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SYSTEMATIC REVIEW

What is the seasonal distribution of community acquired pneumonia over time? A systematic review

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Summary

Background: Community-acquired pneumonia (CAP) is a growing public health concern in many developed countries including Australia. CAP account for an estimated two percent of all overnight hospital admissions in Australia. Despite the significant burden on the Australian healthcare system and the high level of morbidity and mortality associated with CAP, there has been a paucity of research on the incidence of disease in this country, particularly in relation to seasonal variation of emergency department presentations and subsequent admission.

Methods: The following search terms were used: community-acquired AND pneumonia AND/OR seasonal AND season AND/OR variation OR differences. The limits used for the search terms included: "All Adult"; the years 1948 to current or 1948 to week 1 May 2012, (depending on the database); English language; and with full text. The databases searched included MEDLINE, Embase and CINAHL.

Results: Distinct seasonal patterns in the occurrence of CAP were observed: 34% of CAP admissions occurred in spring; 18% in autumn; 26% in winter; and 22% in summer ($p = 0.036$). Hospital admissions for CAP were significantly higher in the winter and spring ($p < 0.001$) and highest in December (20.5%) and January (25.1%). Peak hospitalisations from January through to April were observed. The included studies were conducted in the northern hemisphere where the months December to February relate to winter.

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Conclusions: International studies have shown an association between seasonal variation and the occurrence of CAP in temperate and subtropical climates. Selected studies had methodological limitations that limit conclusions and applicability to clinical practice. There are no studies in the Australian context. Further epidemiological studies are required to elucidate this important aspect of the epidemiology of CAP.

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What is known

- Despite vast improvements in antibiotic and supportive therapy, community-acquired pneumonia (CAP) remains a persistent global public health problem.
- Understanding the seasonal variations in emergency department (ED) presentations and hospital admissions for CAP is important. Identifying seasonal peaks enables predictions in clinical demand to be more accurately made. This may facilitate better planning and utilisation of services both within EDs and across wider organisations. This has been largely unexplored in the Australian context.

What this paper adds

- The seasonal distribution of CAP admissions varies by age and gender in countries with varying geography, climate, population distributions and other environmental conditions.
- Similar studies in Australia are necessary as this is a major gap in our knowledge of understanding CAP emergency department presentations and hospital admissions over time.

Introduction

Despite vast improvements in antibiotic and supportive therapy, community-acquired pneumonia (CAP) remains a persistent global public health problem. Lower respiratory infections including pneumonia remain the fourth leading cause of death worldwide.¹ In Australia, it is estimated that pneumonia accounts for two percent of all hospital overnight admissions.² Australian studies examining the occurrence of CAP have predominantly focused on the association between circulating respiratory viruses and CAP^{3–6}; the empiric treatment and management of CAP^{7–9}; or the efficacy of severity scores to rate the severity of CAP.^{10–12}

An aspect of incidence that has been largely unexplored in the Australian context is seasonal variation in emergency department (ED) presentations and admissions for CAP in isolation. CAP exists year round so understanding seasonal variations in and of its self will be valuable in understanding the burden this disease places on hospital services over time. Seasonal peaks in ED demand have been shown to have a negative impact on ED length-of-stays and access to inpatient beds.⁵ These directly contribute to ED overcrowding. Identifying seasonal peaks will enable predictions in clinical demand to be more accurately made. At a macro level this

can facilitate better planning and utilisation of services both within EDs and across wider organisations.

The correlation between increases in influenza and other circulating respiratory viruses and admissions for CAP and pneumonia has been widely documented internationally^{13–24} and within Australia.^{4–6} Kelly and associates (2009) examined patients hospitalised with either influenza or CAP during the H1N1 pandemic. Only a small proportion of patients admitted with CAP were identified as having concurrent influenza.⁶ These findings indicate that seasonal presentations for CAP alone place a significant burden on hospital admissions during peak influenza periods. Whether this is the case during non-influenza seasons and over time is worth investigating independently (Fig. 1).

The aims of this review were to investigate seasonal differences in the occurrence of CAP in relation to hospital admissions and to identify age and gender variations in the occurrence of the seasonal distribution of the disease.

Methods

Search methods

A systematic review of the current literature was conducted using the following databases: MEDLINE; Embase; and CINAHL. The following search terms were applied: community-acquired AND pneumonia AND/OR seasonal AND season AND/OR variation OR differences. The limits used for the search terms included: "All Adult"; the years 1948 to current or 1948 to week 1 May 2012, (depending on the database); English language; and with full text.

No additional records including papers not in circulation or other unpublished material were identified through searching other sources.

Selection of studies for the review: To be included, a study had to fulfil several criteria. Studies were selected where outcome measures were specifically defined as the incidence of hospital admissions for CAP or pneumonia over time using daily, monthly or yearly diagnoses of pneumonia from hospital medical records. The search included both viral and bacterial pneumonia. Given we were interested in the seasonal variation of pneumonia specifically, studies examining pneumonia and concurrent circulating respiratory viruses were excluded. Studies were also selected where the exposure measurements were defined as day of admission for CAP or pneumonia, season and age and gender. As we are interested in modelling the seasonal variations in CAP and pneumonia by age and gender over time we included studies where time series techniques such as correlational analysis and regression models were used. Studies which included only paediatric study samples were excluded. In all studies included in the review we assessed the applicability of the

Figure 1 Search criteria for review.

study design and analytical techniques and examined the extent to which the samples included in the studies were generalisable to other populations.

In conducting this narrative review, the findings have not been aggregated and the results are presented in summary form.

Results

Search results

A total of 37 studies were identified as appropriate for assessment of eligibility. Five were excluded because they discussed seasonality of invasive pneumococcal disease including pneumonia, meningitis and septicaemia with no differentiation between the specific disease processes. A further 16 studies were excluded from the analysis as they examined the incidence of pneumonia in association with influenza and other respiratory viruses. The remaining 12 studies identified by the search were excluded on the basis they were not related to seasonal variation ($n=9$) or were specific to paediatric study samples ($n=3$). Excluded studies are listed in Table 2. The remaining 4 studies were identified as meeting inclusion criteria for this review.

The studies which met the inclusion criteria for this review were selected on the basis of being relevant specifically to incidence of CAP or pneumonia requiring an admission to hospital and seasonal variation in adult populations.

Three of the selected studies were retrospective time-series analyses^{25–27} and one was a prospective analysis.²⁸

The term CAP and pneumonia will be used throughout this review and not interchangeably. This is because the included studies used ICD-9 diagnoses codes not specific to CAP.

The findings of the included studies pertain to both viral and bacterial pneumonia due to the low specificity of the ICD-9 diagnosis codes used.

Major findings

Seasonal distribution of CAP and pneumonia hospital admissions

A prospective study of community-acquired pneumonia conducted by Lieberman and colleagues²⁸ found a statistically significant seasonal variation: 34% of incidents of CAP occurred in spring; 18% in autumn; 26% in winter; and 22% in summer ($p=0.036$) (Table 1). A further retrospective analysis of seasonal variation in hospital admissions for CAP conducted over five years by Lieberman and associates²⁵ found the number of hospitalisations for CAP in the winter and spring were significantly higher than in the summer and autumn, though with some variation between age groups. Unlike the first study conducted by Lieberman and colleagues,²⁸ winter was found to have the highest admission rates for CAP accounting for a total of 31.3% of hospital admissions compared with 29.4% occurring in the months of spring. No significant statistical differences were found when comparing winter and spring admission rates for CAP.

Table 1 Characteristics of included studies.

Author(s), year of publication, journal	Methods	Outcome definition	Major findings
Lieberman D, Lieberman D and Porath A, 1996, <i>European Respiratory Journal</i>	Design: prospective Time period: November 1st 1991 and October 31st 1992 Setting/population: Beer-Shevain, south of Israel Sample size: $n = 346$ Inclusion criteria: aged 17–94 Exclusion criteria: Patients with positive blood tests for HIV; patient's with lung malignancies; and patient's discharged from hospital less than 21 days prior to current presentation. 16 patients who died in hospital were included in the study	Monthly hospital admissions for CAP	The peak month for CAP admissions to hospital was January while August had the fewest. Overall, 34% of CAP occurred in spring; 18% in autumn; 26% in winter; and 22% in summer ($p = 0.036$)
Lieberman D, Lieberman D, and Friger MD, 1999, <i>Journal of Infection</i>	Design: retrospective Time period: January 1st 1990 to December 31st 1994 Setting/population: Beer-Shevain, south of Israel Sample size: $n = 4101$ Inclusion criteria: ages 0–16 years; 17–64 years; 65+ years and all age groups combined Exclusion criteria: Presentations within 14 days of previous discharge from the hospital; patients hospitalised in surgical wards, the neurology department, the premature neonatal department and the gynaecology wards	Weekly hospital admissions for CAP	The number of hospitalisations for CAP in the winter and spring was found to be significantly higher than in the summer and autumn for all age groups combined and for each age group separately ($p = 0.00001$). Admissions were significantly higher in winter in the 0–16 years group ($p = 0.0001$) and significantly higher in the spring for the 17–64 age group ($p = 0.002$)
Synajakangas P, Keistinen T and Tuuponen T, 2001, <i>International Journal of Circumpolar Health</i>	Design: retrospective time-series analysis Time period: 1972–1993 Setting/population: Finland Sample size: $n = 453,393$ Inclusion criteria: age groups 0–16 years; 17–63 years (working-aged persons); and 64+ years	Average number of monthly hospital admissions for pneumonia or pneumonia-associated illness for study duration	Admissions for pneumonia were highest in December accounting for 20.5% and 25.1% in January. The months of lowest admissions were found to be July (–19.7%) and August (–24.3%). There was a total of 265,210 admissions for pneumonia for males compared with 188,183 for females
Hsiu-Chen Lin, Ching-Chun Lin, Chin-Shyan Chen and Herng-Ching Lin, 2009, <i>Chronobiology International</i>	Design: Retrospective time-series analysis Time period: 1998–2005 Setting/population: Taiwan Sample size: $n = 477,541$ Inclusion criteria: 18 years of age and over Exclusion criteria: Readmissions within 30 days of previous presentation	Monthly hospital admissions for pneumonia	Seasonal trends demonstrated a peak in hospitalisations from January through to April followed by a sharp decrease from May through to October for all age groups, combined groups and sexes. The monthly pneumonia admission rates ranged from a low of 1.91/10,000 in November 1998 to a high of 5.64/10,000 in March 2005. The mean monthly admission rate for males was 3.95/10,000 compared with 2.57/10,000 for females. Monthly pneumonia admission rates were found to be significantly associated with ambient temperature

Table 2 Characteristics and findings from excluded studies.

Author(s), year of publication, journal:	Methods	Outcome definition	Major findings
Kim P, Musher D, Glezen P, Rodriguez-Barradas M, Nahm W, and Wright C, 1996, <i>Clinical Infectious Diseases</i>	Design: Prospective Time period: June 1990–May 1993 Setting/population: four tertiary hospitals in the metropolitan area of Houston, TX, US Sample size: $n = 480$ Inclusion criteria: isolation of <i>S. pneumoniae</i> , all ages	Bi-weekly numbers of pneumococcal and viral isolates	The incidence of IPD was found to be 22.6 cases per 100,000 67% were isolated during the period October through March (OR, 2.06; 95% CI, 1.58–2.66). 36% were isolated during the period November through January (OR, 1.69; 95% CI 1.27–2.23; $p < 0.050$). Significant correlations were found between the occurrence of pneumococcal disease and the isolation of respiratory syncytial virus ($p < 0.001$), influenza virus ($p < 0.001$), and all viruses except influenza virus ($p < 0.001$); and air pollution, as measured by SO_2 levels ($p < 0.001$). The inverse correlation between the presence of cold weather and infection for adults was high $p < 0.001$
Crighton E, Moineddin R, Mamdani M and Upshur R, 2004, <i>Epidemiology and Infection</i>	Design: Retrospective time-series Time period: 1 April 1988 to 31 March 2002 Setting/population: Ontario, Canada Sample size: $n = 339,803$ Inclusion criteria: principal discharge diagnosis of influenza or pneumonia ICD-9 codes: 480–487	All admissions with a principal discharge diagnosis of influenza or pneumonia (ICD-9 code: 480–487)	Peak hospitalizations occurred in winter (January) at an average rate of approximately 27/100,000 and the trough occurred in August at a rate of just over 11/100,000. Seasonality was found to be most consistent in the youngest (0–4) and oldest age groups (greater than 80 years) Seasonal peaks occurred in January for all adult age groups and both sexes and February for the 0–4 years age group. The peak rates occurred earlier (November or December) for the 5–9 and 10–19 years age groups and also begin to increase earlier – September compared to October or November for all other groups
Jackson M, Neuzil K, Thompson W, Shay D, Yu O, Hanson C, and Jackson L and Jackson M, 2004, <i>Clinical Infectious Diseases</i>	Design: Prospective population-based Time period: 1st March 1998–28th February 2001 Setting/population: members of Group Health Cooperative (GHC) in Washington State, US Sample size: $n = 1266$ Inclusion criteria: >65 years on March 1 1998; Discharge diagnosis ICD-9-CM codes 480–487.0 Exclusion criteria: resident of a nursing home; previous hospitalisation within 7 days	Bi-weekly presentations of CAP	Of the 1266 included, 1413 cases were confirmed CAP. In the greater than 85 year age group CAP was found to occur in 52.3 events per 1000 person-years. Peak rates of CAP were found to be positively associated with viral influenza circulation. The proportion of hospitalisations for pneumonia did not vary between influenza and non-influenza periods

Table 2 (Continued)

Author(s), year of publication, journal:	Methods	Outcome definition	Major findings
Thomas T, Poehling K, Hartet T, Arbogast P, Halasa N, Edwards K, et al., 2005, <i>The American Journal of Medicine</i>	Design: Prospective correlational Time period: January 1995–June 2002 Setting/population: five Tennessee counties in the US Sample size: $n = 4147$ Inclusion criteria: isolation of <i>Streptococcus pneumoniae</i> (<i>S. pneumoniae</i>)	Weekly frequencies of laboratory diagnosed <i>S. pneumoniae</i> ; Respiratory syncytial virus (RSV); and influenza	Weekly frequency of <i>S. pneumoniae</i> correlated directly with the weekly frequency of isolation of RSV ($p = <0.001$) and influenza ($p = <0.001$). The average weekly frequency of <i>S. pneumoniae</i> during RSV and influenza seasons was higher than during the non-viral seasons ($p = 0.001$ for each year). The onset of the influenza season ranged from late November to early February while the onset of the RSV season ranged from late September to early November. There was no correlation found between weekly frequency of <i>S. pneumoniae</i> , laboratory confirmed RSV and influenza with the daily average of hours of darkness per week
Grabowska K, Högberg L, Pasi Penttinen P, Svensson A, and Ekdahl, K, 2006, <i>BMC Infectious Diseases</i>	Design: Retrospective analysis Time period: 1 January 1994 to 28 March 2004 Setting/population: Swedish Institute for Infectious Diseases Control IPD and influenza data Sample size: $n = 12,010$ Inclusion criteria: All isolates positive for <i>Streptococcus pneumoniae</i>	Weekly cases of <i>Streptococcus pneumoniae</i>	The analysis shows a yearly increase of 72–118 <i>Streptococcus pneumoniae</i> cases due to influenza. This corresponds to 6–10% per year or 12–20% per influenza season 12–20% of <i>Streptococcus pneumoniae</i> cases during influenza season in Sweden were secondary to influenza
Watson M, Gilmour R, Menzies R, Ferson M and McIntyre P, 2006, <i>Clinical Infectious Diseases</i>	Design: Ecological study Time period: 5 May 2000–27 October 2000 Setting/population: metropolitan New South Wales, Australia Sample size: $n = 681$ Inclusion criteria: postcode within region of Greater Sydney	Weekly number of cases of <i>S. pneumoniae</i> , respiratory viruses and influenza A or B	RSV activity was significantly positively correlated with <i>S. pneumoniae</i> activity in children but not with influenza virus activity. There was a weak inverse relationship between Para influenza virus activity and <i>S. pneumoniae</i> activity and a stronger inverse relationship between weekly mean maximum temperature, weekly mean minimum temperature, and occurrence of <i>S. pneumoniae</i> In adults, there was no significant correlation between RSV or influenza virus activity alone in <i>S. pneumoniae</i> , but the combination of RSV and influenza was significantly correlated with <i>S. pneumoniae</i>
Crichton E, Elliott S, Moineddin R, Kanaroglou P and Upshur, R, 2007, <i>Epidemiology and Infection</i>	Design: Retrospective population-based ecological Time period: 1 April 1992 and 31 March 2001 Setting/population: Ontario, Canada Sample size: $n = 241,803$ Inclusion criteria: All principal discharge diagnoses of influenza or pneumonia (ICD-9 codes 480–487)	All diagnosis of pneumonia or influenza	The yearly hospitalisation rate for the province was 242/100,000. The highest rates were seen among the elderly (≥ 65 years) where they were 1393/100,000 for males and 969/100,000 for females. In comparison, rates were 258/100,000 for males in the youngest group (0–14 years) and 202 for females. The lowest rates are seen in the 15–64 years age group. Statistically significant ($p = <0.050$) comparative morbidity figures were generally seen in northern counties. Among males aged 0–14 years, two northern areas were found to have rates that were between 2.2 and 5 times higher ($p = <0.050$) than the provincial mean. These statistically significant patterns of comparative morbidity figures being high in northern rural areas and low in southern urban counties were found across all age groups and between genders

Table 2 (Continued)

Author(s), year of publication, journal:	Methods	Outcome definition	Major findings
Di'az A, Barria P, Niederman M, Restrepo M, Dreyse J, Fuentes G, et al., 2007, <i>Chest</i>	Design: Prospective cohort study Time period: 27th February 2003–15th April 2005 Setting/population: Sample size: $n = 176$ Inclusion criteria: greater 16 years; diagnosis of CAP Exclusion criteria: transfer from another healthcare facility; hospitalisation within 30 days; active treatment for cancer or HIV positive status; use of immunosuppressive agents and history of organ transplant; active TB	Monthly admissions for CAP	Specific microbial aetiology was identified in 55% of the sample. Respiratory viruses were isolated in 32% of cases. Respiratory viruses were isolated more often in the months of autumn or winter (28%; $p = 0.011$). Respiratory viral pathogens were more likely to be isolated in patients greater than 65 years of age (20%; $p = 0.070$)
Simmerman J, Chittaganpitch M, Levy J, Chantra S, Maloney S, Uyeki T et al., 2009, <i>PLoS ONE</i>	Design: Prospective population-based Time period: January 2005–December 2008 Setting/population: Sa Kao province in eastern Thailand and Nakhon Phanom province in northeast Thailand Sample size: $n = 10,075$ Inclusion criteria: diagnosis of pneumonia Exclusion criteria: Patients transferred from another hospital; readmitted within 3 days from same hospital; newborn babies	All diagnosis of pneumonia	1346 (10.3%) of enrolled clinical pneumonia patients tested positive for influenza. During 2005, 2006 and 2008, pneumonia hospitalizations associated with influenza A virus infections were greatest during the winter months of June through October. In contrast, in 2007 a sharp increase was observed during the months of January through April when a sharp increase in influenza type A activity was observed during January to April. Influenza B virus infections did not demonstrate a consistent seasonal pattern
Boyle J, Crilly J, Keijzers G, Wallis M, Lind J, Sparks R, et al., 2010, <i>Emergency Medical Journal</i>	Design: Retrospective descriptive study Time period: June–September for the years 2005–2009 (identified peak months for the influenza season in the southern hemisphere) Setting/population: 27 public hospital EDs in Queensland, Australia Sample size: $n = 21,780$ (presentations for influenza-associated illnesses) Inclusion criteria: One of 11 ICD-10 codes: A08.4; B34.9; J10.8; J11.1; J18.0; J18.1; J18.2; J18.8; J18.9; Z04.8.	Monthly influenza presentations	Results Influenza-related presentations increased significantly over the 5 year study period from 3.4% in 2005 to 9.4% in 2009, reflecting a 276% relative increase. Occurrences in admission rate decreased over time from 28% in 2005 to 18% in 2009. Length of stay also decreased over the study period from a median of 210 min in 2005 to 164 min in 2009. Concurrent of influenza and pneumonia dominated the admissions for pneumonia though there was no further analysis of this

Table 2 (Continued)

Author(s), year of publication, journal:	Methods	Outcome definition	Major findings
Walter N, Taylor T, Shay D, William W, Thompson W, Brammer L, et al., 2010, <i>Clinical Infectious Diseases</i>	Design: Retrospective population-based ecological Time period: 1st July 1995–30th June 2006 Setting/population: Aggregated surveillance data divided in to the 4 US census regions: Northeast, Midwest, South, and West Sample size: $n = 34,274$ Inclusion criteria: all cases of isolated <i>S. pneumoniae</i>	Weekly cases of invasive pneumococcal pneumonia	It was estimated that during influenza periods, 13.5% (95% CI, 12.3–14.7%), 11.4% (95% CI, 10.7–12.7%), and 11.9% (95% CI, 11.1–13.6%) of pneumococcal pneumonia cases were influenza-associated in the north eastern, southern, and western regions, respectively. Influenza-associated pneumococcal pneumonia cases represented 4.5–6.0% of total annual cases of pneumococcal pneumonia. Among persons aged 5–64 years, we estimated that 16.7% (95% CI, 15.3–18.2%) and 15.4% (95% CI, 14.5–17.2%) of pneumococcal pneumonia cases occurring during influenza weeks in the north eastern and southern regions representing 6.2% (95% CI, 5.7–6.7%) and 7.1% (95% CI, 6.7–7.9%) of the total annual burden of invasive pneumococcal pneumonia in this age group in these areas
Wei Cui W, Zhao H, Lu X, Wen Y, Zhou Y, Deng B, Wang Y, et al., 2010, <i>Infectious Diseases</i>	Design: Retrospective chart review Time period: November 4, 2009–December 31, 2009 Setting/population: First Affiliated Hospital of China Medical University, Shenyang, China Sample size: $n = 68$ Inclusion criteria: Patients hospitalised with pneumonia and confirmed 2009 H1N1 virus infection Exclusion criteria: aged under 18 years, pregnant	Consecutive cases with confirmed diagnosis of pneumonia and H1N1	30 out of the 68 included patients (44%) were admitted to an intensive care unit and 10 (14.7%) died. Almost 80% of admissions were between the ages of 18–49 years with only 1% (1) aged over 65 years of age. 23 of the 68 patients (34%) had at least one underlying medical condition
Dodek P, Norena M, Keenan S and Teja, A., 2011, <i>Journal of Critical Care</i>	Design: time series analysis Time period: January 2002 and March 2006 Setting/population: Vancouver Coastal Health Authority in the province of British Columbia, Canada Sample size: $n = 740$ Inclusion criteria: Adults admitted to one of three medical-surgical intensive care units with CAP Exclusion criteria: patients who had been in hospital for more than three days before admission to ICU; patients with aspiration pneumonia; patients whose place of residence at the time of admission was outside the geographic boundaries	Weekly admissions to ICU with CAP	ICU admissions for CAP peaked each year in the winter and spring months. A single annual peak was independently associated with the number of patients admitted to ICU with CAP—rate ratio 1.12 with 95% CI 1.00–1.26. However, neither the weather measurements nor the weekly rate of reported influenza-like illness were significantly associated

Table 2 (Continued)

Author(s), year of publication, journal:	Methods	Outcome definition	Major findings
Von Baum B, Schweiger T, Welte R, Marre N, Suttorp M, Pletz S, et al., 2011, <i>European Respiratory Journal</i>	Design: Prospective Time period: June 1 2002–April 30, 2007 Setting/population: 12 clinical centres throughout Germany Sample size: $n = 5032$ Inclusion criteria: All patients with a diagnosis of CAP Exclusion criteria:	Bi-monthly cases of confirmed CAP	1337 (27%) cases had a definite CAP-causing pathogen identified 3274 patients were hospitalised; 102 (3%) of these had influenza-associated pneumonia. 78 (62%) of the patients with pure influenza-associated pneumonia and 24 (71%) of the patients with mixed influenza-associated pneumonia were admitted to hospital There were seasonal peaks of incidence during January and March each year, with considerable variations in numbers within years 160 cases (3.2% of the total sample) had influenza-associated CAP
Kelly P, Kotsimbos T, Reynolds A, Wood-Baker R, Hancox B, Brown M, et al., 2011, <i>Medical Journal of Australia</i>	Design: Prospective case series Time period: 1st July to 4th December 2009 Setting/population: 8 acute care hospitals forming the Flu CAN sentinel hospitals in Australia Sample size: $n = 68$ Inclusion criteria: aged over 18 years, recruited within 48 hours of admission Exclusion criteria: less than 18 years of age	Admissions for laboratory-confirmed (H1N1)	Of the 538 admissions for influenza 465 patients (86.4%) had the pandemic strain, representing 9.3% of total admissions with pandemic (H1N1) 2009 influenza ($n = 4992$) recorded nationally in 2009. 250/465 (53.8%) were women, 67/453 (14.8%) were Indigenous, and the median age was 46 years (interquartile range, 29–58 years). Comorbidities were present in 354/464 patients (76.3%), and 40 were pregnant (30.3% of women aged 15–49 years). FluCAN reported that 102 patients (21.9%) were admitted to ICUs, and of patients admitted to hospital, 26 (5.6%) died. FluCAN results were very similar to national notification data and published ICU admissions data. Of 1468 patients hospitalised with pneumonia, 718 (48.9%) were tested for influenza and 163 (11.1%) were co-infected with the pandemic strain
Kim S, Kilgore P, Lee S, Nyambat B and Ki M, 2011, <i>Journal of Health and Population Nutrition</i>	Design: Retrospective population Time period: January 2002–December 2005 Setting/population: South Korea Sample size: $n = 989,472$ Inclusion criteria: all pneumonia and influenza related ICD-10 primary or secondary discharge codes Exclusion criteria:	Weekly discharge data for pneumonia and influenza or pneumonia-like illness	48.4% of admissions were for children aged < 5 years. 21.2% occurred in persons 5–49 years; and 21.5% occurred in 65 years and greater. 18.7% of total cases were positively associated with specific aetiology. Two seasonal peaks in hospitalisations for children < 5 years occurred: in the winter months (October to January) and spring months (April to June). Those aged 5–64 had shorter winter and spring peaks in hospitalisations while those aged greater than 65 were found to have a sustained year-round rate of hospitalisations with several peaks of smaller duration for all study years ($p < 0.05$)

Comparatively, 19.6% and 19.7% of hospitalisations for CAP occurred in summer and autumn respectively. This was found for all age groups combined and for each individual age-group aggregate ($p < 0.010$) for each age group where a p -value of < 0.050 was considered statistically significant.

Synajakangas and colleagues²⁶ conducted a time-series analysis of monthly hospitalisations for pneumonia in Finland from 1972 to 1993. The study found variations in seasonality of incidence of pneumonia as well as large variation between age groups. Like the second study undertaken by Lieberman and associates²⁵ the winter month of January was found to have the highest proportion of annual hospital admission rates for pneumonia accounting for 25.1%, while December had the second highest with 20.5%. Admissions were significantly lower in the summer months of July (−19.7%) and August (−24.3%).

Lin and associates²⁷ conducted a population-based time-series analysis of hospitalisation data for pneumonia admissions from 1998 to 2005 in Taiwan. The study found seasonal trends in admissions for pneumonia with a peak in hospitalisations from January through to April (late winter and early spring) followed by a sharp decrease in May and a trough from August through to October (late summer and early autumn) for each individual age group, all age groups combined and when comparing genders. Again, significant seasonal variation in admission rates for pneumonia was found for all age and sex groups and for the entire sample was found ($p < 0.010$). The monthly pneumonia admission rates ranged from a low of 1.91/10,000 people in November 1998 to a high of 5.64/10,000 people in March 2005. The authors noted that the higher number of admissions for pneumonia in 2005 may have been attributed to a higher rate of influenza occurring in that particular year compared with the preceding years studied (1998–2004).

Distribution of CAP and pneumonia by age

Seasonal differences in peak admissions for CAP in two individual age groups were identified in the study by Lieberman and colleagues.²⁸ Admissions in the 0–16 year age group peaked in winter while the 17–64 year age group peaked in spring. When all age groups were combined and in the greater than 65 years group, differences in admission rates for CAP between winter and spring were not found to be significant.

The study undertaken by Lieberman and colleagues²⁵ examined three age-group aggregates (0–16 years; 17–64 years; and 65 years and greater) as well as all age-groups combined. They identified similar findings to that of the former study where admissions for CAP peaked in the winter and spring when all ages were combined as well as each individual age group. The same pattern of admission rates for the 0–16 years and the 17–64 year age groups were identified while no statistically significant trends in seasonal differences were identified in the greater than 65 years age group. One explanation offered by the authors to describe the observed variances between age groups was differences in specific aetiological agents causing CAP as well as differences in their frequency distribution throughout the seasons of the year. The authors identified the presence of the bacterium *Mycoplasma pneumoniae* as being more common in the region being studied in spring

and more prevalent in younger people compared with older adults, potentially accounting for the observed differences between age groups.

Synajakangas and colleagues²⁶ examined three age groups, 0–16 years, 17–63 years and greater than 64 years. Overall, a total of 17.9% admissions were for people under the age of 16 years; 29.4% were in persons of working age; and 52.7% were in persons over the age of 64 years. Comparable to findings from the two studies conducted Lieberman and colleagues,^{25,28} this study found admissions for pneumonia peaked in the winter month of December in the 0–16 year age group. Peaks in admissions in the 17–64 year age group were found to be highest in winter in this study compared to spring in the two Lieberman studies. Hospitalisations for pneumonia in the greater than 64 years age group were found to be highest in January in the Finnish study compared with no statistical significance found in seasonal peak for this group (or when all ages were combined) in either of the studies conducted by Lieberman and associates.^{25,28}

Three age-group aggregates were examined by Lin and colleagues,²⁷ 18–64 years; 65–74 years; and greater than 75 years as well as all age-groups combined. They found the number of hospital admissions for pneumonia peaked from January through to April (late winter and early spring) for all age and gender groups and for the whole sample. A total of 40.61% admissions for pneumonia during the period studied were in the 18–64 year age group. A further 21.52% occurred in the 65–74 year age group and 37.86% occurred in the greater than 75 years age group.

Distribution of CAP and pneumonia by gender

The study conducted by Lieberman et al.²⁸ did not examine seasonal differences in hospital admissions for CAP and gender. The remaining studies that examined gender differences and incidence of pneumonia found a higher number of males were admitted to hospital for the disease compared with females. Over the five year period studied by Lieberman and colleagues²⁵ there were 2335 (56.9%) admissions for CAP in males compared with 1766 (43.1%) in females. In the study conducted by Synajakangas and associates²⁶ in Finland, statistically significant differences between gender admissions for pneumonia were found in all three age group aggregates. Of the total 453,393 hospitalisations for pneumonia included in the study, 265,210 were male and 188,183 were female. In the less than 16 years age group, 46,489 admissions were males compared with 34,733 females. 29.4% of the total admissions for pneumonia were in the 17–63 years age group with 94,742 admissions for men compared with 39,573 for females. In the greater than 64 years age group, there were 123,979 admissions for men compared with 113,877 for females. Lin and colleagues²⁷ found 60.91% of admissions for pneumonia were for males compared with 39.09% for females. No further break-down in gender differences was noted in this study.

Climactic differences and CAP

In studies where the focus was on seasonal factors, findings are not directly comparable as they vary in climate, geography, population and other environmental conditions. For example, Lin and colleagues²⁷ focused on a population

of Taiwan are of Chinese Han background and Lieberman and colleagues^{25,28} conducted in the city of Beer-Sheva in the semi-arid desert Negev region in the south of Israel. The association between pneumonia hospitalisations and seasonal weather factors has been found to vary across geographic regions.²⁹ Findings from tropical or temperate locations are therefore not applicable to mild or colder climates. For this reason additional studies from populations of varying geography and climate including Australia are necessary to fully understand the region specific variations in CAP over time.

Discussion

This review has found a seasonal variation among patients with community acquired pneumonia. Possible factors contributing to this variation have been postulated to be lower ambient temperatures, a higher number of circulating respiratory bacteria and viruses in the winter months, and a larger number of people in-doors together.²⁷

The frequency of hospitalisations for CAP and pneumonia are highly correlated with age with the highest rates in the very young and the elderly.^{14,15,17,18,30} Poorer outcomes in the elderly with CAP have been attributed to multiple factors: severity of disease; pre-morbid function and co-morbid state; frailty (diminished reserve); age-related immune function changes; while age has also been independently associated with increased morbidity and mortality in CAP.³⁰ The study conducted by Lin and associates²⁷ linked the higher incidence of the disease in the greater than 75 years age group to weaker immune systems and a higher occurrence of general infections. The included studies used wide age-group aggregate ranges making meaningful age comparisons difficult. Age group aggregates must be narrow enough to detect potential differences between groups.

Each of the reviewed studies found higher admission rates for CAP and pneumonia among males compared with females for all age-groups examined. Demographic data for Finland as of 2012 shows there were approximately 2,666,622 males compared with 2,760,052 females³¹ indicating that the differences in admissions for pneumonia between males and females may not be due to a greater number of males in that country. The inclusion of a military hospital in this study is possibly reflected by the large differences seen in admissions between males and females for pneumonia in the 17–64 year age group (94,742 and 39,573 respectively). National military service is compulsory in Finland for men aged over seventeen years.

Gender differences in the incidence of infection can occur because of differences in clinical characteristics including socio-demographics, chronic health issues, health behaviours, or differences in the immune response to infection.³² The 2012 demographic data for Taiwan and Israel may suggest a different pattern. In 2012, Taiwan had an estimated 11,627,461 males compared with 11,607,475 females while Israel has an estimated 3,806,585 males compared with 3,784,173 females.^{33,34} Variations in presentation rates may help in planning for emergency medicine demands and timely access to inpatient beds. There has been a sustained trend towards increasing presentations to hospitals over the last 10 years, in excess of population increases.³⁵

Such increases have been exacerbated at times of higher incidence of respiratory illnesses. Effective prediction of demand may enable hospitals to open “swing beds” or expand their permanent bed complement to meet waiting time standards.³⁶ It is important that such information is utilised not only by EDs, but also by hospitals to manage potential access block at times of increased demand.³⁷

Strengths of included studies

A feature of the studies conducted by Lieberman and colleagues,²⁵ Synajakangas and associates,²⁶ and Lin and colleagues²⁷ were the time series design which allows examination of time trends such as seasonality and day to day variations. The longitudinal design of these studies also resulted in large sample sizes. Both multivariate analysis and univariate analyses were conducted by Lieberman et al.²⁵ and Lin et al.²⁷ This allowed meteorological parameters of each season to be correlated.

A further strength of the study conducted by Lin and colleagues²⁷ was that it is virtually exempt from potential confounding by differences in ethnicity among the sample population. This is due to 98% of Taiwanese being Chinese Han background. However, their findings may only then be generalisable to other Asian populations.

Limitations of included studies

A number of limitations were identified in the included studies. The studies conducted by Lieberman and associates^{25,28} and Synajakangas and colleagues²⁶ applied a limited number of variables and statistical analyses which do not necessarily imply causality between two variables, as suggested in the studies. The choice of including one or a limited number of hospitals^{25,26,28} introduces the potential for selection bias due to variations in practice between hospitals such as admission criteria and availability of hospital beds.

The prospective study of CAP conducted by Lieberman and colleagues²⁸ looked at data for the period of one year. Using data collected for the period of one year alone, it is not possible to confirm or negate that the period observed represented an epidemic period for the incidence of CAP and trends over time are not able to be observed. A major limitation of the study conducted by Synajakangas and associates²⁶ was the practice of annualising the monthly admission rates for pneumonia for the entire study period (1972–1993). Annualising monthly rates obscures year-to-year variations and does not allow for the examination of trends over time.

The inclusion of International classification of disease (ICD) version 9 codes pertaining to pneumonia and influenza in studies examining pneumonia confuses the results making it impossible to determine pneumonia as the primary diagnosis. A possible reason for the inclusion of these codes may have been to increase sample size. The efficacy associated with using ICD-10-CM codes to accurately identify a diagnosis of pneumonia has been validated.^{24,38} Any future study examining pneumonia in isolation would warrant using the revised version (ICD-10-CM) and limiting inclusion to codes which are specific to pneumonia.

Studies examining community-acquired pneumonia specifically have used varying criteria to determine that the

disease process was truly acquired in the community and not nosocomial (hospital-acquired) or health-care acquired. Lieberman and colleagues²⁸ excluded all patients who had been hospitalised within 21 days of the presentation of interest to capture patients with CAP. In the 1999 study, previous hospitalisation within 14 days was utilised by Lieberman and associates to exclude patients with hospital-acquired pneumonia. When examining community-acquired infections, exclusion of a hospitalisation within at least three months prior to episode of interest should be retained to ensure the episode truly is community-acquired.^{38,39}

Limitations of this Review: A limitation of this review was the lack of findings on potential causes for CAP. Seasonal variations in admissions for CAP may be directly related to seasonal variations in pathogen exposure. Our review underestimates the true burden of the disease as patients managed in the outpatient setting were not included.

Summary

In conclusion, there is a lack of epidemiological Australian studies examining incidence rates of community-acquired pneumonia and its association with seasonal variation. Among existent international studies, CAP has been associated with seasonal variation and variations by age and gender. These studies have methodological limitations that limit conclusions and applicability to clinical practice. A greater understanding of the seasonal patterns which influence ED presentations for CAP in Australia will result in the development of more informed policies and better planning of hospital services. Increased knowledge on seasonal variation of CAP in our region may also contribute to a greater understanding of the pathogenesis of the disease.

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