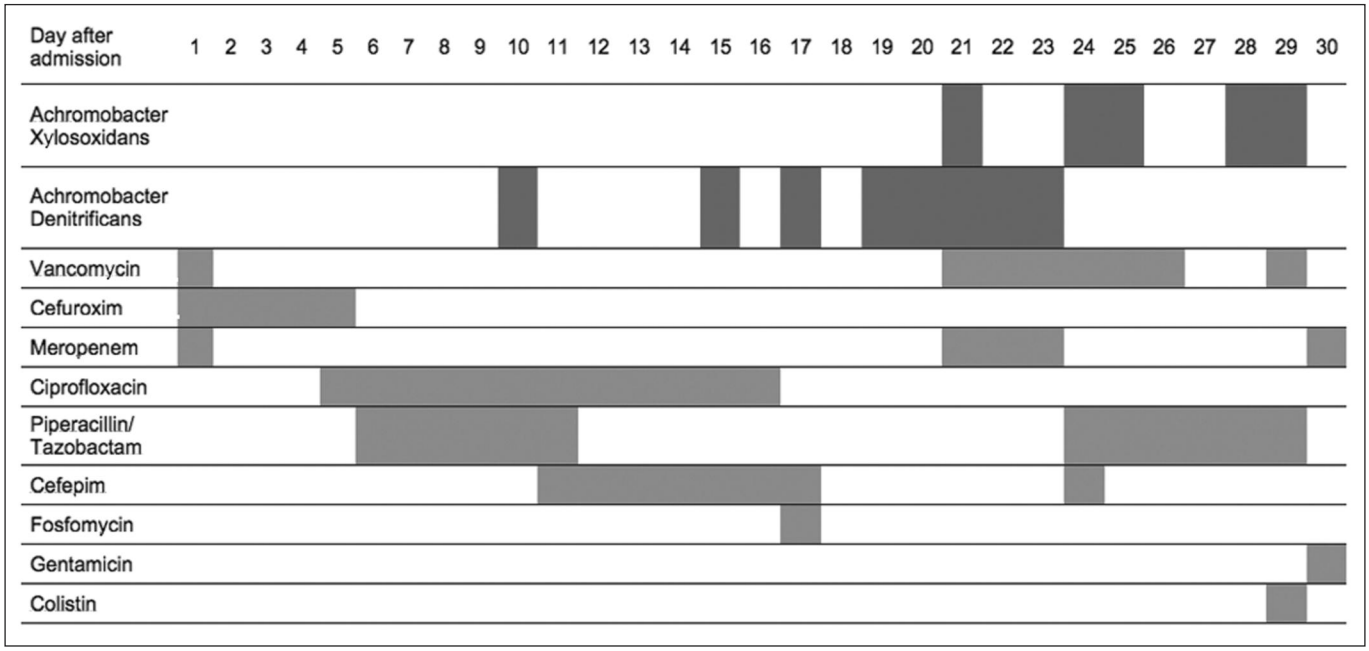

Fig. 3 - Typical clinical course of burn patient with *Achromobacter* infection: appearance of infectious disease and coagulation markers, vital parameters and lactate in blood related to antibiotic therapy (new detection of *Achromobacter* species marked).

mobacter xylosoxidans has been associated with outbreaks of infection in burn units. They concluded that *Achromobacter*-associated infections in burn units are markedly under-reported.[14,17] To our knowledge, there have not yet been any long-term retrospective studies searching for and evaluating patients in ICBUs contaminated with *Achromobacter*.

Over the 10-year study period, we only detected *Achromobacter* contamination at the time of admission before any treatment was performed in one patient, suggesting that in this case, contamination occurred outside the hospital. *Achromobacter* species were initially detected in the other 19 patients during the course of their ICBU stay. *Achromobacter* species are known to be common contaminants of "wet" environmental areas in the surgical ward.[11] They have been mainly isolated from respirators, incubators and disinfectants.[12,13] All 19 patients were directly exposed to these types of devices, suggesting that contamination via "wet" environmental areas in the ICBU was likely. We found evidence of endogenous spread of *Achromobacter* species in seven patients (spread of *Achromobacter* from the upper respiratory system to the wound bed in one, from the wound bed to the upper respiratory system in one, from the wound bed to catheter tip in two, from the wound bed to the upper respiratory system first and later to the bloodstream in two, and from the wound bed to the urinary tract in one patient). We found no evidence of transmission of *Achromobacter* species from any of the colonized patients to any other patient in the ICBU. Although we see the absence of *Achromobacter* transmission as confirmation that rigorous hygiene measures were followed by our department, we identified patient-to-patient spread of highly infectious bacteria (e.g. *Acinetobacter baumanii*) during the same period. Therefore, we think that the absence of *Achromobacter* transmission reflects the low intrinsic pathogenicity *of Achromobacter* species for humans. To date, to the best of our knowledge, infections with Achromobacter species have only been reported for immunocompromised patients.[1-4] The results of our study demonstrate that severe burn injury compromises the human immune system to an extent that allows contamination by and infection with *Achromobacter* species.

Achromobacter xylosoxidans, which we found in the wound swab cultures of 70% of our 20 contaminated patients, is the most common species.[27] The actual number of patients with wounds contaminated by *Achromobacter xylosoxidans* among our burn patient population might be even higher. We base this assumption on the findings of Vu-Thien et al., who reported inconsistency between the culture results of environmental swabs and clinical specimens (positive and negative for *Achromobacter xylosoxidans,* respectively).[12]

Achromobacter species show multidrug resistance to ampicillin, sulbactam, cefalosporin, carbapenem, aminoglycosides and quinolone. They are usually sensitive to piperacillin/tazobactam, tigecyclin and colistin.[12,17] We found a similar resistance pattern when the organisms were first isolated (example is given for patient 18 in *Fig. 2*). There was a shift in antibiotic resistance over the hospital courses of two severely infected and septic patients. This finding might be attributed to transfer of antibiotic resistance between *Achromobacter* species and other bacterial species detected in swab cultures (*Fig. 2*). Miskell et al. identified transfer of antibiotic resistance from *Achromobacter* species to *Pseudomonas aeruginosa*.[28] In our study, our initial detection of *Achromobacter* species concomitant with *Pseudomonas aeruginosa* in the cultures of wound swabs of all 3 septic patients supports this theory.

The key aim of this study was to identify factors that supported contamination or infection by *Achromobacter* species in burn patients. We found evidence that the main factors associated with both *Achromobacter* contamination and severe septic course were TBSA and burn depth. Nevertheless due to the small number of Achromobacter-associated septic patients we cannot confirm statistically significant differences (*Table III*). Our results are consistent with the findings of Andel et al., who found that TBSA clearly affected survival.[29] However, in contrast to the results of Andel et al., we found evidence that burn depth was associated with severe septic course. We found evidence that the ABSI score and GCS were worse, and the need for escharotomy, administration of catecholamines and haemofiltration was more frequent in all contaminated and septic patients with *Achromobacter* species than in the patients without *Achromobacter* species. Andel et al. and Mlcak et al. conducted research in this field. They found that neither BMI, gender, nor ABSI score and GCS had a statistically significant effect on patient outcomes.[30]

Because not much is known about the treatment of *Achromobacter* wound contamination and infection, choosing antimicrobial therapy for this organism is quite difficult.[12,14-17] In critical care medicine, the early initiation of appropriate antibiotic therapy is widely accepted to be of paramount importance for the success of long-term therapy.[31] Adequate treatment of bacterial infection in ICBU burn patients is important for preventing morbidity and mortality, since these patients are well known to be at high risk of nosocomial infections and infection-related mortality.[32-35]

Today, antibiotics are among the best selling drugs worldwide.[36] Eshwara et al. recommended the administration of adequate early antibiotic therapy for *Achromobacter* species isolated from cultures of wound swabs, even with sterile blood cultures.[37] Zhi Yang et al. concluded that *Achromobacter xylosoxidans* isolated from cultures of wound swabs should not be underestimated, regardless of sterile blood cultures.[17] In our study of a cohort of burn patients, antibiotic therapy was promptly tailored to the results of antibiogram and resistogram typing, without specifically targeting *Achromobacter*. Regardless of an uninterrupted therapeutic regime, four patients developed infection and three patients developed sepsis associated with *Achromobacter* species. Additionally, in one of these patients, *Achromobacter xylosoxidans* was the only isolate in his last swab and blood cultures (*Figs. 2 and 3*).

Critical care investigators currently widely believe that the decision to administer antibiotics should be made with careful deliberation for all critically ill patients because of multidrug resistance and concerns regarding antibiotics and organ function.[31] Soleymanzadeh-Moghadam et al. found that excessive and inappropriate use of antibiotics in the ICU may be detrimental to patient health and treatment costs. Therefore, responsible administration of antibiotic therapy includes careful attention to indications, dosage and duration of treatment.[32] We believe that these principles should also apply to patients with *Achromobacter* colonization and infection.

Conclusions

Our study found that patients with severe burns must be regarded as immunocompromised and are at risk for contami-

nation and infection with *Achromobacter* species. Even in the absence of positive blood cultures, bacterial pathogenicity cannot be ruled out with certainty, and careful monitoring, with focus on cultures of wound swabs and infection parameters, should therefore be routinely performed. Because *Achromobacter* strains rapidly change antibiotic resistance patterns, there are currently no established treatment recommendations. In our department, we therefore focus on strengthening the patient's immune status in addition to initial antibiotic therapy followed by effective antibiotic therapy based on the results of antibiogram and resistogram typing.

Study limitations

This study was limited by the small number of patients, identified over the 10-year study period, who were either contaminated by or infected with *Achromobacter* species. Additional studies involving more patients are needed to clarify the consequences of *Achromobacter* infection in burn patients.

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