Epidemiol. Infect. (2007), **135**, 1376–1383. © 2007 Cambridge University Press
doi:10.1017/S0950268807007844 Printed in the United Kingdom

The bacteriology of pneumonia diagnosed in Western Australian emergency departments

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(*Accepted 22 November 2006; first published online 5 February 2007*)

SUMMARY

We used Western Australian emergency department data linked to hospital morbidity, death and microbiology data to describe the bacteriology of pneumonia according to age. The 'atypical' organisms and viruses were not assessed. A total of 6908 patients over a 3-year period were given an emergency department diagnosis of pneumonia, 76·9% were admitted and 6·3% died in hospital. Blood was cultured from 52·9% of patients with 6·4% growing potential pathogens. *Streptococcus pneumoniae* was the most common organism isolated and accounted for 92% of pathogens in those aged <15 years. Isolation of Enterobacteriaceae species tended to increase with age and accounted for around 25% of isolates from the elderly. Sputum was cultured from 25·3% of patients and bacteria were isolated from 30·3% of samples, commonly *Haemophilus influenzae* and *S. pneumoniae*. Isolates from sputum showed no distinct trend across age groups. These patterns question the value of routine blood and sputum cultures and have implications for empiric therapy for the elderly.

INTRODUCTION

Detailed information on the epidemiology of pneumonia in Australia is limited. Hospital separation statistics indicate that ~65000 patients leave Australian hospitals each year with this principal diagnosis [1]. However, details on the number of patients presenting to hospitals with pneumonia but not subsequently admitted and the aetiology of this illness from the Australian perspective are lacking.

The development of data linkage in Western Australia has enabled epidemiological analysis of population data for a number of medical conditions such as prostate cancer [2], diabetes [3] and surgical site infections [4]. The data linkage process allows records from individual contributing datasets to be identified as belonging to the same patient. This is achieved by comparing pairs of records on the basis of particular variables or identifiers. Data linkage allows a view of the different health services accessed by the patient at particular points of time, including the same episode of care, and the patient's health outcomes. In Western Australia, data from the state hospital morbidity dataset (HMDS), incorporating ~14 million hospital separation records from 1970, is routinely linked to the state's death register and other specialized datasets [5]. Although an administrative dataset, the HMDS contains discharge information including, International Classification of Diseases (ICD) coded discharge diagnoses, procedures and

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length of hospital stay. Recently, records from the Emergency Department (ED) Information System (EDIS), which allows real-time entry of ED patient data, have been linked to the HMDS and death register. This allows analysis of both admitted and non-admitted patients. For the study of infectious diseases, including pneumonia, incorporating microbiology data further extends the utility of data linkage.

The aim of our study was to use ED, hospital morbidity, mortality and microbiology linked datasets to investigate the bacteriology of pneumonia of both admitted and non-admitted patients with a focus on the differences across the lifespan. Use of linked data allowed us to analyse all cases diagnosed in the EDs of the four metropolitan teaching hospitals of Perth, Western Australia spanning a 3-year period.

METHODS

Study design and data source

This was a retrospective study of a cohort consisting of all patients given an ED diagnosis of pneumonia from July 2000 to July 2003 at any of the four metropolitan teaching hospitals in Perth, Western Australia. Collectively these hospitals serve a population of around 1·5 million people and had ~520 000 attendances, including both children and adults, during the study period.

ED, hospital morbidity and mortality records were patient linked by the Western Australian Data Linkage Unit. Record linkage brings together records from different datasets for the same individual into a single cumulative file. Linkages are identified through probabilistic matching using Automatch software (Matchware Technologies Inc., Silver Spring, MD, USA). Principal matching fields such as surname, first given name, date of birth, sex and address are weighted according to the likelihood of uniqueness and subjected to multiple passes through Automatch. Clerical checking is undertaken of possible matches which fall into the 'grey area' of definite matches and definite non-matches [6–8].

The ED and morbidity records relating to the same episode of care were then matched by comparing ED arrival and discharge times to hospital admission times. Microbiology records containing bacterial culture and antibiotic susceptibility results were matched to the ED records on the basis of hospital, medical record number and dates of specimen collection, ED arrival, ED discharge and hospital separation. The resultant dataset consisted of ED records, hospital morbidity records, death data and microbiology results.

The cohort was selected based on the ICD codes for pneumonia recorded in the diagnosis field of the ED record. These codes included; Ninth Revision (ICD-9) codes 481, 482, 483, 485, 486 and Tenth Revision Australian Modification (ICD-10-AM) codes J13, J14, J15, J16 and J18. In addition, the diagnosis text fields of the remaining records were searched for the words, respiratory–infective–pneumonia.

Data analysis

Viral and the 'atypical' causes of pneumonia, including *Mycoplasma pneumoniae*, *Chlamydia pneumoniae* and *Legionella* spp. were not assessed. To avoid including possible hospital-acquired infection, only blood or sputum taken within 2 days of ED arrival was included in the analysis for admitted patients. *Staphylococcus epidermidis*, non-specified coagulase-negative staphylococci and other organisms commonly originating from normal skin flora or the environment were considered probable contaminants of blood cultures. We examined the pattern of blood and sputum culturing and the organisms isolated according to age. Admitted and non-admitted groups were compared by using the χ^2 or two-sided Fisher's exact test where appropriate. Age *vs.* culturing was tested for linear trend using Epi-Info version 6 (CDC, Atlanta, GA, USA). All other analyses were performed using SPSS version 12 (SPSS Inc., Chicago, IL, USA). The level of significance was set at $P = 0{\cdot}05$.

The antibiotic susceptibility testing was based on guidelines from the Clinical and Laboratory Standards Institute (formerly known as the National Committee for Clinical Laboratory Standards) [9, 10] and was performed as part of normal laboratory practice. Susceptibilities to the antibiotics recommended as first-line therapies for bacterial pneumonia as described in the widely accepted Australian guidelines [11] were examined for the common organisms isolated. Resistance to di- or flu-cloxacillin was reported as methicillin resistance.

Ethics

Ethics approval for the study was received from the Western Australian Confidentiality of Health Information Committee, The University of Western

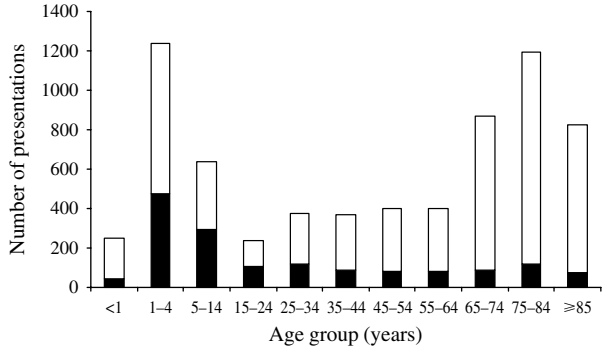

Fig. 1. Number of admissions (□) and non-admissions (■) given an ED diagnosis of pneumonia by age group.

Fig. 2. Blood cultured % age group (–◇–) and significant positive blood cultures % age group with blood cultured (–■–) for patients diagnosed with pneumonia.

Australia Human Research Ethics Committee and the Human Research Ethics Committees of each of the teaching hospitals.

RESULTS

There were 6908 presentations given an ED diagnosis of pneumonia with numbers increasing for each year of the study (2095, 2278, 2535). Males accounted for 3784 (54·8%) presentations and the median age was 53·5 years with peaks at 1–4 years (17·9% of pneumonia diagnoses) and 75–84 years (17·4%). There were 436 (6·3%) deaths within hospital, with 29 (0·4%) occurring in the ED. Excluding those that died in the ED, 5293 (76·9%) of presentations diagnosed with pneumonia were admitted with a median length of hospital stay of 4 days. Admission occurred in over 50% for all age groups, decreasing from 81·7% for those <1 year to a low of 53·4% for those aged 5–14 years then increasing with age to a peak of 90·6% for those aged ⩾85 years (Fig. 1).

Blood culture

Overall, 3656 (52·9%) presentations (194/1586, 12·2% non-admissions, 3451/5293, 65·2% admissions, and 11/29, 37·9% deaths in ED) had blood taken either in the ED or if admitted, within 2 days of ED arrival. Blood was cultured from more than 50% of those aged <1 year and for age groups ⩾25 years (Fig. 2) and generally increased according to age ($P<0·001$).

Organisms were isolated from the blood of 364 (10·0%) presentations (14/194, 7·2% non-admissions, 346/3451, 10·0% admissions, $P=0·202$; 4/11, 36·4% deaths in ED) with 16/3656 (0·4%) presentations yielding a polymicrobial culture. *Staph. epidermidis*, non-specified coagulase-negative staphylococci and other skin or environmental probable contaminants were commonly isolated with 127/364 (34·9%) presentations with positive cultures growing only these organisms. If these are excluded, the proportion of presentations with at least one significant blood culture becomes 6·4% (12/194, 6·2% non-admissions, 221/3451, 6·4% admissions, $P=0·904$) with a low of 1·9% for those aged 5–14 years and a high of 9·7% for those aged 35–44 years (Fig. 2). The proportion of blood cultures with potential pathogens isolated generally increased according to age ($P<0·001$).

The most common potential pathogen, *Streptococcus pneumoniae*, was isolated from <6·0% of those in each age group and overall, in 98/3656 (2·7%) presentations that had blood cultured. This organism accounted for 41·4% of the 237 presentations with at least one type of potential pathogen isolated (5/12, 41·7% non-admissions, 92/221, 41·6% admissions, Fisher's exact test, $P=1·000$, 1/4, 25·0% deaths in ED). *Escherichia coli* and *Staphylococcus aureus* were the two next most common organisms isolated (40/237, 16·9%, and 38/237, 16·0% of probable significant blood cultures respectively). Other species of potential pathogens were isolated from fewer than 10 patients. *S. pneumoniae* accounted for 92·6% of potential pathogens isolated from those aged <15 years, decreasing thereafter with increasing age. Exceptions to this trend were for the 45–54 years age group (61·1%) and for those aged ⩾85 years (28·2%). The variety of potential pathogens isolated was greater for the elderly with members of the Enterobacteriaceae family accounting for ⩾25% of isolates, excluding possible contaminants, for age groups ⩾65 years (Table 1).

https://doi.org/10.1017/S0950268807007844 Published online by Cambridge University Press

Table 1. *Potential pathogens isolated from blood of patients diagnosed with pneumonia according to age group*

Age group (years)	*n*	*S. pneumoniae* (%)	*E. coli* (%)	Other Enterobacteriaceae (%)	*Staph. aureus* (%)	Other potential pathogens (%)
<1	6	6 (100·0)				0
1–4	16	15 (93·8)				1 (6·3)
5–14	5	4 (80·0)				1 (20·0)
15–24	7	6 (85·7)			1 (14·3)	0·0
25–34	19	13 (68·4)	1 (5·3)		3 (15·8)	2 (10·5)
35–44	21	10 (47·6)	2 (9·5)		7 (33·3)	2 (9·5)
45–54*	18	10 (55·6)	3 (16·7)		2 (11·1)	2 (11·1)
55–64	17	6 (35·3)	2 (11·8)	1 (5·9)	4 (23·5)	4 (23·5)
65–74	35	7 (20·0)	7 (20·0)	3 (8·6)	6 (17·1)	12 (34·3)
75–84	54	9 (16·7)	18 (33·3)	7 (13·0)	9 (16·7)	11 (20·4)
⩾85	39	11 (28·2)	6 (15·4)	6 (15·4)	6 (15·4)	10 (25·6)

* In addition one co-infection with *S. pneumoniae* and *E. coli*.

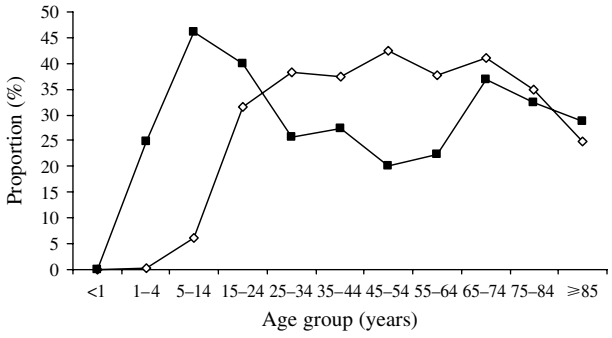

Fig. 3. Sputum cultured % age group (–◇–) and positive cultures % age group with sputum cultured (–■–) for patients diagnosed with pneumonia.

Sputum culture

There were 1742 (25·3%) presentations (83/1586, 5·2% non-admissions, 1656/5293, 31·3% admissions, and 3/29, 10·3% deaths in ED) that had sputum taken either in the ED or if admitted, within 2 days of ED arrival. Sputum was cultured for over 30% of all age groups aged ⩾25 years up to the 85 years age group (Fig. 3) and generally increased according to age ($P<0·001$).

Organisms were isolated from the sputum of 528 (30·3%) presentations (28/83, 33·7% non-admissions, 497/1656, 30·0% admissions, $P=0·471$; 3/3, 100% deaths in ED). Although the number of sputum specimens cultured for children was lower than for the elderly, the proportion of positive cultures was highest for age groups 5–14 years (18/39, 46·2%) and 15–24 years (30/75, 40·0%) (Fig. 3). However, there was no significant trend in the proportion of positive sputum cultures according to age ($P=0·648$).

The most common organisms isolated from sputum in both admissions and non-admissions were *Haemophilus influenzae* (187, 10·7% of presentations that had sputum cultured, 35·4% of positive cultures) followed by *S. pneumoniae* (137, 25·9% of positive cultures). These two species accounted for 21/28 (75·0%) non-admissions yielding an organism. Other common species isolated from admitted patients included *Pseudomonas aeruginosa* (79, 15·9% of positive cultures), *Staph. aureus* (54, 10·9% of positive cultures) and *Moraxella catarrhalis* (31, 6·2% of positive cultures). Two (7·1% of positive cultures) non-admissions and 48 (9·7% of positive cultures) admissions produced polymicrobial cultures. *H. influenzae* was isolated from the same culture as *S. pneumoniae* (14), *Staph. aureus* (4), *M. catarrhalis* (3), *P. aeruginosa* (2), *Neisseria meningitidis* (1) and *S. pneumoniae* plus *M. catarrhalis* (1). In addition to *H. influenzae*, *S. pneumoniae* was isolated from the same culture as *P. aeruginosa* (5), *M. catarrhalis* (4), *Staph. aureus* (1) and Lancefield's Group C streptococcus (1). Unlike blood, there was no obvious microbial pattern found in sputum according to age (Table 2). However, *H. influenzae* was found noticeably more frequently in those aged ⩾85 years (51·7%) compared to those younger (range 28·9–36·7%). While six paediatric presentations yielded *P. aeruginosa*, these related to four patients, three of whom had cerebral palsy recorded as co-diagnoses in the morbidity record.

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Table 2. *Most common organisms isolated from sputum of patients diagnosed with pneumonia according to age group*

Age group (years)	No. presentations*	*S. pneumoniae* (%)	*H. influenzae* (%)	*P. aeruginosa* (%)	Enterobacteriaceae (%)	*Staph. aureus* (%)
5–14	18	5 (27·8)	6 (33·3)	6 (33·3)	0	2 (11·1)
15–24	30	12 (40·0)	11 (36·7)	4 (13·3)	2 (6·7)	3 (10·0)
25–34	37	19 (51·4)	12 (32·4)	2 (5·4)	1 (2·7)	1 (2·7)
35–44	38	13 (34·2)	11 (28·9)	4 (10·5)	0	10 (26·3)
45–54	34	7 (20·6)	10 (29·4)	3 (8·8)	7 (20·6)	6 (17·6)
55–64	41	15 (36·6)	12 (29·3)	5 (12·2)	1 (2·4)	1 (2·4)
65–74	132	31 (23·5)	45 (34·1)	25 (18·9)	9 (6·8)	14 (10·6)
75–84	137	24 (17·5)	49 (35·8)	21 (15·3)	18 (13·1)	13 (9·5)
⩾85	60	10 (16·7)	31 (51·7)	11 (18·3)	4 (6·7)	5 (8·3)

* Some patients produced more than one organism hence % may total more than 100.

Both blood and sputum cultured

Both blood and sputum specimens were taken either in the ED or within 2 days of ED arrival from 1145 (16·6%) presentations (19/1586, 1·2% non-admissions, 1124/5293, 21·2% admissions, 2/29, 6·9% deaths in ED). However, as time of specimen collection was not always recorded, it was not possible to determine the interval between specimen collection. Further, data on whether antibiotics were administered prior to specimen collection were not recorded in the electronic datasets. Of the 1145 presentations, 733 (64·0%) did not produce positive cultures from either specimen type, 70 (6·1%) produced positive blood cultures only, 293 (25·6%) produced positive sputum cultures only and 49 (4·3%) produced both positive blood and sputum cultures although the isolates were not necessarily the same organism type.

S. pneumoniae was grown from the sputum of 98 (8·6%) presentations having both specimens cultured but only 17 (17·3%) of these grew the organism also in blood. Further, these 17 represented 50% of the 34 presentations growing *S. pneumoniae* from blood.

E. coli was isolated from both blood and sputum in one (0·09%) case, from blood only in 10 (0·9%) and from sputum only in 11 (1·0%) cases. *Staph. aureus* was isolated from both blood and sputum in three (0·3%) cases, from blood only in seven (0·6%) and from sputum only in 32 (2·8%) cases.

Antibiotic susceptibilities

Of those presentations with *S. pneumoniae* isolated and subsequently tested for penicillin susceptibility, 11/94 (11·7%) produced resistant organisms from blood and 11/131 (8·4%) produced resistant organisms from sputum. Two presentations had penicillin-resistant organisms isolated from both specimen types (Table 3).

Staph. aureus resistant to methicillin were found in the sputum of 16/55 (29·1%) presentations but in the blood of only 5/38 (13·2%) presentations (Table 3).

DISCUSSION

Data linkage was a useful tool in this epidemiological study. It allowed us to describe the bacterial pathogens isolated from both admitted and non-admitted patients, and identify hospital lengths of stay and in-hospital deaths. Further, the datasets we used included records of all patients presenting at the four main hospital EDs in Perth and thus the study was close to being population based. We included both paediatric and adult patients.

The number of presentations given an ED diagnosis of pneumonia increased for each year of the study. This trend is also evident according to Australia-wide data for hospital discharge diagnoses [1]. It is unknown whether the increase is due to a change in diagnostic testing, coding, or to a true increase in the incidence of pneumonia. However, a decrease in pneumonia for the younger age groups is now expected due to the introduction into Australia of the childhood pneumococcal vaccination programme which commenced in 2005 [12]. Further, there is evidence from other countries that suggests vaccinating young children may also reduce the rate of disease in adults due to decreased transmission of pneumococci [13].

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Table 3. *Potential pathogens isolated from blood or sputum and their susceptibilities to recommended antibiotics*

		Blood		Sputum	
Organism	Antibiotic	No. tested	Presentations yielding resistant organism	No. tested	Presentations yielding resistant organism
S. pneumoniae	Penicillin	94	11* (11·7%)	131	11* (8·4%)
H. influenzae	Amoxycillin	5	0	118	32 (27·1%)
	Amoxycillin + clavulanate only†	2	0	68	0
Staph. aureus	Methicillin	38	5 (13·2%)	55	16 (29·1%)
P. aeruginosa	Gentamicin	5	1 (20·0%)	81	4 (4·9%)
	Ticarcillin + clavulanate	5	0	81	18 (22·2%)
E. coli	Gentamicin	40	3 (7·5%)	18	0
	Ticarcillin + clavulanate	40	3 (7·5%)	18	2 (11·1%)
	Ceftriaxone	40	0	18	0
Klebsiella pneumoniae	Gentamicin	8	0	12	1 (8·3%)
	Ticarcillin + clavulanate	8	1 (12·5%)	12	0
	Ceftriaxone	8	0	12	1 (8·3%)

* In addition 2 intermediate (blood), 1 intermediate (sputum).
† Not reported as being tested against amoxycillin only.

Around 75% of those given an ED diagnosis of pneumonia were admitted which is considerably higher than the estimated 34% admission for all causes [14]. As expected, admission was highest for the very young and the very old. Interestingly, there was no statistical difference in the proportion of positive blood cultures between admitted and non-admitted patients. This was also the case with sputum cultures.

There has been much debate about the usefulness of blood cultures particularly in less severe pneumonia because the yield from cultures is low and the culture results rarely change patient management [15–17]. In our study, blood was cultured from over 50% of presentations but significant positive cultures were obtained from only 6·4% of these. Other studies have reported proportions ranging from 5·7% [16] to 13% [18]. It is possible that the 'atypical' or viral agents of pneumonia may account for a proportion of the negative cultures. However, some organisms may be less invasive than others. In our study, for example, *H. influenzae* and *P. aeruginosa* were isolated more frequently from sputum than blood. Therefore, it is difficult to compare the pattern of causative organisms from different studies because of differences in type of specimen, cohort assessed and diagnostic tests used. Nevertheless, as with previous work [16, 18, 19], *S. pneumoniae* was the most frequent organism isolated from blood. This was seen for both admitted and non-admitted patients and for most age groups. For those aged <15 years, only 2/27 patients grew potential pathogens other than *S. pneumoniae* and this equates to around 0·2% of children who had blood cultured. The low overall proportion of positive blood cultures for children, and the present vaccination programme directed towards the most common pathogen isolated, suggests a need for a re-evaluation of the practice of routine culturing of blood from children diagnosed with pneumonia.

Although not obvious with the sputum culture results, isolation of Enterobacteriaceae from blood tended to increase with age. This may have implications for empiric therapy for those aged >65 years. It may be appropriate to consider therapy which includes antibiotics directed towards Enterobacteriaceae spp. which may not be part of current treatment guidelines for mild community-acquired pneumonia. Our data did not include information on whether patients had mild or severe pneumonia, or possible comorbidities, and further investigation of this issue would be useful.

H. influenzae accounted for at least 25% of positive sputum cultures for each age group and overall was the most common organism isolated from this specimen type. Other organisms did not show any distinct patterns. We did not classify the sputum isolates as

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likely pathogens or likely contaminants. Given the relative difficulty of producing a sputum specimen, particularly by children, some contamination from the upper respiratory tract is likely. Although *H. influenzae* and *S. pneumoniae* are regarded as pathogens they may be part of the normal flora of the nasopharynx [20]. Therefore, assigning causation because of isolation from sputum only may not be clear cut, particularly when more than one type of organism is recovered. This raises the question of the value of routine sputum cultures, at least in uncomplicated cases.

Around 11% of presentations with *S. pneumoniae* cultured from blood and 8% from sputum grew penicillin-resistant organisms. A previous Australian study [21] reported a similar figure for invasive *S. pneumoniae* in young children but a higher result (17%) for those aged >65 years. Methicillin-resistant *Staph. aureus* was found in twice the proportion of sputum cultures as blood and demonstrates the importance of monitoring antibiotic susceptibilities of organisms isolated from a variety of specimen types. Differences in resistance to antibiotics between invasive and non-invasive strains of other organisms have previously been reported [22].

There were some limitations to our study. The cohort was defined by the ED diagnosis and doing so allowed us to include non-admitted patients. However, this is a provisional diagnosis and the results need to be considered with this in mind. Blood and sputum cultures taken after 2 days of ED arrival were not included in the analysis to reduce the possibility of including hospital-acquired infections. However, we did not exclude patients with a recent previous hospital admission as not all of these occurrences could be identified in our datasets. It is therefore possible that a small number of isolates identified were acquired during a previous admission. The study did not include laboratory data testing for the presence of *C. pneumoniae*, *M. pneumoniae* and *Legionella* organisms. Overseas serological studies have suggested *M. pneumoniae* may be a common cause of pneumonia [23, 24]. However, testing for the 'atypicals' is not routinely performed. Therefore, appropriately designed surveillance studies are required to estimate the frequency of these organisms.

Despite these limitations, our study has provided an insight into the bacteriology of pneumonia diagnosed in Western Australian EDs over a 3-year period. While the value of routine blood and sputum cultures in this cohort is questionable, planned surveillance is necessary to ensure that empiric microbial treatment is appropriate, especially in the elderly, and to assess the effects of childhood pneumococcal vaccination.

ACKNOWLEDGEMENTS

S. L. I. was funded by a National Health and Medical Research Council public health postgraduate research scholarship number 353715. The authors thank the Directors of the Emergency Departments and Microbiology Laboratories of Princess Margaret Hospital for Children, Fremantle Hospital, Royal Perth Hospital and Sir Charles Gairdner Hospital for access to the data and acknowledge the assistance of Julie-Ann Da Silva and Brett Richards for providing the data extracts.

DECLARATION OF INTEREST

None.

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