Necrotising fasciitis in the North-East of Scotland: a 10-year retrospective review

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ABSTRACT

INTRODUCTION Necrotising fasciitis is a life-threatening rapidly progressing bacterial infection of the skin requiring prompt diagnosis and treatment. Optimum care warrants a combination of surgical debridement, antibiotics and intensive care support. All cases of necrotising fasciitis in 10 years in the North East of Scotland were reviewed to investigate and improve patient care.

METHODS Cases between August 2006 and February 2016 were reviewed using case notes and electronic hospital records. Data including mode of admission, clinical observations, investigations, operative interventions, microbiological and clinical outcomes was collected and reviewed. Analysis required multidisciplinary input including microbiology, infectious disease, trauma and orthopaedics, plastic surgery and intensive care teams.

RESULTS A total of 36 cases were identified. The mean laboratory risk indicator for necrotising fasciitis (LRINEC) score was 7 and 86% of patients fulfilled the criteria for necrotising fasciitis. Patients were commonly haemodynamically stable upon admission but deteriorated rapidly; 36% of patients had a temperature of over 37.5 degrees C on initial observations; 29/36 patients were discharged, 6 patients died acutely (acute mortality rate of 17%); 18/31 of cases were polymicrobial with *Streptococcus pyogenes*, the common organism. Six amputations or disarticulations were performed from a total of 82 operations in this group, with radical debridement the usual primary operation. The mean time to theatre was 3.54 hours. Highly elevated admission respiratory rate (50 breaths/minute) was associated with increased mortality.

CONCLUSIONS Necrotising fasciitis presents subtly and carries significant morbidity and mortality. A high index of suspicion allows early diagnosis and intervention. We believe that a pan-specialty approach is the cornerstone for good outcomes.

KEYWORDS

Necrotising fasciitis – Microbiology – Septicaemia – Critical care

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Introduction

Necrotising fasciitis is an uncommon although not rare medical and surgical emergency. An estimated 500 cases present each year in the UK,¹ with an incidence of 0.4 and 0.53 cases per 100,000 population.² It is a rapidly progressing infection of the skin and, as the largest organ of the body, this can be life threatening without prompt diagnosis and surgical and medical intervention.

The modern definition and first use of the term ‘necrotising fasciitis’ was coined by Wilson in 1952,³ describing a rapidly progressing infection resulting in fascial necrosis. Wilson outlines the histopathological features of the disease, a necrotising infection involving the deep fascia and soft tissue. Historical descriptions however, date back to the fifth century.⁴ During the 18th and 19th centuries, British naval surgeons referred to necrotising fasciitis as hospital gangrene.⁵ During the American Civil war, Joseph

Jones, a Confederate army surgeon published a detailed description of this condition.

Necrotising fasciitis can be monobacterial, polymicrobial or fungal,⁶ with a reported mortality ranging from 25% to 75%.¹

We publish our experience treating necrotising fasciitis in a UK tertiary referral centre. A retrospective review of each of our cases was performed with the combined input of the microbiology, infectious disease and surgical specialities (trauma and orthopaedics, plastics and general surgery) and the intensive care teams.

Aetiology

Necrotising fasciitis can occur after compromise to skin integrity or via haematogenous spread. The most common anatomical areas associated with necrotising fasciitis are the extremities, abdomen and perineum.

Risk factors that have been identified as being associated with developing necrotising fasciitis include intravenous drug use, diabetes mellitus, age over 50 years, hypertension and both obesity and malnutrition.⁷ Trauma is also an important factor, and most of the historical literature describes necrotising fasciitis associated with battle wounds.⁴ Blunt trauma and seemingly innocuous injuries such as muscle strains have been identified to be associated with *Streptococcus pyogenes* (group A Streptococcus necrotising fasciitis in particular).⁸ Although the reasons for this remain unclear, it has been suggested that the underlying damaged muscle is predisposed to infection and that regenerating muscle cells may be susceptible to *S. pyogenes* via a binding protein.⁹

The diagnosis of necrotising fasciitis is difficult with the initial diagnosis of cellulitis commonly being made. In a collection of studies looking at clinical manifestations, including 304 patients and 309 limbs, Angoules *et al* found erythema to be the most common clinical sign at 75% followed by pain (63%) and oedema (49%).² Others included indurace, fluctuance, bullae, skin necrosis, crepitus, jaundice and subcutaneous gas visible on x-ray.⁶

Necrotising fasciitis is characterised by rapidly progressing widespread necrosis of the subcutaneous tissues, superficial fascia and skin. Contaminating bacteria or fungi track along subcutaneous tissue planes producing endo- and exotoxins which can cause vascular thrombosis, tissue ischaemia liquefactive necrosis and often lead to systemic illness, multi organ failure and death.¹⁰ This is reflected in the histology analysis of tissues showing acute inflammation of subcutaneous fat and areas of tissue necrosis.

Morgan *et al*⁶ highlight the four types of necrotising fasciitis. Type 1 is the most common (70–80% cases) and is polymicrobial, usually with mixed aerobes and anaerobes often bowel flora derived. Type II (20–30% cases) is monomicrobial and the organism responsible is usually *S. pyogenes* but can include *S. aureus*. Type III is more common in Asia, with Gram negative often marine-related organisms. Type IV relates to fungal necrotising fasciitis. Candidal necrotising fasciitis is very rare and is associated with immunocompromised patients. Zygomycotic necrotising infections (*Mucor* and *Rhizopus* spp.) typically affect immunocompromised patients after severe trauma and burns.¹¹

Characteristic surgical findings of 'dishwater fluid' is due to the lysis of polymorphs and serous discharge together with macroscopic fascial necrosis, myositis or myonecrosis. Exotoxin release produces hypotension, multi organ failure and disseminated intravascular coagulation.

Angoules *et al*² also collected data from 355 patients from microbiological studies finding that *S. aureus* was the most commonly cultured pathogenic microorganism being grown in 67 patients (18.9%) followed by Streptococcus group A in 50 (13.7%), *S. viridans* in 36 (10.1%) and coagulase-negative Staphylococcus in 30 (8.5%). *Escherichia coli* species were also isolated in 23 patients (6.5%).

In particular, the incidence of *S. pyogenes* invasive infections has been rising in both the United States and Europe since the 1980s,¹² and as a result both the World Health Organization and subsequently the European Union have started enhanced surveillance initiatives to investigate this incidence.¹³ The UK undertook enhanced population based surveillance in 2003–2004 and found 3775 confirmed cases of *S. pyogenes* overall, and showed a 34% seven-day mortality rate for type II necrotising fasciitis.

Group A streptococcus is traditionally typed by serological detection of cell-wall antigens using T and M antigen typing, however since the late 20th century *S. pyogenes* has been categorised using DNA sequencing by the *emm* gene family, which encodes M protein types.¹⁴ In the UK, *emm* type 1 is generally the most common strain.¹⁵ However, there has been a recent epidemic of highly invasive *emm* type 3 group A *S. pyogenes*, which has been linked to phage-carrying novel virulence genes.¹⁶ Furthermore, there has been a recent rise in a new *emm* type 89 variant in the UK, Europe and North America, which has been linked with recombination of core genomic regions.¹⁵

Owing to the lack of agreed early external clinical signs, a high index of suspicion is key to the early identification and thus treatment of this disease. Early surgical debridement and prompt antibiotic therapy initially covering against aerobic Gram-positive cocci, Gram-negative rods and a variety of anaerobes usually in the form of multidrug regimens can be lifesaving.¹⁷

A multidisciplinary approach is required in managing these complex patients who will require regular review, haemodynamic support and often repeated operations in theatre for further debridement, amputation or disarticulation and subsequent closure/deformity correction with both plastic surgical and orthopaedic input as appropriate.

Materials and methods

We conducted a retrospective review of all patients admitted to Aberdeen Royal Infirmary, a regional tertiary referral centre, with clinically or microbiologically confirmed diagnosis of necrotising fasciitis between August 2006 and February 2016. These patients were identified using a combination of hospital coding from medical records and databases held in the intensive care unit, microbiology laboratory and trauma orthopaedic unit. During the study period, it was not routine practice to send tissue samples taken in theatre for histopathological analysis to confirm necrotising fasciitis on histology, and therefore histology as the gold standard for confirmation of diagnosis was not available. Although initially based on either clinical suspicion or microbiology findings, the diagnoses of necrotising fasciitis was confirmed by the surgical team at the time of their debridement or fasciotomy by the presence of necrotic tissue macroscopically.

Admission documentation, patient characteristics, investigations, operative interventions, blood tests and microbiological samples were assessed.

The mode of admission or referral pathway and admission to higher care was also noted. Infection site, causative organism and antibiotic administered were confirmed using case note review. Operative documentation was scrutinised, and patient outcomes were also recorded.

All samples for microbiology were processed in the Department of Medical Microbiology at Aberdeen Royal Infirmary, with standard UK microbiology laboratory procedures for the processing of tissue samples and deep operative swabs. Significant isolates are identified and referred for antimicrobial sensitivity testing with isolates of *S. pyogenes* being sent to the reference laboratory at the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory, New Lister Building, Glasgow Royal Infirmary for confirmation and *emm* typing.

Results

A total of 36 patients with an identified clinical or microbiological diagnosis of necrotising fasciitis were admitted to Aberdeen Royal Infirmary between August 2006 and February 2016. There were 15 female and 23 male patients with mean age of 52 years (range 19–78 years). Table 1 shows a summary of the cases in our unit.

Microbiology

Our local protocol requires deep tissue samples to be sent at the time of surgical intervention. In 32 of the 36 cases, appropriate samples were sent according to this standard. For three patients, no samples at all were received in the microbiology laboratory. In one case, a wound swab and blood culture bottle were sent. In one case, the samples received cultured no organism. The rate of recovery of organisms was therefore 96.9% (31/32).

Systemic bacteraemia was uncommon in this group with only four patients having positive blood cultures, each patient had a single organism isolated on culture. These organisms were *E. coli*, *S. pyogenes*, *Bacteroides vulgatus* and *Veillonella* sp.

In our case series, polymicrobial infection (type 1 necrotising fasciitis) was more common in the microbiologically confirmed cases 58% of cases (18/31). Six cases of polymicrobial infection included *S. aureus*. Drug resistance was not a predominant issue in our population with only 1 isolate of extended spectrum beta-lactamase producing *Enterobacteriaceae* and no isolates of methicillin-resistant *S. aureus*, vancomycin resistant *Enterococci*, or carbapenem producing *Enterobacteriaceae*. *Candida* sp. were only isolated in two cases as part of polymicrobial infection.

S. pyogenes was the most common isolate in monomicrobial (type 2 necrotising fasciitis) in 8 of 13 cases followed by *S. aureus* (two cases) and one case each of group C *Streptococcus*, *E. coli* and *Bacteroides*, which is also in keeping with the literature.¹⁸

Emm-typing was available for seven of nine isolates of *S. pyogenes*. This showed that four cases were *emm*-type 1, with one case each of *emm* types 3.1, 76 and 80. Upper-limb involvement was strongly associated with *S. pyogenes* infection (five of seven cases) in this cohort.

General results

Fourteen patients were admitted via referral from accident and emergency, 17 via direct referral from general practice. Three were elective admissions and diagnosis of necrotising fasciitis was made after admission, one patient was a tertiary centre transfer and in one case the mode of referral was unable to be identified. Presenting haemodynamic observations are shown in Table 1. Table 2 shows the medical comorbidities in the population.

Alcohol dependence and smoking were the most common documented medical comorbidity in 12 patients (33%). Previously published risk factors⁷ for necrotising fasciitis, such as diabetes mellitus, intravenous drug abuse, age greater than 50 years, hypertension and malnutrition/obesity are highlighted in Table 1. The mean LRINEC score for the 36 patients was 7.¹⁹

Twenty-nine patients were admitted to the intensive care unit with two patients admitted to the surgical high-dependency unit; 49% of patients presented within working hours (8am to 16pm) and 51% presented outside normal working hours. The average time to theatre from admission was 3.53 hours (range 45 minutes to 18 hours 35 minutes).

Our data show that, in our patient cohort, the pelvis and perineum was the most commonly affected site. Thirty patients required the use of three or more antibiotics in combination with flucloxacillin (28/36 cases), benzylpenicillin (24/36 cases), clindamycin (23/36 cases), gentamycin (15/36 cases) and metronidazole (15/36 cases) being the most commonly used antibiotics. Piperacillin/tazobactam was also frequently used (9/36 cases). Our local protocol advises a combination of intravenous flucloxacillin 2 g six hourly, benzylpenicillin 2.4 g intravenous six hourly, intravenous clindamycin 1.2 g eight hourly and gentamicin 7 mg/kg and the prescribing reflects this protocol.

Outcomes

A total of 29 of the 36 patients were discharged, 6 patients died acutely and 1 died within a year of the necrotising fasciitis diagnosis, of unrelated disease. This acute mortality rate of 17% is in keeping with or better than other comparable published series mortality figures.²⁰ In total, six amputations or disarticulations were performed from a total of 82 operations carried out with radical debridement being as expected the most common primary operation.

Discussion

Aberdeen Royal Infirmary appears to receive a relatively high number of cases of necrotising fasciitis. The expected presenting haemodynamic status of the patients reflect what has been previously described of slight hypotension, normothermia, mildly elevated heart rate and respiratory rate. From our data, we can see that an admission respiratory rate which is grossly elevated. For example, above 26 breaths/minute ranging to 55 breaths/minute appears to be associated with increased mortality but due to the numbers involved in our study this cannot be statistically proven.

Table 1 Summary of cases													
No.	Mode of admission	Risk factors	Initial temp. (°C)	Initial heart rate (bpm)	Initial blood pressure (mmHg)	Initial respiratory rate (breaths/minute)	LRINEC score	qSOFA score	Microbiology (category)	Antibiotic treatment	Anatomical region	Definitive surgery	Outcome
1	elective	age > 50 years	37.7	75	138/92	16	3	0	no tissue samples	gentamicin, metronidazole, co-trimoxazole, amoxicillin	chest	no surgery	discharged
2	A&E	none	35.9	88	95/54	20	7	1	<i>Staphylococcus aureus</i> (type II)	flucloxacillin, gentamicin, benzylpenicillin, metronidazole	lower limb	debridement and fasciotomy	discharged
3	A&E	age > 50 years	34.9	128	102/74	22	10	2	<i>S. pyogenes emm</i> type 1.0 (type II)	flucloxacillin, benzylpenicillin, clindamycin, metronidazole, Tazocin®	abdomen	debridement	died acutely
4	GP	age > 50 years, alcohol dependence	40.5	100	105/62	15	8	0	<i>S. aureus</i> , <i>Escherichia coli</i> (type I)	ceftriaxone, metronidazole	abdomen	debridement	discharged
5	A&E	alcohol dependence, type II diabetes mellitus	35.9	140	93/63	26	7	2	<i>S. milleri</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>S. agalacticae</i> (type I)	gentamicin, Tazocin®	abdomen	debridement	discharged
6	hospital transfer	age > 50 years, type II diabetes mellitus	38	100	133/72	not recorded (intubated)	8	2	<i>Bacteroides fragilis</i> (type I)	gentamicin, vancomycin, metronidazole, ciprofloxacin	pelvis and perineum	debridement of Fournier's gangrene, laparotomy and defunctioning colostomy	discharged
7	GP	intravenous drug abuse	36.5	100	101/57	16	9	0	<i>Veillonella sp.</i> , <i>Enterobacter cloacae</i> , <i>S. milleri</i> (type I)	flucloxacillin, benzylpenicillin, metronidazole	pelvis and perineum	debridement	discharged
8	elective	age > 50 years	36.5	78	152/90	17	0	0	<i>E. coli</i> , <i>Candida galbrata</i> (type I)	flucloxacillin, Tazocin®	abdomen	debridement, laparotomy and defunctioning colostomy	died acutely
9	elective	none	36	58	118/62	15	2	0	no tissue samples	flucloxacillin	chest	debridement	discharged

10	GP	age > 50 years	35.7	105	125/68	17	7	0	mixed anaerobes, <i>Candida sp.</i> , <i>B. vulgatus</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin, metronidazole	pelvis and perineum	debridement, laparotomy and defunctioning colostomy	discharged
11	A&E	alcohol dependence	40.5	110	95/58	15	5	1	<i>Peptoniphilus asaccharolyticus</i> , <i>S. aureus</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, co-amoxiclav	head and neck	debridement	discharged
12	GP	age > 50 years, alcohol dependence	36.3	80	126/76	12	4	0	<i>S. aureus</i> , (type II)	flucloxacillin, teicoplanin	lower limb	debridement and fasciotomy	discharged
13	GP	age > 50 years, alcohol dependence	38.4	105	187/120	15	6	0	<i>S. aureus</i> , <i>Proteus mirabilis</i> , <i>Providentia rettgeri</i> (type I)	flucloxacillin, benzylpenicillin, gentamicin, metronidazole	pelvis and perineum	debridement of Fournier's gangrene	discharged
14	GP	age > 50 years, alcohol dependence, obesity	38	119	107/68	36	7	1	<i>B. fragilis</i> , <i>E. coli</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	abdomen	debridement, laparotomy and defunctioning colostomy	discharged
15	GP	intravenous drug abuse	37.3	101	101/65	17	8	0	<i>S. aureus</i> , <i>Prevotella bivia</i> , <i>B. melangiogenics</i> , (type I)	flucloxacillin, benzylpenicillin, clindamycin, metronidazole, teicoplanin	lower limb	debridement and fasciotomy	discharged
16	GP	age > 50 years, type II diabetes mellitus	40	90	110/56	16	10	0	<i>S. milleri</i> , <i>E. coli</i> , mixed anaerobes (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	debridement	discharged
17	GP	intravenous drug abuse	38	100	80/50	18	10	1	mixed anaerobes (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	debridement	discharged
18	A&E	age > 50 years	38	120	120/70	20	6	1	<i>S. pyogenes</i> , <i>emm</i> type 3.1 (type II)	flucloxacillin, gentamicin, Tazocin®	upper limb	debridement and fasciotomy	discharged
19	A&E	age > 50 years, alcohol dependence	36.4	124	69/54	14	10	1	<i>S. pyogenes</i> , <i>emm</i> type 76.0 (type II)	flucloxacillin, clindamycin, ceftriaxone, metronidazole	lower limb	below knee amputation	discharged
20	GP	alcohol dependence, obesity	38.5	119	107/68	36	7	1	<i>E. coli</i> , <i>B. fragilis</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	debridement, laparotomy and defunctioning colostomy	discharged

Table 1 (Continued)													
No.	Mode of admission	Risk factors	Initial temp. (°C)	Initial heart rate (bpm)	Initial blood pressure (mmHg)	Initial respiratory rate (breaths/minute)	LRINEC score	qSOFA score	Microbiology (category)	Antibiotic treatment	Anatomical region	Definitive surgery	Outcome
21	A&E	age > 50 years	36.5	112	109/80	55	6	2	<i>S. pyogenes emm</i> type 1 (type II)	flucloxacillin, benzylpenicillin, gentamicin	upper limb	arm amputation	died acutely
22	GP	age > 50 years	35.1	78	143/86	19	8	0	<i>Klebsiella, citrobacter</i> (type I)	co-amoxiclav, temocillin and metronidazole	lower limb	debridement	discharged
23	A&E	intravenous drug abuse	36.5	95	118/79	15	8	0	no tissue samples	clindamycin, meropenam	pelvis and perineum	debridement	discharged
24	GP	age > 50 years	39.3	118	153/83	12	8	0	<i>Enterococcus, coliform</i> (type I)	flucloxacillin, clindamycin, metronidazole, gentamicin, Tazocin®, telcoplanin	pelvis and perineum	debridement	discharged
25	GP	age > 50 years, alcohol dependence	35.7	110	111/64	18	8	0	<i>E. coli</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, Tazocin®	pelvis and perineum	debridement, laparotomy and defunctioning colostomy	discharged
26	GP	age > 50 years	38.4	127	90/70	18	8	1	no tissue samples	benzylpenicillin, clindamycin, gentamicin, metronidazole, Tazocin®	upper limb	debridement and fasciotomy	discharged
27	A&E	age > 50 years, alcohol dependence	36	78	99/51	14	6	1	<i>Peptostreptococcus anaerobius, Prevotella disciens</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	lower limb	hip disarticulation	died within 1 year
28	A&E	age > 50 years, alcohol dependence	37.2	121	146/86	22	6	1	<i>S. sanguinis, mixed anaerobes</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin, Tazocin®	head and neck	debridement	died acutely
29	A&E	none	38.5	128	106/56	24	8	1	<i>S. pyogenes emm</i> type 1 (type II)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	upper limb	debridement and fasciotomy	discharged
30	A&E	age > 50 years	39.4	106	144/102	19	7	0	<i>S. pyogenes, S. aureus, E. coli</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, Tazocin®, linezolid	upper limb	debridement and fasciotomy	discharged

31	GP	age > 50 years	37.8	118	118/62	16	6	0	<i>S. pyogenes</i> (type II)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	upper limb and fasciotomy	debridement	discharged
32	GP	age > 50 years, intravenous drug abuse	37.0	80	110/65	12	9	0	<i>S. aureus</i> , <i>Enterococcus faecalis</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	debridement	discharged
33	A&E	intravenous drug abuse, alcohol excess	36.5	95	100/40	not recorded	7	n/a	Group C <i>Streptococcus</i> (type I)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	hindquarter amputation	discharged
34	GP	intravenous drug abuse	35.7	76	110/78	12	9	0	no growth	flucloxacillin, benzylpenicillin, clindamycin, gentamicin	pelvis and perineum	debridement	discharged
35	A&E	intravenous drug abuse	36	110	unrecordable	50	7	3	<i>S. pyogenes</i> , <i>emm</i> type 80 (type II)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin, metronidazole	upper limb arm amputation		died acutely
36	A&E	age > 50 years	36.5	130	75/50	55	6	3	<i>S. pyogenes</i> , <i>emm</i> type 1 (type II)	flucloxacillin, benzylpenicillin, clindamycin, gentamicin, metronidazole, ciprofloxacin	upper limb shoulder disarticulation		died acutely
A&E, accident and emergency department; GP, general practitioner;													

Table 2 Medical comorbidities in the patient population

Comorbidities	Cases	
	(n)	(%)
Alcohol dependence	10	28
Intravenous drug abuse	9	25
Psychiatric history	6	17
Hepatitis C	6	17
Cancer	5	14
Deep vein thrombosis	5	14
Type II diabetes mellitus	3	8
Chronic kidney disease	3	8
Cerebrovascular accident	2	6
Human immunodeficiency virus	1	3
Morbid obesity	1	3
Paraplegia	1	3
Peripheral vascular disease	1	3
Myocardial infarction	1	3
Rheumatoid arthritis	1)	3

Aberdeen Royal Infirmary has relatively good outcomes with 81% of presenting patients being discharged from hospital and only 17% dying acutely in hospital; 14% of the patients required amputations or disarticulations, though of those requiring amputation or disarticulation, 50% died which most likely reflects the severity of the disease.

A significant proportion of our patients were immunocompromised secondarily due to other comorbidities such as diabetes, pre-existing cancer, chronic renal failure and rheumatoid arthritis. Twenty-five per cent of our patient cohort were intravenous drug abusers, with a 56% hepatitis C diagnosis in this subgroup. This information demonstrates the likelihood of underlying medical comorbidities predisposing to an increased risk of bacterial invasion.

One weakness of our study is that histological confirmation of necrotising fasciitis is not present for every patient reported. This is due to the fact that sending tissue samples to the pathology laboratory for confirmation of necrotising fasciitis was not routine practice in our unit before this study. Therefore, it could be possible that not all of these cases are true necrotising fasciitis, and this may explain our lower mortality rates than previously reported studies. However, a consultant surgeon from the relevant specialty was present and scrubbed during these procedures and tissue necrosis was reported macroscopically at the time of surgery. Combined with microbiological analysis and multidisciplinary clinical acumen before debridement, misdiagnosis is less likely. Although trauma is important risk factor in necrotising fasciitis, none of our patients had a history of trauma. None of these patients had battle injuries as our unit is not a designated military hospital in the UK.

The variety of bacteria affecting our patient cohort show the difficulty in initial management and treatment with targeted antibiotic therapy.

In our study population, type 1 necrotising fasciitis was more common than type 2, in keeping with other European studies.²¹ We found 21 cases of type I necrotising fasciitis and 10 cases of type II. There were no cases of type III (marine organisms) and no cases of purely type IV (fungal). Although in two cases *Candida* was cultured was in conjunction with multiple other organisms, so was classified as type I. The predominant isolate in type 2 necrotising fasciitis was *S. pyogenes*, which is common in UK based studies. The incidence of *S. pyogenes* increased over time in this study with the nine cases occurring between 2013 and 2016. This coincides with a general increase of notifications of invasive group A streptococcal disease in the UK.²²

Of the six patients who died acutely in our cohort, four of these patients had *S. pyogenes* identified on culture. *S. pyogenes* is known to be associated with mortality and this remains clear from our experience.^{8,15,18} *Emm* typing has now become standard practice in UK microbiology laboratories and is particularly relevant for the identification of strains and to recognise 'true' outbreaks.²³ Although *emm* types 1, 3 and 89 are common in the UK and associated with invasive disease.^{15,15,16,24}

Emm type 1 *S. pyogenes* was the most common in our group and we did not identify any isolates of the more recently identified *emm* 89 type. The time to theatre average was 3.54 hours but there were significant range differences from 45 minutes to 18 hours and 35 minutes. The difficulty in diagnosis is highlighted by these figures.

The pelvis and perineum was as expected the most commonly affected site and required input from general, plastics and orthopaedic surgeons for operative treatment. Fournier's gangrene (polymicrobial necrotising fasciitis of the perianal, perineal or genital areas)²⁵ was only identified in two patients in our cohort. The majority of our patients required ongoing treatment in the intensive care unit requiring further medical support and subsequent rehabilitation.

Necrotising fasciitis is a surgical emergency with a high rate of morbidity and mortality. The data from the North East of Scotland have allowed further development of standard protocols for initial identification, treatment and surgical intervention. Our data show that this disease presents with initially slight clinical patient abnormality and therefore there is a need for a high index of suspicion to allow prompt intervention.

We found a wide range in time to theatre in our cohort, with a delay of up to over 18 hours for one patient. Although the reason for this are multifactorial, the main reason our delays were identification of necrotising fasciitis and the subsequent clinical decision to treat with debridement. Prompt recognition of necrotising fasciitis is the first step, and thereafter a clear plan initiated of multimodal antibiotic therapy and debridement in theatre. Most of our patients had underlying medical comorbidities and this should raise suspicion in the unwell adult

for necrotising fasciitis with swelling, erythema and pain. The causative bacteria can be variable but initial therapy should cover polymicrobial necrotising fasciitis as per local regional antimicrobial guidelines. Until microbial aetiology and sensitivities are known, broad-spectrum antibiotics should be administered that cover the most common aetiologies for necrotising fasciitis. Until group A streptococcal involvement is excluded, antimicrobial agents that inhibit toxin productions such as clindamycin or linezolid should be included empirically.²⁶ Classically necrotising fasciitis is a surgical emergency and expedient surgical treatment is also of paramount importance. In our centre we have a six-category alphabetised booking system for emergency theatres, with category 'A' booked patients aimed to be brought to theatre within 45 minutes. We are fortunate to have multiple emergency theatre teams on site and in our experience if a patient is booked as a high category, although there can be the occasional logistical delays transporting the patient within the hospital site, in general the criteria is honoured, and the patient reaches theatre on time. We found that delays in time to theatre were caused by a delay in diagnosis and clinical treatment planning. We have strived to decrease time to theatre by attempting to identify these patients with a 'Think Nec Fasc' educational programme and prompt posters in key clinical areas such as the emergency department resuscitation bay, the trauma and orthopaedic ward and the plastic surgery ward. This program is designed to decrease the time to diagnosis and time to theatre as an aid to decision making.

The quick sepsis-related organ failure assessment (qSOFA) score²⁷ was introduced by the Sepsis-3 group in 2016 as an abbreviated version of the sepsis-related organ failure assessment (SOPA) score often used in critical care help identify patients who are at risk of poor outcomes with infection. Although this scoring system did not exist prior to our cohort, we have scored each patient retrospectively based on their initial observations in hospital to identify if this scoring system may help in identifying necrotising fasciitis patients. The scoring system is out of 3, with a score of 2 or higher associated with an intensive care stay or death. One point is allocated for low blood pressure (systolic ≤ 100 mmHg), high respiratory rate (≥ 22 breaths/minute) or altered mental state (Glasgow Coma Score ≤ 14).²⁷

Of the four patients with type II necrotising fasciitis who died acutely, all had a qSOFA score of 2 or more on initial observations. This is reflective of the aggressive nature of type II necrotising fasciitis. Of the remaining two patients in our cohort with type I necrotising fasciitis who died acutely they scored 0 and 1 on the qSOFA score on initial observations, highlighting that no scoring system is foolproof. LRINEC scores for all of our patient cohort are shown in Table 1. In clinical practice we have not found this system particularly useful in diagnosis or as an aid to decision making, as although a score of greater than 6 is associated with necrotising fasciitis, a score below 6 does not rule it out. Introduction of regular use of scoring systems including LRINEC and qSOFA are

certainly useful adjuncts, but ultimately it remains a clinical diagnosis.

Before this study, a specific necrotising fasciitis care pathway did not exist in our hospital. Although we identified the requirement for a multi-disciplinary approach. One of the problems highlighted here was referral from both emergency department staff and general practitioners to multiple specialties (accident and emergency, general surgery, orthopaedics, plastics) but with no consensus as to which specialties and how many to involve. The 'Think Nec Fasc' programme highlights all suspected necrotising fasciitis patients to be referred to plastic surgery as a standard, but also subcategories the location to further specialties to ensure multidisciplinary involvement early on. For example, if there is limb involvement then refer to plastics and orthopaedics also, if there is abdominal involvement plastics and general surgery, and if there is evidence of vascular compromise refer to the vascular surgeons as an adjunct. In particular, those patients with a high qSOFA score should be considered for early surgical involvement.

Although hyperbaric oxygen has been reported to be of benefit in isolated cases²⁸ we have not used this for the treatment of necrotising fasciitis in our unit. Logistically, treating acutely septic patients with hyperbaric oxygen is complicated and the hyperbaric department on our clinical campus is mainly used for diving related injuries and illness. Immunoglobulin therapy is an emerging field and has been successfully used to treat necrotising fasciitis in combination with traditional treatments.²⁹ Although not used in this cohort, it could be considered in future cases, particularly in streptococcal toxic shock, although current evidence is conflicting regarding its efficacy.³⁰

Conclusion

We recommend treating type II necrotising fasciitis more aggressively and paying particular attention to patients with a high qSOFA score on initial observations, as we have found this broadly to be associated with mortality. We also recommend a necrotising fasciitis care pathway with clear agreed hospital-wide guidelines for specialties to involve which will aid in timely decision making.

When treated efficiently and effectively, we have found that patients with this life-threatening disease can benefit from life-saving treatment. Even with the multidisciplinary approach and prompt clinical diagnosis and treatment, necrotising fasciitis carries significant mortality.

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