BMJ Paediatrics Open

The BRiCK study: an analysis of the Burden and Response in Cellulitis in Kids

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2021-001130
Article Type:	Original research
Date Submitted by the Author:	17-Apr-2021
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Keywords:	Epidemiology, Microbiology, Dermatology

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Title: The BRiCK study: an analysis of the Burden and Response in Cellulitis in Kids

Short Title: Cellulitis Burden and Response

ORIGINAL ARTICLE

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Key words:
Cellulitis; skin and soft tissue infections; Children; *Staphylococcus aureus; Streptococcus pyogenes*

Word Count: 2357

Abstract

Aim: To characterise the epidemiology, clinical features and treatment of paediatric cellulitis.

Methods: A retrospective study of children presenting to a paediatric tertiary hospital in Western Australia, Australia in 2018.

Results: 302 episodes of cellulitis were included comprising 206 (68.2%) admitted children and 96 (31.8%) non-admitted children. The median age was 5 years (interquartile range [IQR] 2-9), 40 (13.2%) were Aboriginal and 180 (59.6%) male. The extremities were the most commonly affected body site amongst admitted and non-admitted patients. Admitted patients were more likely to have facial cellulitis compared with non-admitted patients (27.2% vs 5.2%, p<0.01). Wound swab was the most frequent microbiological investigation (133/302, 44.0%), yielding positive cultures in the majority of those tested (111/133, 83.5%). The most frequent organisms identified were *Staphylococcus aureus* (94/111, 84.7%) (methicillin susceptible *S. aureus* (60/94, 63.8%), methicillin resistant *S. aureus* (34/94, 36.2%)) and *Streptococcus pyogenes* (22/111, 19.8%) with 14 identifying both *S. aureus* and *S. pyogenes*. Intravenous (IV) flucloxacillin was the preferred antibiotic (154/199, 77.4%), with median IV duration 2 days (IQR 2-3), oral 6 days (IQR 5-7) and total 8 days (IQR 7-10).

Conclusions: Cellulitis is a common reason for presentation to a tertiary paediatric hospital. We confirm a high prevalence of extremity cellulitis and demonstrate that children with facial cellulitis often require admission. Cellulitis disproportionately affected Aboriginal children and children below five years. Prevention involves early recognition and treatment of skin infections.

What is already known on this topic:

1. Cellulitis is a common skin infection, caused by *Staphylococcus aureus* and *Streptococcus pyogenes*.
2. Cellulitis contributes the largest portion of the disease burden caused by *S. pyogenes* in Australia.
3. Cellulitis in children includes periorbital infection and infection of the extremities.

What this paper adds:

1. Cellulitis is a common condition in children accounting for 1.1% of presentations to the paediatric tertiary hospital in Western Australia.
2. Facial cellulitis is a common cause for admission to hospital, with a large proportion of this being periorbital cellulitis.
3. Children under five years and Australian Aboriginal children are disproportionately admitted for cellulitis.

Introduction

Cellulitis is a localised skin infection due to disruption of the physical barrier allowing pathogen entry.[1,2] In children it is commonly due to trauma, insect bites or varicella, predominantly affecting the face or extremities.[2-4] Common pathogens are *Streptococcus pyogenes* (Group A streptococci (GAS)) and *Staphylococcus aureus*.[1,2,6-8] Cellulitis is non-purulent, making pathogen detection challenging, hence GAS contribution may be underestimated.[1] In Australia, cellulitis contributes the greatest burden of GAS disease across all ages, ahead of impetigo, pharyngitis and invasive GAS.[9] An improved understanding of the burden of paediatric cellulitis will inform the role for a GAS vaccine in cellulitis prevention.

Although presumably common, few studies describe the burden of cellulitis in Australian children. The proportion of admissions, clinical features and treatment of cellulitis in hospitalised children in Australia remains unknown. In one linked dataset, skin and soft tissue infections (SSTI) accounted for 3% of all paediatric hospital admissions, with cellulitis as the second most frequent admission reason.[5] Aboriginal children were 15 times more likely to be admitted for SSTI compared to non-Aboriginal.[5] Furthermore, SSTI are recognised as the most common group of bacterial infections in children.[10] Although cellulitis is often managed in primary care, hospitalisation is required for severe, progressive cellulitis.[5,11,12]

We aimed to describe the epidemiology, clinical features, treatment and adherence to guidelines for cellulitis in children presenting to hospital.

Methods

Study design and population

A retrospective chart review was conducted at Perth Children's Hospital (PCH), the only tertiary paediatric centre in Western Australia (WA) with an estimated 60,000 presentations to the Emergency Department (ED) annually.

Records were identified using the International Classification of Disease (ICD) 10 coding for cellulitis (Table S1). At PCH, all inpatient records from 1 January to 31 December 2018 were screened for inclusion. Due to the time constraints of the study ED presentations from 1 July to 31 December 2018 only were reviewed. Exclusion criteria were patients aged ≥16 years, alternative diagnosis more likely on detailed chart review or where insufficient documentation was available to assess for inclusion. Orbital cellulitis and odontogenic cellulitis were excluded from this review, as their management is considerably different from that of traditional cellulitis.

Cellulitis (ICD10 codes L03.01 – L03.11 and H60.1 – H60.13) is a bacterial infection of the superficial layers of the skin (epidermis, dermis and subcutaneous tissues) characterised by erythema, pain, warmth, swelling and rapid progression. Recurrent cellulitis was defined as an additional admission for cellulitis occurring >30 days from the index diagnosis to exclude the possibility of counting relapses or treatment failure (representation within 30 days of hospital discharge). SSTI includes cellulitis, impetigo, skin abscess, scabies and fungal infections. Extremities are the hands and feet including digits. Geographical location was ascertained by postcode, grouped according to Australian Statistical Geography Standard Remoteness Structure on the basis of relative access to health care services.[13]

Data Collection

Data was extracted from paper and electronic hospital records, including demographics, admission duration, clinical findings, investigations, management and outcomes. The

characteristics assessed included age, Aboriginal status, geographical location, presence of common co-morbidities and recurrent cellulitis. Data was captured and stored in a standardised purpose-built REDCap database by a medically trained abstracter.[14,15] Adherence to treatment duration was assessed against the IV to oral switch guidelines.[16]

Data analysis

Data was analysed using descriptive and comparative statistics. The proportion of Aboriginal children in the study was compared to the 2016 Census data for WA using a binomial probability test.[17] The frequency of cellulitis affecting specific body sites were compared between admitted and non-admitted patients using Pearson's chi square tests and Fisher's exact tests as appropriate. Analysis of variance (ANOVA) compared age at diagnosis between admitted and non-admitted patients. The number of patients who attended follow-up with a paediatrician was compared using Pearson's chi square test. Data was analysed using Stata version 16.0 (*Stata Statistical Software: Release 16*. College Station, TX).

Ethics approval

The study was approved by the Western Australian Aboriginal Health Ethics Committee (HREC Ref 923) with reciprocal approval from the University of Western Australia and the GEKO program at the Child and Adolescent Health Service (PRN 29036).

Patient and Public Involvement

Patients and members of the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

Results

Eight-hundred and sixty-seven patients with a primary diagnosis of cellulitis presented to PCH in 2018. Hospital coding errors were present in 11.8% (102/867) of cases: 40 patients excluded with an alternative primary SSTI and 62 with different primary diagnoses coded in the ED notes compared to the discharge summary. Ninety- three patients with odontogenic cellulitis were also excluded. Of the remaining 672 patients, 206 (30.6%) were included in the 12-month admitted cohort and 96 (14.2%) in the 6-month non-admitted cohort (Figure 1). Cellulitis accounted for 1.1% (672/62,985) of all presentations and 0.8% (206/26,884) of annual admissions to PCH.

One hundred and eighty (59.6%) children were male (Table 1). Eleven (3.6%) children re-presented within the study period: 3 children with recurrent cellulitis of a different body site, 4 children with treatment failure requiring re-admission to hospital, 1 child requiring admission after unsuccessful discharge from ED and 3 children with treatment failure representing to ED.

Children below 5 years were over-represented, 147/302 (48.7%). The mean age of children admitted to hospital was 5 years (SD=4.8) and for non-admitted patients 6 years (SD=4.0).

Aboriginal children with cellulitis (40/302, 13.2%) were significantly over-represented compared to being 3.9% of the WA paediatric population ($p<0.01$). Aboriginal children were more likely to be hospitalised (36/40, 90.0%) than their non-Aboriginal peers (170/262, 64.9%).

Table 1. Patient Demographics

		Total (n=302)	Admitted (n=206)	Non-admitted (n=96)
Sex	Male	180 (59.6)	121 (58.7)	59 (61.5)
	Female	122 (40.4)	85 (41.3)	37 (38.5)
Age Group (years)	<5	147 (48.7)	100 (48.5)	47 (48.9)
	5-9	87 (28.8)	56 (27.2)	31 (32.3)
	10-14	52 (17.2)	36 (17.5)	16 (16.7)
	15	16 (5.3)	14 (6.8)	2 (2.1)
Indigenous status	Aboriginal	40 (13.2)	36 (17.5)	4 (4.2)
	Non- Aboriginal	262 (86.8)	170 (82.5)	92 (95.8)
Geographical location	Metropolitan	282 (93.4)	190 (92.2)	92 (95.8)
	Regional/Remote	17 (5.6)	15 (7.3)	2 (2.1)
	International	3 (1.0)	1 (0.5)	2 (2.1)
Previous admission	Cellulitis	27 (8.9)	19 (9.2)	8 (8.3)
	Other SSTI	23 (7.6)	21 (10.2)	2 (2.1)
Comorbidities	Eczema	18 (6.0)	13 (6.3)	5 (5.2)
	Surgery	3 (1.0)	2 (1.0)	1 (1.0)
	URTI	13 (4.3)	10 (4.9)	3 (3.1)

Values are n (%)

†Upper respiratory tract infection includes sinusitis, parasinusitis and tonsilitis/pharyngitis

The most common causes of cellulitis in the study group were insect bites (66/302, 21.8%), trauma (60/302, 19.9%) and impetigo (17/302, 5.6%) (Table 2). In both groups, the most affected body location was the extremities (119/302, 39.4%). The proportion of facial cellulitis was significantly greater amongst admitted patients compared to non-admitted patients (56/206, 27.2% vs 5/96, 5.2%, p<0.01).

Table 2. Possible causes and location of cellulitis

Possible source	Admitted (n=206)	Non-admitted (n=96)
Unknown	76 (36.9)	30 (31.2)
Skin sore	17 (8.3)	-
Trauma	45 (21.8)	15 (15.6)
Insect bite	31 (15.0)	35 (36.5)
Lymphoedema	1 (0.5)	-
Other†	36 (17.5)	16 (16.7)
Location‡	**Admitted (n=206)**	**Non-admitted (n=96)**
Face	56 (27.2)	5 (5.2)
Head and neck	9 (4.4)	3 (3.1)
Upper limbs	14 (6.8)	13 (13.5)
Torso	8 (3.9)	7 (7.3)
Groin and buttocks	11 (5.3)	16 (16.7)
Lower limbs	54 (26.2)	21 (21.9)
Extremities	76 (36.9)	43 (44.8)

Values are n(%)

†other includes animal bite, recent injection site, rash, wound or foreign body infection and sinusitis

‡some cases involved infection of multiple sites

Most admitted patients (199/206, 96.6%) received IV antibiotics, frequently flucloxacillin (154/199, 77.4%) for a median duration of 2 days (IQR 2-3) before step-down to oral antibiotics (Table 3). The median duration of oral antibiotics was 6 days (IQR 5-7). The median total duration of antibiotic therapy was 8 days (IQR 7-10). The most common IV antibiotic regimen for periorbital cellulitis was IV ceftriaxone and flucloxacillin (38/46, 82.6%).

Sixteen (5.3%) admitted children were discharged to the Hospital in the Home (HITH) program for further IV antibiotics. The majority of these children had periorbital cellulitis (9/16, 56.3%).

Fifty-two patients underwent surgical procedures including subcutaneous abscess drainage (37/52, 71.2%), finger or toe-nail removal (14/52, 26.9%) and foreign body removal (1/52, 1.9%).

Table 3. Management and outcomes of patients admitted to PMH/PCH in 2018

	Total (n=206)	Periorbital (n=46)	Other (n=160)
Duration of IV antibiotics, days, median (IQR)	2 (2-3)	3 (2-3)	2 (2-3)
IV antibiotic n (%):	n=199	n=45	n=154
Flucloxacillin	154 (77.4)	41 (91.1)	113 (73.3)
Cefotaxime	2 (1.0)	2 (4.4)	
Ceftriaxone	47 (23.6)	41 (91.1)	6 (3.9)
Cefazolin	38 (19.1)	5 (11.1)	33 (21.4)
Clindamycin	10 (5.0)	-	10 (6.5)
Cotrimoxazole	2 (1.0)	-	2 (1.3)
Benzylpenicillin	1 (0.5)	-	1 (0.6)
Piperacillin/tazobactam	15 (7.5)	4 (8.9)	11 (7.1)
Vancomycin	27 (13.6)	2 (4.4)	25 (16.2)
Other	3 (1.5)	-	3 (1.9)
Duration of oral antibiotics, days, median (IQR)	6 (5-7)	7 (5-8)	5 (5-7)
Oral antibiotic on discharge, n (%):	n=192	n=42	n=150
Flucloxacillin	20 (10.4)	1 (2.4)	19 (12.7)
Cephalexin	103 (53.6)	13 (30.9)	90 (60.0)
Clindamycin	8 (4.2)	1 (2.4)	7 (4.7)
Cotrimoxazole	20 (10.4)	2 (4.8)	18 (12.0)
Amox/clav duo forte	37 (19.3)	24 (57.1)	13 (8.7)
Amoxicillin	2 (1.0)	1 (2.4)	1 (0.7)
Other	4 (2.1)	-	4 (2.7)
Total duration of antibiotic therapy, median (IQR)	8 (7-10)	9 (8-11)	8 (7-10)
Surgery, n (%)	52 (25.2)	-	52 (32.5)
Duration of admission, median (IQR)	3 (2-4)	3 (2-4)	3 (2-4)
Discharged to HITH, n (%)	16 (7.8)	9 (19.6)	7 (4.4)
Follow up with paediatrician documented n(%)	80 (38.8)	15 (32.6)	65 (40.6)

Most non-admitted patients received oral antibiotics only (93/96, 96.9%), commonly cephalexin (70/90, 72.9%) for a median duration of 5 days (IQR 5-7) (Table S2). Documented

follow up was less likely in non-admitted patients compared to those admitted (11.5% vs 38.8%, $p < 0.01$).

The most frequent investigations were full blood count, C-reactive protein and wound swab (Table 4). Blood cultures were performed in 45.6% (94/206) of admitted cases with only two positive results: *Cellulomonas* species and coagulase negative *Staphylococcus* – both probable skin contaminants. Investigations were less common in non-admitted patients.

Table 4. Investigations carried out in children presenting with cellulitis

	Admitted (n=206)	Non-admitted (n=96)
Full blood count performed n (%)	168 (81.6)	5 (5.2)
White blood cell, mean (SD)	13.3 (10.2)	9.83 (3.5)
Elevated† n (%)	96 (57.1)	1 (20.0)
C-Reactive Protein performed, n (%)	166 (80.6)	5 (5.2)
C-Reactive Protein, mean (SD)	31.1 (47.2)	8.3 (12.8)
Elevated† n (%)	111 (66.9)	2 (40.0)
Blood culture performed, n (%)	94 (45.6)	2 (2.1)
Organism identified, n (%)	1 (1.1)	-
Wound swab performed, n (%)	120 (58.3)	13 (13.5)
Organisms identified, n (%)	101 (84.1)	10(76.9)
Imaging, n (%)	123 (59.7)	14 (14.5)
Ultrasound scan, n (%)	35	3
X-ray, n (%)	71	12
Computed tomography, n (%)	13	-
Magnetic resonance imaging, n (%)	4	-

†elevated as per laboratory reported reference range

Wound swabs yielded pathogens in 36.8% (111/302) of patients. *S. aureus* was most frequently identified (n=94, 84.7%): 60 (63.8%) methicillin sensitive *S. aureus* (MSSA); 34 (36.2%) methicillin resistant *S. aureus* (MRSA); and 22 (19.8%) *S. pyogenes* (Table 5). Fourteen

children had mixed gram-positive infections: MSSA and *S. pyogenes* (n=10); MRSA and *S. pyogenes* (n=3); MSSA and MRSA (n=1). *S. pyogenes* was detected in isolation in only 9 cases.

Table 5. Microorganisms identified on wound swab

Microorganism	Admitted (n=101)	Non-admitted (n=10)
Streptococcus pyogenes	20 (19.8)	2 (20.0)
Staphylococcus aureus	86 (85.1)	8 (80.0)
Methicillin Sensitive *S. aureus*	54 (53.5)	6 (60.0)
Methicillin Resistant *S. aureus*	32 (31.7)	2 (20.0)
Staphylococcus lugdunensis,	1 (1.0)	-
Neisseria gonorrhoeae	2 (2.0)	-
Pseudomonas aeruginosa	1 (1.0)	1 (10.0)
Other†	7 (6.9)	-

†other includes *Staphylococcus intermedius, Streptococcus dysgalactiae, Streptococcus intermedius,* mixed anaerobes*, Eikenella corrandes, Pasteurella multocida*

Discussion

This is the first study to analyse the epidemiology and treatment of cellulitis at a tertiary paediatric centre in Australia. We have demonstrated four key findings: (i) cellulitis is common accounting for 1.1% of all presentations to the tertiary hospital; (ii) patients with facial cellulitis are more frequently admitted to hospital; (iii) children under five years and Aboriginal children are disproportionately affected by cellulitis; and (iv) 3.6% of the cohort had recurrent cellulitis.

We confirm that paediatric cellulitis accounts for a significant burden on the hospital system, consistent with previous linked data showing 3% of paediatric hospital admissions in WA were due to SSTI, with cellulitis the second most common diagnosis.[5] The CHOICE trial in Melbourne reported 700 presentations of cellulitis to the Royal Children's Hospital over 17-

months, with 304 (43%) admissions.[18] Our cohort has a higher presentation rate of approximately 56 children per month compared to only 41 per month in Melbourne, whilst our overall admission rate was slightly lower at 30.7%. In the Northern Territory, 2.3% of all paediatric presentations to the Royal Darwin Hospital ED in 2013 were for cellulitis.[19] Prevention of cellulitis will reduce the burden of hospitalisation on children and families. Cellulitis prevention strategies include insect repellent, antiseptics for minor trauma and possibly vaccination when a GAS vaccine becomes available over the next decade. A recent study investigating the health and economic burden of GAS disease in Australia found that, out of the 24 diseases caused by GAS, cellulitis contributed to over half the total burden in both children and adults, further confirming the need for a GAS vaccine.[9]

Children with facial cellulitis are disproportionately hospitalised. This may be representative of the need for multidisciplinary specialist care and the potential for sight-threatening and life-threatening complications in children with periorbital cellulitis. All but one child with periorbital cellulitis in our study group were admitted for IV antibiotics and specialist review (ophthalmology and otolaryngology). This management is supported by in the literature, which suggests that multidisciplinary management and early intervention can improve outcomes for children with periorbital cellulitis.[20] Canadian data has also demonstrated over-representation of facial cellulitis amongst paediatric inpatients (26.8%) compared to non-admitted patients (16.3%) with cellulitis.[21] Similarly, Canadian ED presentations were also predominantly extremity cellulitis (69.5%), due to insect bite (21.6%) and trauma (20.3%).[21]

Aboriginal children and children under 5 years were overrepresented. This is consistent with rates of paediatric hospitalisation for SSTI in WA, showing higher rates within these two

groups[5] and a known heavy burden of skin infections in Aboriginal children.[22] Vaccination against *Haemophilus influenzae* type B and *S. pneumoniae* has been effective in reducing periorbital cellulitis attributable to these pathogens in children below 5 years. It is likely that a GAS vaccine will have a similarly significant effect for cellulitis attributable to GAS.[9]

In our study 3.6% of children had recurrent cellulitis compared to rates of 22 to-49% in adults.[1] In children, recurrent cellulitis is previously only reported in the context of lymphoedema[23] and periorbital cellulitis associated with rhinosinusitis.[24] Our study demonstrates a high rate of recurrent cellulitis in children without these risk factors, with MRSA common in recurrent cellulitis. More studies are required to examine the risk factors for recurrent cellulitis in children and inform the use of prophylactic antibiotics and prevention strategies.

The choice and duration of antibiotics was strongly adherent to international guidelines (1-3 days IV antibiotics, 5-7 days total duration of antibiotics for moderate-severe cellulitis).[16] Children with periorbital cellulitis required longer treatment duration (median 3 days IV, median 7 days total), which was also consistent with recommendations (2-3 days IV, 7-10 days total).[16] Our reported length of stay is comparable to international studies of cellulitis and SSTI.[11,21] Most non-admitted patient received oral antibiotics only, which is consistent with recommendations for treatment of mild cellulitis in children.[16] The choice of antibiotic was also consistent with the PCH antimicrobial stewardship program, ChAMP. Further opportunities to improve management of children with cellulitis presenting to hospital include incorporating evidence for early oral treatment using the highly bioavailable regimens of clindamycin and trimethoprim/sulfamethoxazole.[25] Evidence for use of these agents has been synthesised in recent years for children and adults. With increasing MRSA prevalence,

these MRSA active agents with a strong evidence base are useful for paediatricians to consider.

Pathogen confirmation is difficult in cellulitis. We confirm the futility of blood cultures in cellulitis in immunocompetent children.[26] Wound cultures are more helpful, with over 80% of those tested yielding a positive result. Although MSSA was the most commonly cultured organism, it is believed that the role of GAS may be underestimated. One study, using serology in adults with cellulitis, suggested up to 73% of unculturable cellulitis is due to GAS.[27]

HITH referrals were uncommon despite the availability and accessibility of this program. The Australian CHOICE trial demonstrated that home parenteral antibiotics are safe, effective and cost-effective for children with moderate to severe cellulitis.[20,28] Further efforts to admit children to HITH from ED would improve the quality of life for children with cellulitis. Clinicians working in the ED should consider IV antibiotics via HITH as a viable and cost-effective option for patients with uncomplicated cellulitis.

Limitations include the retrospective nature of the study. However, being the first study to assess cellulitis in Australian children, this design allowed for initial assessment of the population and the generation of hypotheses for further research. We limited the study population to cases presenting to the tertiary centre therefore it may not represent all cases of paediatric cellulitis in WA. In doing so, the study focuses on tertiary management which provides guidance on treatment for the state. Due to time constraints of the study the data collection for the non-admitted cohort was limited to the proximal six months. The data observed represented less than half the expected number of non-admitted cases per annum.

The discrepancy likely arises due to the fact that cellulitis is likely more common in the summer months as reported in an adult literature.[29] A further limitation is the absence of blinding of the abstractor. Whilst we acknowledge this may introduce bias in retrospective chart reviews, the focus of the study was on epidemiological factors such as age, sex, Aboriginal status and body site affected, which are not susceptible to interpretation bias given they are non-objective findings. Additionally, the study population represents only moderate to severe cases of cellulitis as milder cases are usually ambulatory.[30]

Based on our findings, future research should consider the effectiveness of targeted prevention strategies for the high-risk groups identified. As the progress in the development of a GAS vaccine continues it is important to develop mechanisms to monitor this burden to determine what proportion of cellulitis in childhood is preventable with a GAS vaccine.

Funding:

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests:

I declare that that I have read and understood BMJ policy on declarations of interest.

I have no competing interests to declare.

Contributorship:

A.B devised the study. A.B and E.S. planned the project, with input from the other authors. E.S and C.M completed the data collection and data analysis. E.S. led the manuscript writing. All authors provided critical feedback and helped shape the research, analysis and

manuscript. All authors meet requirements of authorship as per the ICMJE guidelines for authorship.

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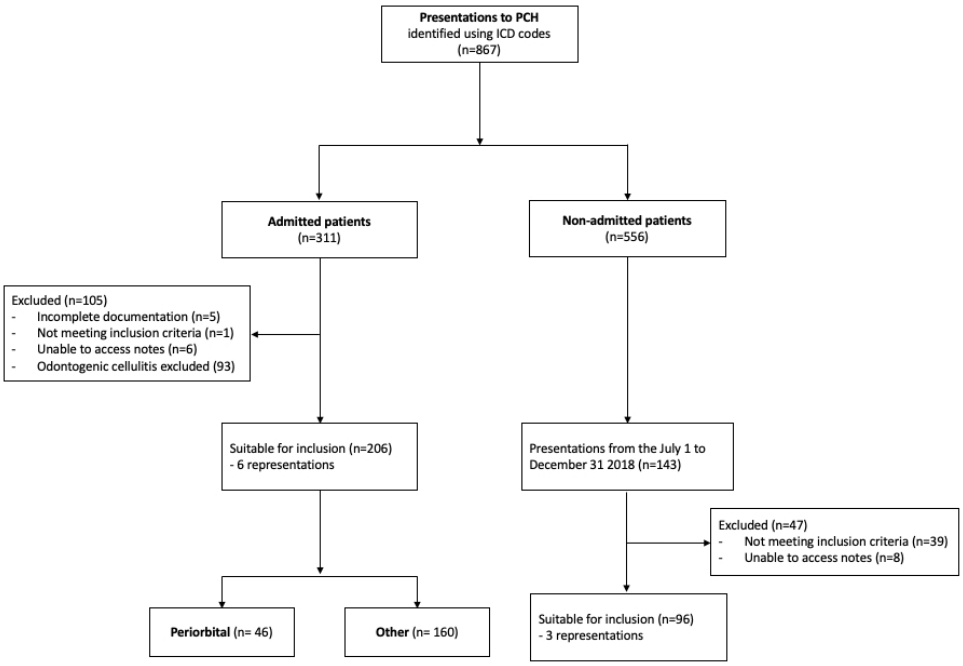

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Supplementary Material

Table S1. ICD-10-AM Diagnosis Codes Used to Identify Cellulitis Presentation

ICD Code	Classification
L03.01	Cellulitis of Finger (ICD10)
L03.02	Cellulitis of Toe (ICD10)
L03.10	Cellulitis of Upper Limb (ICD10)
L03.11	Cellulitis of Lower Limb (ICD10)
L03.2	Cellulitis of Face (ICD10)
L03.3	Cellulitis of Trunk (ICD10)
L03.8	Cellulitis of Other Sites (ICD10)
L03.9	Cellulitis, Unspecified (ICD10)
A46	Erysipelas (ICD10)
H60.1	Cellulitis of external ear
H60.10	Cellulitis of external ear
H60.11	Cellulitis of external ear
H60.12	Cellulitis of external ear
H60.13	Cellulitis of external ear

Table S2. Management and outcomes of emergency presentations to PCH in 2018

Duration of parenteral antibiotics, days (median, IQR)	1 (1-1)
Parenteral antibiotic, n (%):	n=3
Ceftriaxone IM	1 (33.3)
Flucloxacillin IV	1 (33.3)
Cephazolin IV	1 (33.3)
Duration of oral antibiotics, days, median (IQR)	5 (5-7)
Oral antibiotic, n (%):	
Flucloxacillin	10 (10.4)
Cephalexin	70 (72.9)
Clindamycin	1 (1.0)
Cotrimoxazole	4 (4.2)
Amoxicillin + clavulanic acid	10 (1.0)
Topical therapies	
Mupirocin ointment or cream	6 (6.2)
Bactrim ointment	1 (1.0)
Chloramphenicol drops	1 (1.0)
Follow up with paediatrician documented n(%)	11 (11.5)

BMJ Paediatrics Open

Cellulitis in Children: a retrospective single centre study from Australia

Journal:	*BMJ Paediatrics Open*
Manuscript ID	bmjpo-2021-001130.R1
Article Type:	Original research
Date Submitted by the Author:	22-Jun-2021
Complete List of Authors:	Salleo, Elise; The University of Western Australia Faculty of Health and Medical Sciences, Medical School; The University of Western Australia, Telethon Kids Institute MacKay, Conor; The University of Western Australia Faculty of Health and Medical Sciences, Medical School; The University of Western Australia, Telethon Kids Institute Cannon, Jeffrey; The University of Western Australia Faculty of Health and Medical Sciences, Medical School; Telethon Kids Institute, Wesfarmers Centre for Vaccines and Infectious Diseases King, Barbara; Albany Health Campus Bowen, Asha; Perth Children's Hospital, Department of Infectious Diseases; Telethon Kids Institute, Wesfarmers Centre for Vaccines and Infectious Diseases
Keywords:	Epidemiology, Microbiology, Dermatology

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Title: Cellulitis in Children: a retrospective single centre study from Australia

Short Title: Cellulitis in Children

ORIGINAL ARTICLE

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Key words:
Cellulitis; skin and soft tissue infections; Children; *Staphylococcus aureus; Streptococcus pyogenes*

Word Count: 2726

Abstract

Aim: To characterise the epidemiology, clinical features and treatment of paediatric cellulitis.

Methods: A retrospective study of children presenting to a paediatric tertiary hospital in Western Australia, Australia in 2018. All inpatient records from 1 January to 31 December 2018 and ED presentations from 1 July to 31 December 2018 were screened for inclusion.

Results: 302 episodes of cellulitis were included comprising 206 (68.2%) admitted children and 96 (31.8%) non-admitted children. The median age was 5 years (interquartile range [IQR] 2-9), 40 (13.2%) were Aboriginal and 180 (59.6%) male. The extremities were the most commonly affected body site amongst admitted and non-admitted patients. There was a greater proportion of facial cellulitis in admitted patients (27.2%) compared with non-admitted patients (5.2%, p<0.01). Wound swab was the most frequent microbiological investigation (133/302, 44.0%), yielding positive cultures in the majority of those tested (109/133, 82.0%). The most frequent organisms identified were *Staphylococcus aureus* (94/109, 86.2%) (methicillin susceptible *S. aureus* (60/94, 63.8%), methicillin resistant *S. aureus*) and *Streptococcus pyogenes* (22/109, 20.2%) with 14 identifying both *S. aureus* and *S. pyogenes*. Intravenous (IV) flucloxacillin was the preferred antibiotic (154/199, 77.4%), with median IV duration 2 days (IQR 2-3), oral 6 days (IQR 5-7) and total 8 days (IQR 7-10).

Conclusions: Cellulitis is a common reason for presentation to a tertiary paediatric hospital. We confirm a high prevalence of extremity cellulitis and demonstrate that children with facial cellulitis often require admission. Cellulitis disproportionately affected Aboriginal children and children below five years. Prevention of cellulitis involves early recognition and treatment of skin infections such as impetigo and scabies.

What is already known on this topic:

1. Cellulitis is a common skin infection, caused by *Staphylococcus aureus* and *Streptococcus pyogenes*.
2. Cellulitis contributes the largest portion of the disease burden caused by *S. pyogenes* in Australia.
3. Cellulitis in children includes periorbital infection and infection of the extremities.

What this paper adds:

1. Cellulitis is a common condition in children accounting for 1.1% of presentations to the paediatric tertiary hospital in Western Australia.
2. Facial cellulitis is a common cause for admission to hospital, with a large proportion of this being periorbital cellulitis.
3. Children under five years and Australian Aboriginal children are disproportionately admitted for cellulitis.

Introduction

Cellulitis is a localised skin infection caused by disruption of the physical barrier allowing pathogen entry.[1,2] In children it is commonly caused by trauma, insect bites or varicella, predominantly affecting the face or extremities.[2-4] Common pathogens are *Streptococcus pyogenes* (Group A streptococci (GAS)) and *Staphylococcus aureus*.[1,2,5-7] Cellulitis is non-purulent, making pathogen detection challenging, hence GAS contribution may be underestimated.[1] In Australia, cellulitis contributes the greatest burden of GAS disease across all ages, ahead of impetigo, pharyngitis and invasive GAS.[8] An improved understanding of the burden of paediatric cellulitis will inform the role for a GAS vaccine in cellulitis prevention.

Although presumably common, few studies describe the burden of cellulitis in Australian children. The proportion of admissions, clinical features and treatment of cellulitis in hospitalised children in Australia remains unknown. In one linked dataset, skin and soft tissue infections (SSTI) accounted for 3% of all paediatric hospital admissions, with cellulitis as the second most frequent admission reason.[9] Aboriginal children were 15 times more likely to be admitted for SSTI compared to non-Aboriginal.[9] Furthermore, SSTI are recognised as the most common group of bacterial infections in children.[10] Although cellulitis is often managed in primary care, hospitalisation is required for severe, progressive cellulitis.[9,11,12]

We aimed to describe the epidemiology, clinical features, treatment and adherence to antibiotic guidelines for cellulitis in children presenting to hospital.

Methods

Study design and population

A retrospective chart review was conducted at Perth Children's Hospital (PCH), the only tertiary paediatric centre in Western Australia (WA) with an estimated 60,000 presentations to the Emergency Department (ED) annually.[13]

Records with a primary diagnosis of cellulitis were identified using the International Classification of Disease (ICD) 10 coding (Table S1). At PCH, all inpatient records from 1 January to 31 December 2018 were screened for inclusion. Due to the time constraints of the study ED presentations from 1 July to 31 December 2018 only were reviewed. Exclusion criteria were patients aged ≥16 years, alternative diagnosis more likely on detailed chart review or where insufficient documentation was available to assess for inclusion. Orbital cellulitis and odontogenic cellulitis were excluded from this review, as their management is considerably different from that of traditional cellulitis.

Cellulitis (ICD10 codes L03.01 – L03.11 and H60.1 – H60.13) is a bacterial infection of the superficial layers of the skin (epidermis, dermis and subcutaneous tissues) characterised by erythema, pain, warmth, swelling and rapid progression. Recurrent cellulitis was defined as an additional admission for cellulitis occurring >30 days from the index diagnosis to exclude the possibility of counting relapses or treatment failure (representation within 30 days of hospital discharge). SSTI includes cellulitis, impetigo, skin abscess, scabies and fungal infections. Extremities are the hands and feet including the finger and toes. Geographical location was ascertained by postcode, grouped according to Australian Statistical Geography Standard Remoteness Structure on the basis of relative access to health care services.[14]

The Hospital in the Home (HITH) service consists of a team of trained clinical nurses. It provides acute care at home for children who are medically stable and require ongoing

regular medical care. They conduct daily home visits to provide treatments such as IV antibiotics, dressings and clinical assessments. Patients can be referred to HITH directly from ED in order to avoid an admission or from an inpatient unit to facilitate early discharge.

Data Collection

Data was extracted from paper and electronic hospital records, including demographics, admission duration, clinical findings, investigations, management and outcomes. The characteristics assessed included age, Aboriginal status, geographical location, presence of common co-morbidities and recurrent cellulitis. Data was captured and stored in a standardised purpose-built REDCap database by a medically trained abstracter.[15,16] Adherence to treatment duration was assessed against the intravenous (IV) to oral switch guidelines.[17]

Data analysis

Data was analysed using descriptive and comparative statistics. According to the 2016 Census data, 3.9% of the WA paediatric population are Aboriginal.[18] The proportion of Aboriginal children in the study was compared to the Census data using a binomial probability test. The frequency of cellulitis affecting specific body sites, identified causes, investigations performed and follow-up with a paediatrician were compared between admitted and non-admitted patients using Pearson's chi square tests and Fisher's exact tests as appropriate. Chi square tests were used to compare the age of study participants to the 2016 WA population data.[19] Data was analysed using Stata version 16.0 (*Stata Statistical Software: Release 16*. College Station, TX).

Ethics approval

The study was approved by the Western Australian Aboriginal Health Ethics Committee (HREC Ref 923) with reciprocal approval from the University of Western Australia and the GEKO program at the Child and Adolescent Health Service (PRN 29036).

Patient and Public Involvement

Patients and members of the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

Results

Eight-hundred and sixty-seven patients with a primary diagnosis of cellulitis presented to PCH in 2018. This included 311 admitted patients and 556 non-admitted patients. Hospital coding errors were present in 11.8% (102/867) of cases: 40 patients excluded with an alternative primary SSTI and 62 with different primary diagnoses coded in the ED notes compared to the discharge summary. Ninety- three patients with odontogenic cellulitis were also excluded. Of the remaining 672 patients, 206 (30.6%) were included in the 12-month admitted cohort and 96 (14.2%) in the 6-month non-admitted cohort. Further details on the exclusion reasons are presented in Figure 1. Cellulitis accounted for 1.1% (672/62,985) of all presentations and 0.8% (206/26,884) of annual admissions to PCH.

One hundred and eighty (59.6%) children were male (Table 1). Eleven (3.6%) children re-presented with cellulitis during the study period: 3 children with recurrent cellulitis of a different body site, 4 children with treatment failure requiring re-admission to hospital, 1 child requiring admission after unsuccessful discharge from ED and 3 children with treatment failure representing to ED.

Table 1. Patient Demographics

		Total (n=302)
Sex	Male	180 (59.6)
	Female	122 (40.4)
Age Group (years)	<5	147 (48.7)
	5-9	87 (28.8)
	10-14	52 (17.2)
	15	16 (5.3)
Indigenous status	Aboriginal	40 (13.2)
	Non- Aboriginal	262 (86.8)
Geographical location	Metropolitan	282 (93.4)
	Regional/Remote	17 (5.6)
	International	3 (1.0)
Previous admission	Cellulitis	27 (8.9)
	Other SSTI	23 (7.6)
Comorbidities	Eczema	18 (6.0)
	Surgery	3 (1.0)
	URTI	13 (4.3)

Values are n (%)

Children below 5 years were over-represented in the study population, 147/302 (48.7%, p<0.001) (Table 2). The median age of children admitted to hospital was 5 years (IQR 2-9) and for non-admitted patients 5 years (IQR 2-8).

Table 2. Comparison of study participants and the WA population by age group

Age Group (years)	Study	WA Population†	P-value
<5	147 (48.7)	161 727 (31.9)	p<0.001
5-9	87 (28.8)	164 153 (32.4)	
10-14	52 (17.2)	150 806 (29.8)	
15‡	16 (5.3)	29 934 (5.9)	
Total	302	506 620	

Values are n (%)

† WA population data from the 2016 Australian census.[19]

‡Children aged 16 years and above were excluded from the study

Aboriginal children with cellulitis (40/302, 13.2% [95% CI = 9.4 - 17.1%]) were significantly over-represented in the study population compared to being 3.9% of the WA paediatric population (p<0.001) (Table 3). Aboriginal children were more likely to be admitted to hospital (36/40, 90.0% [95%CI: 81-99%]) than their non-Aboriginal peers (170/262, 64.9% [95%CI: 59-71%], p<0.001) (Table 4).

Table 3. Comparison of study participants and the WA population by Indigenous status

	Study population	WA Population†	P-value
Aboriginal	40 (13.2%) [95% CI = 9.4 - 17.1%]	3.9%	p<0.001
Non-Aboriginal	262 (86.8%) [95% CI = 82.9 - 90.6%]	96.1%	
Total	302 (100%)	100%	

† Data from the 2016 Australian Census[18]

Table 4. Proportion of Aboriginal and Non-Aboriginal patients admitted to hospital

	Aboriginal	Non-Aboriginal	P-value
Admitted	36 (90%) [95% CI = 81 - 99%]	170 (65%) [95%CI = 59-71%]	p<0.001
Non-Admitted	4 (10%) [95% CI = 1-19%]	92 (35%) [95% CI =29 – 41 %]	
Total	40	262	

Values are n (% [95% CI])

The most common causes of cellulitis in the study group were insect bites (66/302, 21.8%), trauma (60/302, 19.9%) and impetigo (17/302, 5.6%) (Table 5). In both groups, the most affected body location was the extremities (119/302, 39.4%). The proportion of facial cellulitis was significantly greater amongst admitted patients compared to non-admitted patients (56/206, 27.2% vs 5/96, 5.2%, p<0.001).

Table 5. Possible causes and location of cellulitis

Possible source	Admitted (n=206)	Non-admitted (n=96)	
Unknown	76 (36.9)	30 (31.2)	p=0.339
Skin sore	17 (8.3)	0 (0)	p=0.004
Trauma	45 (21.8)	15 (15.6)	p=0.207
Insect bite	31 (15.0)	35 (36.5)	p<0.001
Lymphoedema	1 (0.5)	0 (0)	-
Other†	36 (17.5)	16 (16.7)	p=0.862
Location‡	**Admitted (n=206)**	**Non-admitted (n=96)**	
Face	56 (27.2)	5 (5.2)	p<0.001
Head and neck	9 (4.4)	3 (3.1)	p=0.758
Upper limbs	14 (6.8)	13 (13.5)	p=0.056
Torso	8 (3.9)	7 (7.3)	p=0.255
Groin and buttocks	11 (5.3)	16 (16.7)	p=0.001
Lower limbs	54 (26.2)	21 (21.9)	p=0.416
Extremities	76 (36.9)	43 (44.8)	p=0.191

Values are n (%)

†other includes animal bite, recent injection site, rash, wound or foreign body infection and sinusitis

‡some cases involved infection of multiple sites

Most admitted patients (199/206, 96.6%) received IV antibiotics, frequently flucloxacillin (154/199, 77.4%) for a median duration of 2 days (IQR 2-3) before step-down to oral antibiotics (Table 6). The median duration of oral antibiotics was 6 days (IQR 5-7). The median total duration of antibiotic therapy was 8 days (IQR 7-10). The most common IV antibiotic regimen for periorbital cellulitis was IV ceftriaxone and flucloxacillin in combination (38/46, 82.6%).

Sixteen (5.3%) admitted children were discharged to the HITH program for further IV antibiotics. The majority of these children had periorbital cellulitis (9/16, 56.3%).

Fifty-two patients underwent surgical procedures including subcutaneous abscess drainage (37/52, 71.2%), finger or toe-nail removal (14/52, 26.9%) and foreign body removal (1/52, 1.9%).

Table 6. Management and outcomes of patients admitted to PMH/PCH in 2018

	Total (n=206)	Periorbital (n=46)	Other (n=160)
Duration of IV antibiotics, days, median (IQR)	2 (2-3)	3 (2-3)	2 (2-3)
IV antibiotic n (%):	n=199	n=45	n=154
Flucloxacillin	154 (77.4)	41 (91.1)	113 (73.3)
Cefotaxime	2 (1.0)	2 (4.4)	
Ceftriaxone	47 (23.6)	41 (91.1)	6 (3.9)
Cefazolin	38 (19.1)	5 (11.1)	33 (21.4)
Clindamycin	10 (5.0)	-	10 (6.5)
Cotrimoxazole	2 (1.0)	-	2 (1.3)
Benzylpenicillin	1 (0.5)	-	1 (0.6)
Piperacillin/tazobactam	15 (7.5)	4 (8.9)	11 (7.1)
Vancomycin	27 (13.6)	2 (4.4)	25 (16.2)
Other	3 (1.5)	-	3 (1.9)
Duration of oral antibiotics, days, median (IQR)	6 (5-7)	7 (5-8)	5 (5-7)
Oral antibiotic on discharge, n (%):	n=192	n=42	n=150
Flucloxacillin	20 (10.4)	1 (2.4)	19 (12.7)
Cephalexin	103 (53.6)	13 (30.9)	90 (60.0)
Clindamycin	8 (4.2)	1 (2.4)	7 (4.7)
Cotrimoxazole	20 (10.4)	2 (4.8)	18 (12.0)
Amox/clav duo forte	37 (19.3)	24 (57.1)	13 (8.7)
Amoxicillin	2 (1.0)	1 (2.4)	1 (0.7)
Other	4 (2.1)	-	4 (2.7)
Total duration of antibiotic therapy, median (IQR)	8 (7-10)	9 (8-11)	8 (7-10)
Surgery, n (%)	52 (25.2)	-	52 (32.5)
Duration of admission, median (IQR)	3 (2-4)	3 (2-4)	3 (2-4)
Discharged to HITH, n (%)	16 (7.8)	9 (19.6)	7 (4.4)
Follow up with paediatrician documented n(%)	80 (38.8)	15 (32.6)	65 (40.6)

Most non-admitted patients received oral antibiotics only (95/96, 99.0%), commonly cephalexin (70/95, 73.7%) for a median duration of 5 days (IQR 5-7). Three patients received parenteral antibiotics (Table S2). Documented follow up was less likely in non-admitted patients compared to those admitted (11.5% vs 38.8%, $p < 0.01$).

The most frequent investigations were full blood count, C-reactive protein and wound swab (Table 7). Blood cultures were performed in 45.6% (94/206) of admitted cases with only one positive results: coagulase negative *Staphylococcus,* a probable skin contaminant. Investigations were less common in non-admitted patients (p<0.001) (Table 7).

Table 7. Investigations carried out in children presenting with cellulitis

	Admitted (n=206)	Non-admitted (n=96)	
Full blood count performed n (%)	168 (81.6)	5 (5.2)	p<0.001
White blood cell, median (IQR)	11.9 (8.9-15.5)	8.56 (7.95-11.2)	
Elevated† n (%)	96 (57.1)	1 (20.0)	
C-Reactive Protein performed, n (%)	166 (80.6)	5 (5.2)	p<0.001
C-Reactive Protein, median (IQR)	13.5 (5-36)	2.6 (2.4-5.5)	
Elevated† n (%)	111 (66.9)	2 (40.0)	
Blood culture performed, n (%)	94 (45.6)	2 (2.1)	p<0.001
Organism identified, n (%)	1 (1.1)	-	
Wound swab performed, n (%)	120 (58.3)	13 (13.5)	p<0.001
Organisms identified, n (%)	101 (84.1)	10(76.9)	
Imaging, n (%)	123 (59.7)	14 (14.5)	p<0.001
Ultrasound scan, n (%)	35	3	
X-ray, n (%)	71	12	
Computed tomography, n (%)	13	-	
Magnetic resonance imaging, n (%)	4	-	

†elevated as per laboratory reported reference range

Wound swabs yielded pathogens in 36.1% (109/302) of patients. *S. aureus* was most frequently identified (n=94, 86.2%): 60 (63.8%) methicillin sensitive *S. aureus* (MSSA); 34 (36.2%) methicillin resistant *S. aureus* (MRSA); and 22 (20.2%) *S. pyogenes* (Table 8). Fourteen children had mixed gram-positive infections: MSSA and *S. pyogenes* (n=10); MRSA and *S. pyogenes* (n=3); MSSA and MRSA (n=1). *S. pyogenes* was detected in isolation in only 9 cases. Eight children with recurrent cellulitis had positive wound swabs for MRSA.

Table 8. Microorganisms identified on wound swab

Microorganism	Admitted (n=99)	Non-admitted (n=10)
Streptococcus pyogenes	20	2
Staphylococcus aureus	86	8
Methicillin Sensitive *S. aureus*	54	6
Methicillin Resistant *S. aureus*	32	2
Staphylococcus lugdunensis,	1	-
Pseudomonas aeruginosa	1	1
Other†	7	-

†other includes *Staphylococcus intermedius, Streptococcus dysgalactiae, Streptococcus intermedius,* mixed anaerobes*, Eikenella corrandes, Pasteurella multocida*

Discussion

This study demonstrates four key findings: (i) cellulitis is common accounting for 1.1% of all presentations to the tertiary hospital; (ii) patients with facial cellulitis are more frequently admitted to hospital; (iii) children under five years and Aboriginal children are disproportionately affected by cellulitis; and (iv) 3.6% of the cohort had recurrent cellulitis.

We confirm that paediatric cellulitis accounts for a significant burden on the hospital system, consistent with previous linked data showing 3% of paediatric hospital admissions in WA were due to SSTI, with cellulitis the second most common diagnosis.[9] The CHOICE trial in Melbourne reported 700 presentations of cellulitis to the Royal Children's Hospital over 17-months, with 304 (43%) admissions.[20] Our cohort has a higher presentation rate of approximately 56 children per month compared to only 41 per month in Melbourne, whilst our overall admission rate was slightly lower at 30.7%. In the Northern Territory, 2.3% of all paediatric presentations to the Royal Darwin Hospital ED in 2013 were for cellulitis, making it the 8th most common reason for presentation to the ED.[21] Prevention of cellulitis will reduce the burden of hospitalisation on children and families. Cellulitis prevention strategies from

current national guidelines include insect repellent, antiseptics for minor trauma[22] and possibly vaccination when a GAS vaccine becomes available over the next decade. A recent study investigating the health and economic burden of GAS disease in Australia found that, out of the 24 diseases caused by GAS, cellulitis contributed to over half the total burden in both children and adults, further confirming the need for a GAS vaccine.[8]

Children with facial cellulitis are more frequently hospitalised than children with cellulitis of other sites. This may be representative of the need for multidisciplinary specialist care and the potential for sight-threatening and life-threatening complications in children with periorbital cellulitis. All but one child with periorbital cellulitis in our study group were admitted for IV antibiotics and specialist review (ophthalmology and otolaryngology). This management is supported by in the literature, which suggests that multidisciplinary management and early intervention can improve outcomes for children with periorbital cellulitis.[23] Canadian data has also demonstrated over-representation of facial cellulitis amongst paediatric inpatients (26.8%) compared to non-admitted patients (16.3%) with cellulitis.[24] Similarly, Canadian ED presentations were also predominantly extremity cellulitis (69.5%), due to insect bite (21.6%) and trauma (20.3%).[24]

Aboriginal children and children under 5 years were overrepresented in the study group when compared to the WA population. This is consistent with rates of paediatric hospitalisation for SSTI in WA, showing higher admission rates in children under 5 years and Aboriginal children,[9] and a known heavy burden of skin infections in Aboriginal children.[25] Previous data from Australia demonstrates that Aboriginal children are more likely to be admitted for all health conditions compared to non-Aboriginal children.[26,27] The greatest

disparity in admission is for infectious diseases, including SSTI.[26,27] These high admission rates likely reflect disadvantages relating to the social determinants of health, including poor access to healthcare, overcrowded housing, financial concerns and living in remote locations.[26] It is also observed that children living further distances from healthcare centres generally present later and hence have more severe illness.[27] As such, it is important to address these factors to reduce the rates of cellulitis and SSTI in Aboriginal children. Vaccination against *Haemophilus influenzae* type B and *S. pneumoniae* has been effective in reducing periorbital cellulitis attributable to these pathogens in children below 5 years.[28,29] It is likely that a GAS vaccine will have a similarly significant effect for cellulitis attributable to GAS.[8]

In our study 3.6% of children had recurrent cellulitis compared to rates of 22 to-49% in adults.[1] In children, recurrent cellulitis is previously only reported in the context of lymphoedema[30] and periorbital cellulitis associated with rhinosinusitis.[31] Our study demonstrates a high rate of recurrent cellulitis in children without these risk factors, with MRSA common in recurrent cellulitis. More studies are required to examine the risk factors for recurrent cellulitis in children and inform the use of prophylactic antibiotics and prevention strategies.

The choice and duration of antibiotics was strongly adherent to international guidelines (1-3 days IV antibiotics, 5-7 days total duration of antibiotics for moderate-severe cellulitis).[17] Children with periorbital cellulitis required longer treatment duration (median 3 days IV, median 7 days total), which was also consistent with recommendations (2-3 days IV, 7-10 days total).[17] Our reported length of stay is comparable to international studies of cellulitis and SSTI.[11,24] Most non-admitted patient received oral antibiotics only, which is consistent with

recommendations for treatment of mild cellulitis in children.[17] The choice of antibiotic was also consistent with the PCH antimicrobial stewardship program, ChAMP. Further opportunities to improve management of children with cellulitis presenting to hospital include incorporating evidence for early oral treatment using the highly bioavailable regimens of clindamycin and trimethoprim/sulfamethoxazole.[32] Evidence for use of these agents has been synthesised in recent years for children and adults to treat purulent cellutlitis and other uncomplicated SSTI in the outpatient setting. With increasing MRSA prevalence, these MRSA active agents with a strong evidence base are useful for paediatricians to consider.

Pathogen confirmation is difficult in cellulitis. We confirm the futility of blood cultures in cellulitis in immunocompetent children.[33] Wound cultures are more helpful, with over 80% of those tested yielding a positive result. Although MSSA was the most commonly cultured organism, it is believed that the role of GAS may be underestimated. One study, using serology in adults with cellulitis, suggested up to 73% of unculturable cellulitis is due to GAS.[34]

HITH referrals were uncommon despite the availability and accessibility of this program. The Australian CHOICE trial demonstrated that home parenteral antibiotics are safe, effective and cost-effective for children with moderate to severe cellulitis.[23,35] Further efforts to admit children to HITH from ED would improve the quality of life for children with cellulitis, however it appears that this is not currently common practice. Ibrahim et al., found that there are several barriers to clinicians choosing home treatment with IV antibiotics including younger age, risk of complications, risk of deteriorating unnoticed and risk of needing to represent to hospital.[36] Further education of ED clinicians could reduce these perceived barriers to home

IV antibiotics. ED clinicians should strongly consider IV antibiotics via HITH as a viable and cost-effective option for suitable patients with uncomplicated cellulitis.

Limitations include the retrospective nature of the study, however, this design allowed for initial assessment of the population and the generation of hypotheses for further research. We limited the study population to children with a primary diagnosis of cellulitis presenting to the tertiary centre therefore, it does not include children who presented to the hospital with an alternative diagnosis but were also treated for cellulitis or children managed in primary care.. In doing so, the study focuses on tertiary management which provides guidance on treatment for the state. Due to time constraints of the study the data collection for the non-admitted cohort was limited to the proximal six months. The data observed represented less than half the expected number of non-admitted cases per annum. The discrepancy likely arises due to the fact that cellulitis is likely more common in the summer months as reported in an adult literature.[37] A further limitation is the absence of blinding of the abstractor. Whilst we acknowledge this may introduce bias in retrospective chart reviews, the focus of the study was on epidemiological factors such as age, sex, Aboriginal status and body site affected, which are not susceptible to interpretation bias given they are objective findings. Additionally, the study population represents only moderate to severe cases of cellulitis as milder cases are usually ambulatory.[38]

Based on our findings, future research should consider the effectiveness of targeted prevention strategies for the high-risk groups identified. Cellulitis is an important cause for young and Aboriginal children to be admitted to hospital in Australia. Prevention of childhood

cellulitis requires a multifaceted approach to preventing insect bites, reducing minor trauma and in the future may also include use of a GAS vaccine.

Funding:

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests:

I declare that that I have read and understood BMJ policy on declarations of interest.

I have no competing interests to declare.

Contributorship:

A.B devised the study. A.B and E.S. planned the project, with input from the other authors. E.S and C.M completed the data collection and data analysis. E.S. led the manuscript writing. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors meet requirements of authorship as per the ICMJE guidelines for authorship.

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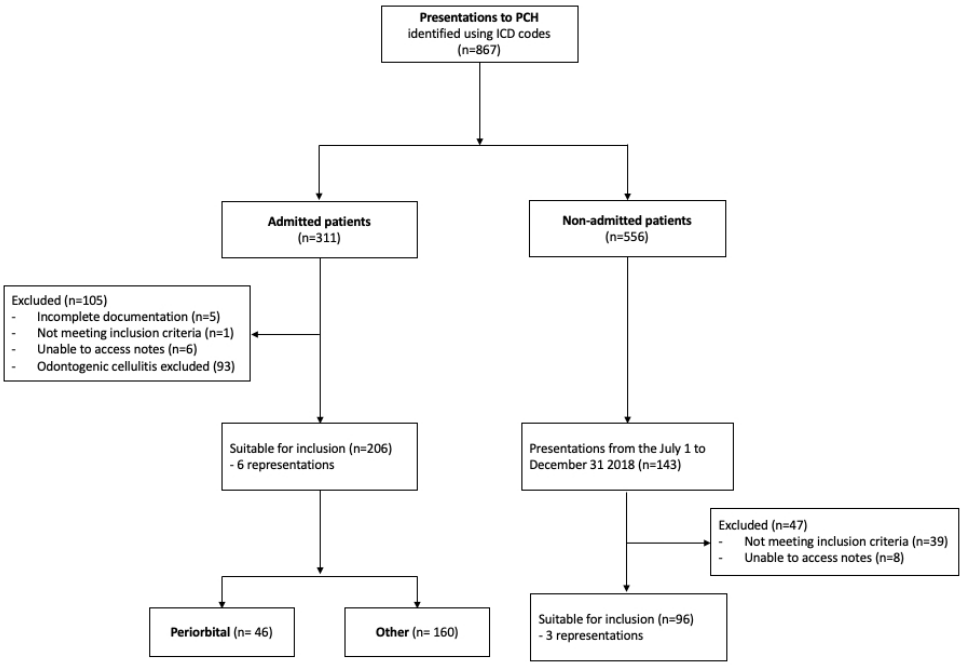

Figure 1. Flow diagram of participants included in the study.

327x236mm (72 x 72 DPI)

Supplementary Material

Table S1. ICD-10-AM Diagnosis Codes Used to Identify Cellulitis Presentation

ICD Code	Classification
L03.01	Cellulitis of Finger (ICD10)
L03.02	Cellulitis of Toe (ICD10)
L03.10	Cellulitis of Upper Limb (ICD10)
L03.11	Cellulitis of Lower Limb (ICD10)
L03.2	Cellulitis of Face (ICD10)
L03.3	Cellulitis of Trunk (ICD10)
L03.8	Cellulitis of Other Sites (ICD10)
L03.9	Cellulitis, Unspecified (ICD10)
A46	Erysipelas (ICD10)
H60.1	Cellulitis of external ear
H60.10	Cellulitis of external ear
H60.11	Cellulitis of external ear
H60.12	Cellulitis of external ear
H60.13	Cellulitis of external ear

Table S2. Management and outcomes of emergency presentations to PCH in 2018

Duration of parenteral antibiotics, days (median, IQR)	1 (1-1)
Parenteral antibiotic, n (%):	n=3
Ceftriaxone IM	1 (33.3)
Flucloxacillin IV	1 (33.3)
Cephazolin IV	1 (33.3)
Duration of oral antibiotics, days, median (IQR)	5 (5-7)
Oral antibiotic, n (%):	
Flucloxacillin	10 (10.4)
Cephalexin	70 (72.9)
Clindamycin	1 (1.0)
Cotrimoxazole	4 (4.2)
Amoxicillin + clavulanic acid	10 (10.4)
Topical therapies	
Mupirocin ointment or cream	6 (6.2)
Bactrim ointment	1 (1.0)
Chloramphenicol drops	1 (1.0)
Follow up with paediatrician documented n(%)	11 (11.5)