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Necrotizing pneumonia due to clonally diverse *Staphylococcus aureus* strains producing Panton-Valentine leukocidin: the Czech experience

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SUMMARY

A prospective study (2007–2013) was undertaken to investigate clinical features and prognostic factors of necrotizing pneumonia caused by *Staphylococcus aureus* producing Panton–Valentine leukocidin (PVL) in the Czech Republic. Twelve cases of necrotizing pneumonia were detected in 12 patients (median age 25 years) without severe underlying disease. Eight cases occurred in December and January and the accumulation of cases in the winter months preceding the influenza season was statistically significant ($P < 0{\cdot}001$). The course of pneumonia was very rapid, leading to early sepsis and/or septic shock in all but one patient. Seven patients died and mortality was fourfold higher in those patients presenting with primary pneumonia than with pneumonia complicating other staphylococcal/pyogenic infection elsewhere in the body. The *S. aureus* isolates displayed considerable genetic variability and were assigned to five lineages CC8 ($n = 3$), CC15 ($n = 2$), CC30 ($n = 2$), CC80 ($n = 1$), and CC121 ($n = 3$) and one was a singleton of ST154 ($n = 1$), all were reported to be associated with community-acquired infection. Four strains were methicillin resistant. The high case-fatality rate can only be reduced by improving the speed of diagnosis and a rapid test to detect *S. aureus* in the airways is needed.

Key words: Community-acquired pneumonia, necrotizing pneumonia, Panton–Valentine leukocidin, septic shock, *Staphylococcus aureus*.

INTRODUCTION

Panton–Valentine leukocidin (PVL) has been extensively studied to better understand its contribution to the pathogenic potential of *Staphylococcus aureus* in humans [1]. The importance of necrotizing pneumonia caused by PVL-producing strains of *S. aureus* was first pointed out by Gillet *et al*. in 2002, who described a group of 16 patients presenting with this disease [2]. To date about 100 cases of necrotizing pneumonia caused by *S. aureus* have been reported in the literature mostly in individual case reports or in small series. Meta-analyses comprising several cases from such sources [3–6] as well as a few larger studies [7, 8] have recently been published. The present study provides unique information of this disease in Central Europe through the uniform and detailed processing of the collected data.

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MATERIALS AND METHODS

Data source and collection

The Czech National Reference Laboratory for Staphylococci (NRLS) permanently collects staphylococcal strains isolated from patients with severe infections across the country, together with clinical data on the disease course. According to the sustained surveillance programme, local microbiological laboratories in the Czech Republic are requested to send *S. aureus* strains from patients with particularly severe and/or atypical forms of infections to the NRLS for detailed analysis. All strains that were sent to the NRLS were included in the study.

PVL-producing strains from patients hospitalized for pneumonia were prospectively collected in the period from December 2007 to December 2013. In the Czech Republic, the National Reference Laboratories may request patients' medical records including discharge and/or autopsy reports. Additional clinical data were collected from attending clinicians and general practitioners through a standardized telephone interview.

Phenotyping of bacterial strains

Conventional biochemical tests, commercial test kits API Staph (bioMérieux, France), and MALDI-TOF mass spectrometry (Bruker Daltonics, Germany) were used for identification and phenotypic characterization of staphylococcal strains. Strains were assayed by reversed passive latex agglutination (Denka Seiken, Japan) for the production of staphylococcal toxic shock syndrome toxin (TSST-1), exfoliative toxins A and B, and enterotoxins A (E), B, C, and D. Antibiotic susceptibility was tested for 14 antibiotics using the disc diffusion method (Antimicrobial Discs, Oxoid, UK) and inhibition zones were interpreted according to the EUCAST breakpoints [9]. Phage-typing was performed by the standard method using the international typing set of phages (Public Health England, London, UK).

Genotyping of bacterial strains

All isolates were genotyped by pulsed-field gel electrophoresis (PFGE) after *Sma*I digestion, staphylococcal protein A gene (*spa*) typing using StaphType software v. 2.2.1 (Ridom, Germany), multilocus sequence typing (MLST) using BioNumerics v. 6.6 (Applied Maths, Belgium) MLST online plugin, *agr* group determination [10], SCC*mec* typing [11], plasmid content analysis [12], and prophage typing [13]. The genes for PVL [14], leukocidin *luk*ED [15], staphylococcal enterotoxins [16], enterotoxin gene cluster (EGC) [17], exfoliative toxin genes [18], immune evasion cluster (IEC) [19], and arginine catabolic mobile element (ACME) [20] were screened using polymerase chain reaction (PCR) or multiplex PCR.

Statistical analysis

The strength of association between risk factors and patients' survival was assessed by relative risk (RR) and the corresponding 95% confidence interval (CI). Fisher's exact test was used to test differences in the proportion of deaths between subgroups. All statistical tests were evaluated as two-sided at a significance level of 0·05. To compare the occurrence of disease during the seasons, an exact conditional test of the hypothesis that the ratio of two Poisson rates equal to one was used. Statistical analyses were performed by Stata software, release 9.2 (Stata Corp LP, USA).

Ethical standards

The study was not interventional. It was approved by the Ethic Committee at the National Institute of Public Health, Prague (3986/2014) who judged that there was no need for informed consent to be obtained for this study.

RESULTS

Patients' data and prospective study of cases

Twelve cases of necrotizing pneumonia caused by PVL-producing *S. aureus* were collected from throughout the Czech Republic during the 6-year period. The reports came from different cities and no epidemiological link was found between them. The patients' characteristics and course of the disease are given in Tables 1 and 2. The male/female ratio was 5/7 (age range 4 months to 59 years, median 25 years). Most cases occurred in the winter season, mainly in December and January which was statistically significant ($P = 0{\cdot}0002$). The diagnosis of necrotizing pneumonia was confirmed by computed tomography imaging in surviving individuals and by autopsy in seven patients who died. In all patients, pneumonia affecting both lungs and abscess formation/necrosis/tissue breakdown was noted; pleural effusion occurred in 10 patients.

None of the patients had severe underlying diseases. The early clinical symptoms were diverse and nonspecific in most patients: fever with myalgia, headache, back pain, or gastrointestinal disorder were present in 10/12 patients 1–2 days before admission.

Table 1. *Necrotizing pneumonia patients' characteristics and medical histories*

Patient no.	Age, years	Sex	Admission to hospital	Underlying diseases	Factors possibly involved in immune disorders*	Pyogenic infection immediately preceding disease onset	First manifestations of the disease before admission†
1	41	F	December 2007	No	Severe long-term stress both at work and at home; lyme borreliosis several months ago	No	Severe back pain for 2 days; first referred to surgery for suspected acute abdomen
2	22	M	December 2007	No	An immigrant living alone without a social network in the Czech Republic for several months	No	Flu-like illness for 4 days prior to admission
3	10 mo.	M	December 2008	No	Infancy	No	Fever, vomiting, and diarrhoea for 3 days, then increasing dyspnoea without cough
4	21	F	January 2009	No	Year-long fatigue, recurrent viral infections, herpes zoster 4 days before admission	No	Herpes zoster ophthalmicus 4 days before admission; fever and headache 1 day before admission
5	28	M	January 2009	No	Intravenous drug user; recurrent extensive labial herpes, last episode 5 weeks ago	No	Back pain and weakness for 10 days before admission; fever 2 days before admission
6	32	M	February 2009	No	A lonely, anxious male, heavy smoker, working as a barman	A chronic furuncle in the right thigh	Neck injury in a brawl several days prior to presentation, then progressive neck pain and dysphagia; neck phlegmon
7	18	F	March 2009	No	A simple person but no known stressor and/or immune defect	Paronychia treated with nail removal 3 weeks previously	Headache, abdominal and back pain, and nausea for 5 days; fever and neck pain for 2 days
8	43	F	January 2011	No	Vegan, with poor communication skills; recurrent respiratory infections in the last 4 months, extensive labial herpes 5 days before admission	Impetigo or extensive labial herpes	Flu-like illness for 4 days; pain in the left buttock
9	37	F	December 2011	Chronic hepatitis B + C	Intravenous drug user; chronic hepatitis B + C	Not known; possibly previous pyodermas due to intravenous drug use	Flu-like illness for several days, nausea and diarrhoea
10	59	F	March 2012	Thyroid disease	Denying stress, but undergoing psychiatric treatment for anxiety on a permanent basis	A furuncle (*S. aureus*) in the scalp	Flu-like illness for 2 days prior to admission
11	4 mo.	F	December 2012	No	Infancy	No	Fever
12	16	M	October 2013	No	An anxious and ambitious schoolboy; no known stress and/or immune defect	No	Sore throat, cough, abdominal pain, nausea, and fever for 1 day before admission

* Stress is considered as a possible cause of temporary immunosuppression.

† Flu-like symptoms: fever, chills, myalgia, headache, dry cough.

Table 2. *Course of necrotizing pneumonia and outcome*

Patient no.	Clinical diagnosis	Leukocyte count on admission ($\times 10^9$/l)	Platelet count on admission ($\times 10^9$/l)	Time from admission to initiation of mechanical ventilation	Secondary diagnoses, complications	Isolation of PVL-positive *S. aureus*	Length of hospital stay	Outcome
1*	Severe pneumonia	Not known	Not known	2 days	Septic shock, MOF, CMVI, oesophageal candidiasis, polyneuromyopathy	Blood, sputum, TA, urine, pleural fluid	68 days	Survived
2*	Severe pneumonia	0·7	84	1 day	Septic shock, MOF	Blood, nasal swab	2 days	Died
3*	Severe pneumonia	11·7†	Not known	4 days	Mediastinitis, shock	Blood, TA, pleural fluid	14 days	Died
4*	Severe pneumonia	1·6	74	Few hours	Septic shock, MOF	Blood, TA	2 days	Died
5*	Septic shock, pneumonia	9·1	130	Immediately	Septic shock, MOF, oesophagitis from vomiting	Blood	8 h	Died
6	Neck phlegmon and abscess, severe pneumonia 2 days after admission	14·6	228	Ventilated early due to neck phlegmon	Septic shock, MODS, perivertebral abscesses, polyneuromyopathy	Blood, TA, pus from the neck abscess	94 days	Survived
7	Parapharyngeal phlegmon, septic lung metastases	10·0	Not known	Not ventilated	Meningitis, epiduritis, severe oral candidiasis	Blood, CSF	51 days	Survived
8	Spondylodiscitis with left iliopsoas abscess, severe pneumonia	1·5	73	2 days	Sepsis, MOF	Blood, BAL, pus from the buttock abscess and lungs	6 days	Died
9	Right-side endocarditis, metastatic abscesses in both lungs	Not known	Not known	2 days	Sepsis, MOF	Blood	87 days	Survived
10	Sepsis, severe pneumonia	0·25†	54·7	2 days	Polyneuromyopathy	Blood, TA, pus from the scalp furuncle	33 days	Survived
11*	Death before admission	n.a.	n.a.	n.a.	n.a.	Organs at autopsy	n.a.	Died
12*	Viral illness, pneumonia, shock	3·9	147	1 day	MOF	Throat, nose, blood	1 day	Died

MOF, Multi-organ failure; MODS, multi-organ dysfunction syndrome; CMVI, cytomegalovirus infection; TA, tracheal aspirate; CSF, cerebrospinal fluid; BAL, bronchoalveolar lavage; n.a., not applicable.
* Patients with primary pneumonia.
† Marked left shift.

Two patients (nos. 3 and 9) developed diarrhoea and yielded *S. aureus* isolates producing enterotoxin A. The course of pneumonia was always very rapid, leading to early sepsis and/or septic shock in all but one patient (no. 7).

Two subgroups of patients could be distinguished with respect to clinical presentation: (i) seven patients (nos. 1–5, 11, 12) developed primary severe pneumonia without pre-existing staphylococcal or pyogenic infection elsewhere in the body; (ii) in four patients (nos. 6, 7, 8, 10), skin and soft tissue infection preceded the pneumonia and PVL-producing *S. aureus* was isolated from the primary site of infection in three of these. The remaining patient (no. 9) was an intravenous drug user with right-sided endocarditis and haematogenous abscesses in both lungs. *S. aureus* invaded the bloodstream in all study patients as evidenced at autopsy in patient no. 11 and by positive blood culture in the others.

The source of *S. aureus* remained unknown in 11/12 patients. Only patient no. 3 was reported to have a history of close contact with a purulent infection (his mother had otitis). With the exception of patient no. 1, all cases were clearly community-acquired infections.

Therapy

For all but one patient, antibiotic therapy was started with various β-lactams, in some cases in combination with other antibiotics. The exception was patient no. 1 who worked in a hospital as a microbiologist. Staphylococci were identified by microscopic examination of her sputum immediately after she was hospitalized. In view of the possibility of methicillin-resistant *S. aureus* (MRSA) sepsis, she was given intravenous vancomycin and gentamicin on the first day. On the next day, she was diagnosed with severe pneumonia and therapy was switched to linezolid + gentamicin + rifampicin. No other patient was treated with linezolid or clindamycin within the first 2 days after admission because the aetiology had not yet been determined and the therapy was targeted at sepsis and/or community-acquired pneumonia caused by common pathogens. No patient received intravenous immunoglobulin.

Patients who survived recovered slowly, partly because of polymyoneuropathy after prolonged intensive care, and partly due to severe lung disease. Nevertheless, even patients who had severe lung damage eventually recovered, and the survivors returned to a good quality of life.

Prognostic factors

The mortality of necrotizing pneumonia in this study was high (7/12, 58%). However, six of the seven patients who died had primary pneumonia compared with one of the remaining five patients who presented with secondary pneumonia as a complication of staphylococcal/pyogenic infection elsewhere in the body. This difference was of borderline statistical significance (RR 4·29, 95% CI 0·72–25·39, $P = 0·072$) (Table 2).

The Czech NRLS has been monitoring systematically the prevalence of genes for PVL in *S. aureus* strains since 2004, and such genes were found in 6·1% of 7027 strains examined up to the end of 2013. Notably, of the PVL-positive strains, 25·3% were classified as methicillin resistant.

Bacterial isolates and their characteristics

The phenotypic and molecular characteristics of the 12 study strains are shown in Table 3. Four strains produced enterotoxin A, and one each enterotoxins B and C. Seven strains were susceptible to all antimicrobials tested and four were MRSA. Phage-typing revealed diverse patterns with four non-typable strains. Genotyping showed substantial variability among the strains and assigned the majority to five clonal complexes (CC8, CC15, CC30, CC80, CC121). Eight strains were unassigned by SCC*mec* typing, and in seven different MLST types, three each were of ST8 or ST121, and two of ST15. All strains isolates carried PVL-encoding genes but lacked the TSST-1 gene and exfoliative toxin A or B genes.

Three (33%) of the MRSA strains from patient nos. 1, 5, and 8 carried the ACME-related *arcA* gene, exhibited the USA300 PFGE banding patterns, and the latter two strains were similar in plasmid profile to the USA300-HOU-MR clone [21]. The fourth MRSA strain was of the very rare sequence type ST154 in MRSA and also harboured a unique composite SCC*mec* element carrying both the *ccr*A2B2 and *ccr*C gene complexes and class B *mec* gene complex.

One methicillin-susceptible *S. aureus* (MSSA) strain (patient no. 6) belonged to the CC80 group which also includes the European PVL-positive MRSA ST80 clone. The affiliation with this group was also confirmed by the presence of the exfoliative toxin D gene (not shown). This clone has been reported to be highly associated with skin infections [22] which

Table 3. *Phenotypic and genotypic characteristics of PVL-positive S. aureus strains from patients with necrotizing pneumonia*

	Phenotypic features				Genotypic features								
Patient no.	Enterotoxin production (RPLA)	Antibiotic resistance (disc diffusion method)*	Methicillin susceptibility type	Phage type	SCC*mec* type	MLST	*Spa* type	CC	*agr* type	Enterotoxin genes	Prophages†	IEC	Plasmids (kb)
1	–	CXT, ERY, CMP, CIP	MRSA	52, 52A, 79, 80, 47, 83A, 84, 85, 95	IVa	ST8	t008	CC8	agr1	–	Sa2-A-ami2 Sa3-Fa-ami3	IEC-B	27
2	C	CXT, TET	MRSA	n.t.	Composite IV + V	ST154	t667	Singleton	agr3	C	Sa2-A-ami2 Sa3-Fa-ami3 Sa6-Ba-ami1	IEC-B	25 and 6
3	A	Susceptible to all drugs	MSSA	29, 52, 52A, 80	n.a.	ST30	t443	CC30	agr3	AGIMNO	Sa1-Ba-ami4 Sa2-Fb-ami2 Sa3-Fa-ami3	IEC-A	20
4	B	Susceptible to all drugs	MSSA	3C, 55, 71	n.a.	ST121	t5723	CC121	agr4	BGIMNO	Sa2-A-ami2 Sa3-Fb-ami3	IEC-E	None
5	–	CXT, ERY, CIP	MRSA	79, 54, 83A, 84, 85, 95	IVa	ST8	t008	CC8	agr1	–	Sa2-A-ami2 Sa3-Fa-ami3	IEC-B	27 and 3
6	–	Susceptible to all drugs	MSSA	n.t.	n.a.	ST728	t6290	CC80	agr3	–	Sa2-A-ami2 defective-ami3	IEC-G	None
7	–	Susceptible to all drugs	MSSA	3C	n.a.	ST121	t1114	CC121	agr4	GIMNO	Sa1-Bc-ami1 Sa2-A-ami2 Sa3-Fb-ami3	IEC-E	None
8	–	CXT, ERY, CIP, MUP	MRSA	52A, 79, 80, 47, 77, 83A, 84, 85, 95	IVa	ST8	t008	CC8	agr1	–	Sa2-A-ami2 Sa3-Fa-ami3	IEC-B	27 and 3
9	A	Susceptible to all drugs	MSSA	n.t.	n.a.	ST15	t346	CC15	agr2	A	Sa1-Bb-ami3 Sa2-Fa-ami2	n.t.	21·7
10	A	Susceptible to all drugs	MSSA	29, 52, 52A, 80, 47, 75, 81	n.a.	ST30	t318	CC30	agr3	AGKOQ	Sa1-Ba-ami4 Sa2-Fb-ami2 Sa3-Fa-ami3	IEC-B	None
11	A	Susceptible to all drugs	MSSA	n.t.	n.a.	ST15	t346	CC15	agr2	A	Sa1-Bb-ami3 Sa2-Fa-ami2	n.t.	21·7
12	–	CMP	MSSA	3C	n.a.	ST121	t435	CC121	agr4	GIMNO	Sa1-Bc-ami1 Sa2-A-ami2 Sa3-Fb-ami3	IEC-E	2·9

RPLA, Reversed passive latex agglutination; MSSA, methicillin-susceptible *S. aureus*; MRSA, methicillin-resistant *S. aureus*; CA-MRSA, community-acquired methicillin-resistant *S. aureus*; MLST, multilocus sequence type; CC, clonal complex; IEC, immune evasion cluster [19]; n.t., non-typable; n.a., not applicable.

* Tested antibiotics: CXT, cefoxitin; ERY, erythromycin; COT, cotrimoxazole; CMP, chloramphenicol; TET, tetracycline; CLI, clindamycin; GEN, gentamicin; VAN, vancomycin; CIP, ciprofloxacin; RIF, rifampicin; LZD, linezolid; FUS, fusidic acid; TGC, tigecycline; MUP, mupirocin.

† Integrase type-head-tail type-amidase type [13].

correlates with patient no. 6′s recollection of a chronic furuncle in the past. Three MSSA strains from patient nos. 4, 7, and 12 belonging to CC121 were genetically similar but not identical. These strains harboured the Sa3 phage known to be associated with IEC type E and a complete cluster of enterotoxin genes (G, I, M, N, O). Two other MSSA strains of CC30 group (patient nos. 3 and 10) harboured three prophages, which were probably associated with the presence of PVL and IEC coding genes. These strains were the only ones to lack the *luk*ED genes. The remaining two strains of CC15 (patient nos. 9 and 11) were genetically identical by all the parameters tested and were the only ones undistinguishable by PFGE.

DISCUSSION

Necrotizing pneumonia caused by PVL-producing strains of *S. aureus* is a rare disease. Its course is unexpectedly rapid and severe, and as a consequence it is expected that the majority of cases are examined for aetiology and reported to the health authorities. As the population of the Czech Republic is about 10 million, the annual incidence of the disease appears to be close to 0·02 cases/100 000 inhabitants based on surveillance data but this cannot be confirmed due to the lack other data sources.

The case mortality in this study is similar to other reports [5, 23]. The predictors of poor prognosis in our patients seem to be: age <25 years, primary pneumonia, leukopenia, and thrombocytopenia. However, the small number of patients makes it difficult to assess the strength of association of these factors with a poor prognosis. *S. aureus* necrotizing pneumonia affects mainly young and previously healthy individuals including children and infants [3, 4, 7, 24–26]. It occurs mainly in the winter season as observed here and by other studies [24, 27–29], but to our best knowledge none of these associations have been supported by statistical evidence. Synergy between *S. aureus* and influenza virus has been suggested [5, 23] and pneumonia caused by PVL-producing *S. aureus* is assumed to follow influenza infection but often only in a minority of cases [4, 30, 31]. Unfortunately, the study patients were not examined to prove/exclude a viral aetiology because their clinical course was highly suggestive for severe sepsis. However, a direct association with influenza may be coincidental because the staphylococcal pneumonia cases described here peaked in December and January while the influenza season peaks in February.

Clinically, necrotizing pneumonia is very difficult disease to diagnose early. Although haemoptysis has been noted by others to be a frequent and relatively specific manifestation of the infection [5, 23], we found only one patient presenting with this symptom although one other complained of pink-stained sputum. By contrast, one patient developed haematemesis due to extensive vomiting on admission and was diagnosed with Mallory–Weiss syndrome at autopsy. Only one patient with rapid primary staphylococcal pneumonia survived and we believe that the early detection of staphylococci in the tracheal aspirate by direct microscopy was crucial in saving this patient's life. It is therefore very important to develop diagnostic methods to detect the presence of *S. aureus* in such samples more rapidly than conventional culture.

Several authors have noted that primary pneumonia (spread of infection through the respiratory tract) is associated with a poorer prognosis than secondary pneumonia (haematogenous spread of infection from a focus in another organ) [3, 4, 7, 32]. It is suggested that in the latter group, patients whose illness began with a skin and soft tissue infection should be separated from those whose first manifestation was infective endocarditis. This classification provides a better clue for the optimal treatment. In this study, the patient who suffered from right-sided endocarditis and secondary pneumonia was the only one who was successfully treated with β-lactams only (oxacillin and meropenem).

Linezolid or clindamycin are recommended for therapy of primary necrotizing pneumonia, both for their ability to inhibit synthesis of PVL and good lung penetration including alveolar lining fluid, bronchial exudate, and pleural effusion [4, 25, 33]. Clindamycin appears to be inferior to linezolid for initial/empirical therapy because resistance develops more frequently. Another theoretical argument against clindamycin results from its pharmacokinetics as the concentration of clindamycin at the site of inflammation depends partly on leukocyte transport. In necrotizing pneumonia, the number of incoming leukocytes is often significantly reduced because of their destruction by PVL, and thus a therapeutic concentration of clindamycin may not always be attained in the affected tissue.

Necrotizing pneumonia affects especially young and healthy people. It might therefore be expected that elderly and/or individuals with more than one comorbid condition would be more susceptible to infection due to poor immune status. A possible explanation for the rarity of this infection in such groups may be that older people who have previously been exposed to the pathogen have developed anti-PVL antibodies. This concept correlates well with the fact that intravenous globulin obtained from unimmunized donors can inactivate PVL [25, 34]. A protective role of anti-PVL antibodies has also been suggested [35].

The prevalence of PVL-producing strains of *S. aureus* has been reported to be strongly linked to the prevalence of CA-MRSA strains with varied genetic backgrounds in different geographical regions [36]. PVL is encoded by phages of the Siphoviridae family exhibiting a highly mosaic structure of the genome [13], but the *luk*-PV genes are always located in a 6·4-kb conserved region consisting of the host lysis module (*ami*2 type), *luk*-PV, and the Sa2 type integrase gene [37] shown in all strains in this study. Previous studies have shown no relationship between PVL production that depends on the phage's life-cycle or the host's background [38], and clinical presentation of the infection [39].

The present study demonstrated that the Czech cases of necrotizing pneumonia were caused by strains with different genetic backgrounds that can be classified into six lineages. We speculate that MSSA strains assigned to the CC15, CC30, and CC121 groups that are frequently found in asymptomatic carriers, may represent novel invasive clones that have acquired not only PVL, but also other virulence genes by horizontal gene transfer and/or have upregulated their inherent virulence factors. Relatively few PVL-positive ST154 strains have been described in the literature, originating mainly from Mongolia and other Central Asian countries [40]. Patient no. 2 was from neighbouring Slovakia, but whether he came into contact with Asian immigrants is unknown. Interestingly, those isolates that underwent MLST and *spa*-typing were t667 [41, 42], as was the ST154 strain in the present report.

In conclusion, this study documents that although highly fatal, necrotizing staphylococcal pneumonia is so rare that its specific therapy by linezolid and/or clindamycin cannot be included in the guidelines for initial therapy of patients with community-acquired pneumonia. Rapid diagnostic methods for *S. aureus* should be developed and implemented to allow early detection of this disease.

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DECLARATION OF INTEREST

None.

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