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Monitoring of community-acquired pneumonia hospitalisations before the introduction of pneumococcal conjugate vaccine into Polish National Immunisation Programme (2009–2016): A nationwide retrospective database analysis

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ABSTRACT

Purpose: Community-acquired pneumonia (CAP) is a common infection with significant morbidity and mortality. In January 2017, Poland introduced pneumococcal conjugate vaccine (PCV) into their national immunisation programme to protect children against invasive pneumococcal disease. This study was designed to investigate pneumonia-related hospitalisation rates and trends from 2009 to 2016 prior to the introduction of nationally funded PCV vaccination.

Methods: Using national public statistic data available from the National Institute of Public Health – National Institute of Hygiene, annual hospitalisation rates for pneumonia were analysed, categorised by aetiology and age (<2, 2–3, 4–5, 6–19, 20–59, 60+ years). Trends over time were assessed, as well as in-hospital mortality.

Results: The overall hospitalisation rate due to pneumonia varied between 325.9 and 372.2/100,000 population. Higher rates of hospitalisation were seen in older adults and children ≤5 years. Trends were observed when analysing hospitalisations by pneumonia aetiology within age groups: between 2009 and 2016, *Streptococcus pneumoniae* hospitalisations significantly increased for children aged <2, 2–3, and 4–5 years, from 5.3 to 12.4, 5.2 to 8.2, and 1.9 to 4.6/100,000 population respectively. Whereas hospitalisations due to *Haemophilus influenzae* pneumonia decreased significantly from 7.8 to 1.8 and 4.8 to 1.9/100,000 children aged <2 and 2–3 years respectively. The numbers of in-hospital deaths increased from 5578 in 2009 to 8149 in 2016, with >85% of deaths in the 60+ age group.

Conclusions: This is the first national study of pneumonia hospitalisations in Poland, providing the baseline data from which to investigate the impact of the change in vaccination policy on pneumonia hospitalisations in Poland.

Abbreviations: CAP, community-acquired pneumonia; EU, European Union; Hib, *Haemophilus influenzae* type b; ICD-9, International classification of diseases, ninth revision; ICD-10, International statistical classification of diseases and related health problems, 10th revision; IPD, invasive pneumococcal disease; NIP, National Immunisation Programme; NIZP-PZH, National Institute of Public Health – National Institute of Hygiene; PCV, pneumococcal conjugate vaccine.

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1. Introduction

Pneumonia is a form of acute respiratory infection that affects the lungs; it is a common disease with variable incidence depending on the country, time-period studied, age and sex of individuals [1,2]. Community-acquired pneumonia (CAP) is the infectious disease which causes the highest number of deaths globally, with the risk of death increasing with age [1]. The Eurostat data recorded that in 2014, 118,300 individuals died due to pneumonia in the European Union (EU), with Poland accounting for 12,300 deaths [3]. Pneumonia is a leading cause of hospitalisation with approximately 1 million people hospitalised annually, as 20–50% of patients across the EU require hospitalisation [4], increasing with patient age [1].

Pneumonia is caused by bacterial, viral and fungal infections, with *Streptococcus pneumoniae* and *Haemophilus influenzae* type b (Hib) amongst the most common bacterial infections and respiratory syncytial virus being the most common viral infection [5]. Studies have broadly demonstrated that *Streptococcus pneumoniae* is the leading cause of hospitalisation for CAP in children and adults [6–8].

Vaccination against invasive pneumococcal disease (IPD) has been available in Poland for the last decade for individuals at high risk of infection, as well as for infants in the City of Kielce (Świętokrzyskie region) and some other municipalities [9]. From 1st January 2017, nationally funded universal childhood immunisation with pneumococcal conjugate vaccine (PCV) was introduced into the National Immunisation Programme (NIP) [10]. This decision followed the positive experience from other countries and the outcomes of PCV vaccination in Kielce [11–14]. The current study was performed to assess pneumonia hospitalisation rates and trends prior to the introduction of nationally funded PCV vaccination, in order to provide a benchmark from which to assess the impact of the vaccination policy change.

2. Materials and methods

2.1. Data sources

Data for hospitalisations and in-hospital deaths in Poland for the years 2009–2016 were obtained from the national database available at the National Institute of Public Health – National Institute of Hygiene (NIZP-PZH) in Warsaw. This database contains information collected as part of the Statistical Research Programme on Public Statistics [15], which covers annually on average 93% of hospitals in Poland (military facilities are excluded). Codes based upon the diagnosis determined by the doctor and recorded in a patient's medical records are routinely collected and submitted to the national database by hospital statistical units. Each hospital has a statutory obligation to report data [2].

The total population in Poland was 38.2 million in 2009, increasing to 38.4 million in 2016. Over the study period, there was a growing proportion of older people (60+ years) (i.e., representing 19.1% in 2009 and 23.6% in 2016) [16]. Population figures for corresponding years, by age group, were available from the Central Office for Statistics [17].

2.2. Data analysis

The data set for analysis included records where the main reason for hospitalisation was pneumonia. Pneumonia-related diagnoses considered for this analysis included International Statistical Classification of Diseases and Related Health Problems; 10th Revision (ICD-10) [18] codes J10.0, J11.0, J12-J15, J15.3, J15.4, J16-J18, J85.1, J86 (Table 1). Hospitalisation rates (the number of occurrences of hospitalisation in relation to the national Polish population) were calculated for each year 2009–2016, using age categories at diagnosis of <2, 2–3, 4–5, 6–19, 20–59, 60+ years. In-hospital mortality was investigated by counting the number of deaths (patient discharge status deceased) among occurrences of hospitalisations for pneumonia in a given year, and by calculating the proportion of deaths occurring within the 60+ years age group.

WINPEPI statistical software was used to conduct statistical calculations [19]. The significance of hospitalisation rate changes over time (trends) were tested with the Mantel test. The null hypothesis (that the trend was insignificant) was tested at the significance level of $p = 0.05$.

3. Results

A total of 1,038,810 pneumonia hospitalisations between 1 January 2009 and 31 December 2016 (eight complete years) were included in the analysis, the number per year varying between 124,393 in 2010 and 143,285 in 2013. A total of 52,266 in-hospital deaths were identified. Fig. 1 shows the number of pneumonia hospitalisations by aetiology as recorded by ICD-10 codes. Between 2009 and 2016, the total number of hospitalisations and the distribution of ICD-10 codes remained fairly stable. Overall, hospitalisation incidence rates ranged between 325.9 occurrences per 100,000 population in 2010 and 372.2 occurrences per

Table 1
Pneumonia-related diagnoses included in the analysis (by ICD-10 code).

ICD-10 code	Name in Polish	Name in English
J10.0	Grypa z zapaleniem płuc wywołana zidentyfikowanym wirusem grypy	Influenza with pneumonia, other influenza virus identified
J11.0	Grypa z zapaleniem płuc wywołana niezidentyfikowanym wirusem	Influenza with pneumonia, virus not identified
J12	Wirusowe zapalenie płuc niesklasyfikowane gdzie indziej	Viral pneumonia, not elsewhere classified
J13	Zapalenie płuc wywołane paciorkowcami (*Stereptococcus pneumoniae*)	Pneumonia due to *Streptococcus pneumoniae*
J14	Zapalenie płuc wywołane pałeczką grypy (*Haemophilus influenzae*)	Pneumonia due to *Haemophilus influenzae*
J15	Zapalenie płuc bakteryjne niesklasyfikowane gdzie indziej	Bacterial pneumonia, not elsewhere classified
J15.3	Zapalenie płuc wywołane przez paciorkowce grupy B	Pneumonia due to streptococcus, group B
J15.4	Zapalenie płuc wywołane przez inne paciorkowce	Pneumonia due to other streptococci
J16	Zapalenie płuc wywołane innymi drobnoustrojami niesklasyfikowane gdzie indziej	Pneumonia due to other infectious organisms, not elsewhere classified
J17	Zapalenie płuc w chorobach sklasyfikowanych gdzie indziej	Pneumonia in diseases classified elsewhere
J18	Zapalenie płuc wywołane nieokreślonym drobnoustrojem	Pneumonia, organism unspecified
J85.1	Ropień płuca z zapaleniem płuc	Abscess of lung with pneumonia
J86	Ropniak opłucnej	Pyothorax

ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18].

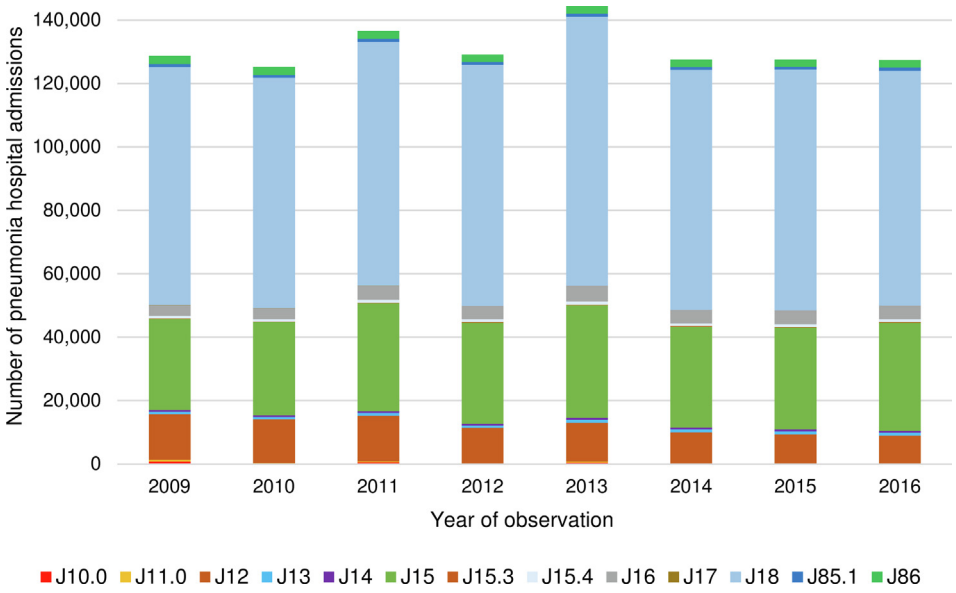

Fig. 1. Number of pneumonia hospital admissions, by ICD-10 code and year, 2009–2016. ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18]

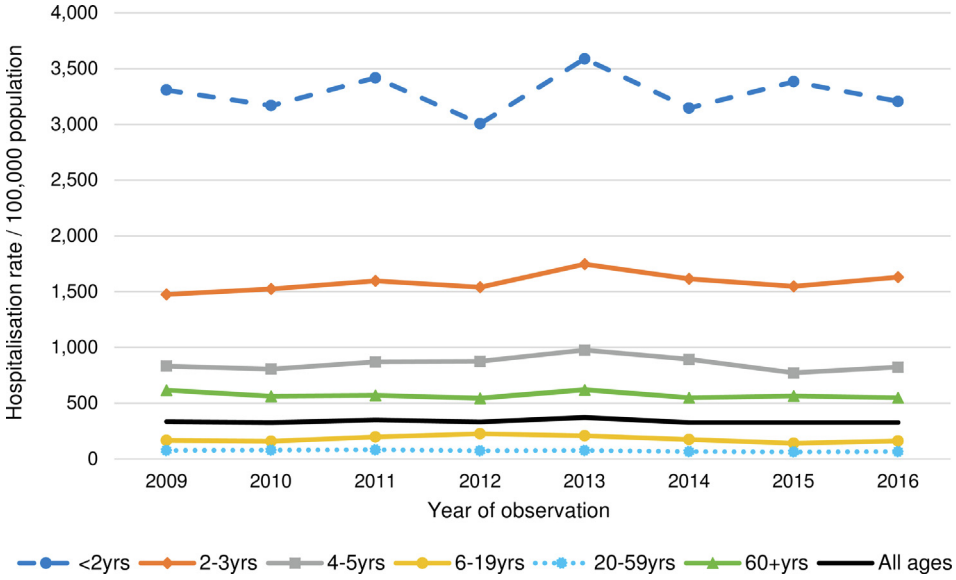

Fig. 2. Hospitalisation rates due to all-cause CAP (all study ICD-10 codes), by age group, 2009–2016. CAP: community-acquired pneumonia; ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18]; yrs: years. Significant trends, $p < 0.05$ for all age groups.

100,000 population in 2013. The most commonly recorded causes of pneumonia were ICD-10 code J18 'Pneumonia, organism unspecified' at rates 190.4–220.6/100,000 population, J15 'Bacterial pneumonia, not elsewhere classified' at rates 75.4–92.2/100,000 population and J12 'Viral pneumonia, not elsewhere classified' at rates 22.7–37.5/100,000 population (Supplementary Table 1).

Fig. 2 presents the all-cause CAP hospitalisation rates over time by age group, based on the totals from all the ICD-10 codes used in the study for pneumonia. Children aged <2 years were most likely to be hospitalised due to pneumonia, occurrences for this age group per 100,000 population varying between 3007 and 3590/100,000 population. The next most susceptible age group was the 2–3 years followed by the 4–5 years and 60+ years age groups.

Fig. 3 presents the 'Bacterial pneumonia, not elsewhere classified' (ICD-10 J15) hospitalisation occurrences, and again occurrences in children aged <2 years were the most frequent, with hospitalisation rates of 511.8–586.0/100,000 population. Fig. 4 shows the upwards trend in occurrences of pneumonia due to *Streptococcus pneumoniae* (ICD-10 code J13). The trends reached significance in the age groups <2, 2–3 and 4–5 years, with hospitalisation rates rising from 5.3, 5.2, 1.9/100,000 population in 2009 respectively to 12.4, 8.2, and 4.6/100,000 population in 2016 respectively ($p < 0.05$). The hospitalisation rate for the 60+ year-old population did not change significantly over time, varying between 5.5 and 6.6 occurrences per 100,000 population.

Fig. 5 shows the reported hospitalisations with ICD-10 code J14, 'Pneumonia due to *Haemophilus influenzae*'. The occurrence rate of hospitalisations decreased significantly for the age groups <2, 2–3, 4–5, 6–19 and increased for the 60+ year-old population. The changes were most noticeable for the <2 years (from 7.8 to 1.8/100,000 population) and 2–3 years (4.8 to 1.9/100,000 population) age groups from 2009 to 2016, with the most pronounced

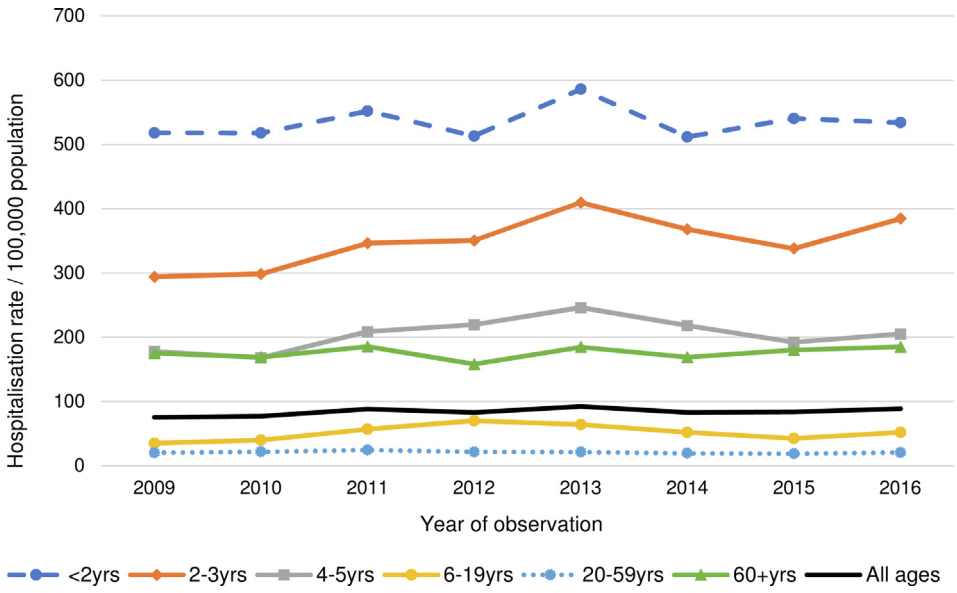

Fig. 3. Hospitalisation rates due to bacterial pneumonia, not elsewhere classified (ICD-10 J15), by age group, 2009–2016. ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18]; yrs: years. Significant trends, $p < 0.05$ for all age groups.

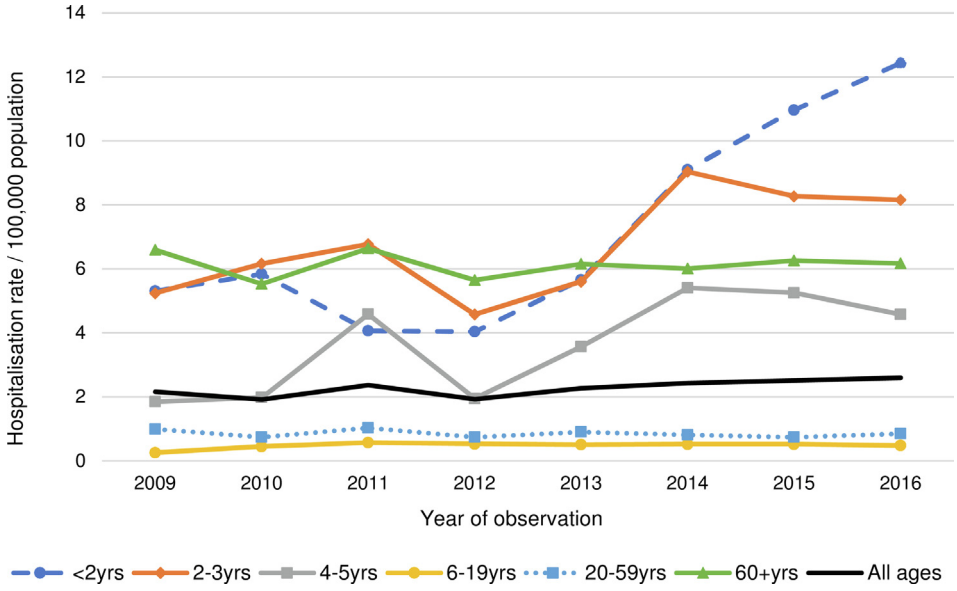

Fig. 4. Pneumonia hospitalisation rates due to *Streptococcus pneumoniae* (ICD-10 J13), by age group, 2009–2016. ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18]; yrs: years. Significant trends, $p < 0.05$ for age groups < 2, 2–3, 4-5yrs.

decreases occurring between 2009 and 2012. The hospitalisation rates for the age group 60+ years were consistently higher than all other age groups (post 2011), with occurrence rates rising from 2009 to 2016 (4.0 to 4.4/100,000 population).

The number of in-hospital deaths among patients admitted to hospital with a diagnosis of pneumonia was 5578 in 2009 and 8149 in 2016. Of these, 85.7% in 2009 and 90.1% in 2016 were in the 60+ years age group. The highest number of deaths were seen for cases diagnosed with ICD-10 J18 followed by ICD-10 J15 codes (Supplementary Table 2).

4. Discussion

Introduction of PCV in National Immunisation Programmes led to a decrease of the invasive and non-invasive pneumococcal diseases burden in vaccinated children and the rest of the population [20].

The present study is the first national comprehensive analysis focusing on hospitalisation for CAP in Poland. Previous studies have described the epidemiology of IPD, the resource utilisation, or have analysed specific age groups or regions [2,9,21–25].

In this retrospective database study, the absolute rates of hospitalisation for pneumonia per year were analysed for the years 2009–2016. The rates varied between 325.9 and 372.2 events per 100,000 population; remaining close to 329 per 100,000 population for the last 3 years. The results were consistent with data from a number of retrospective database studies with similar methodology (Table 2). Overall, studies of older populations saw higher CAP hospitalisation rates, considered to be related to age-related changes in the immune system and the prevalence of chronic diseases [1]. However, variations in rates are seen across all ages.

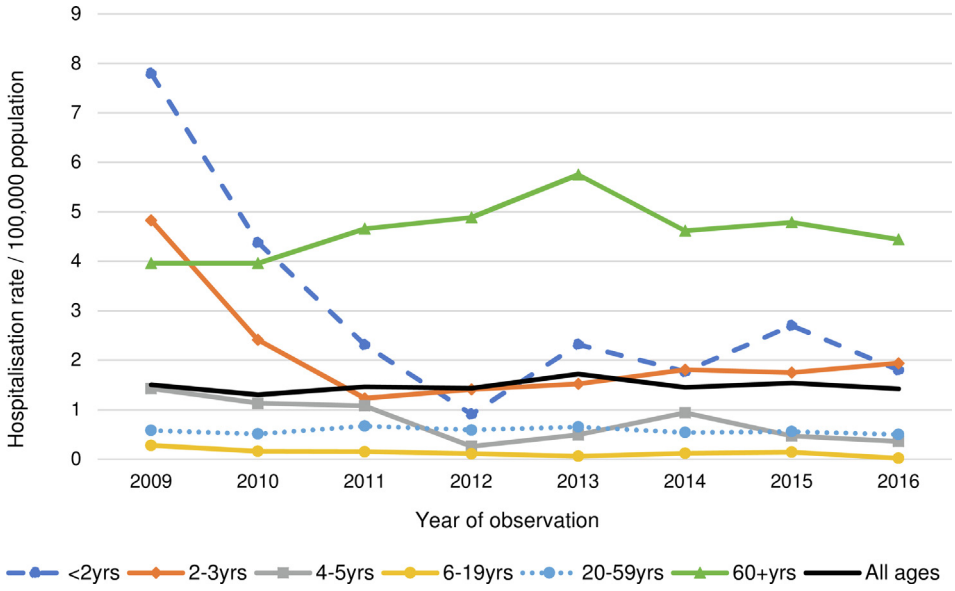

Fig. 5. Pneumonia hospitalisation rates due to *Haemophilus influenzae* (ICD-10 J14), by age group, 2009–2016. ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision [18]; yrs: years. Significant trends, $p < 0.05$ for age groups < 2, 2–3, 4–5, 6–19 and 60 + yrs.

Table 2
Comparison with community-acquired pneumonia hospitalisation rates from recently published European studies using similar research methodology.

Country	Year	Age group	Hospitalisation rate /100,000 population	Refs.
Present study	2009–2016	All ages	325.8–372.1	
Czech Republic	2010	≥50 years	472	[22]
Denmark	2011	All ages	531	[27]
Germany	2005–2006	≥18 years	275–296	[37]
Hungary	2006–2010	≥50 years	832	[22]
Italy	2004–2012	All ages	256.3	[38]
The Netherlands	2008–2011	All ages	295	[26]
Norway	2008–2009	All ages	528–535	[39]
Poland	2009	≥50 years	366	[22]
Portugal	2000–2009	≥18 years	361	[40]
Slovakia	2005–2009	≥50 years	518	[22]
Spain	2004–2013	≥18 years	142.4–163.87	[41]
Spain	2003–2007	≥50 years	627	[42]
The United Kingdom	2004–2005	All ages	198	[43]

Some variation could be explained by methodological differences. In the United Kingdom, it is possible to identify only first events whereas in our analysis, the anonymity of cases prevented this. Some studies used the International Classification of Diseases, Ninth Revision (ICD-9) rather than ICD-10 coding, both systems offering different coding possibilities of pneumonia. However, it is most likely that rate differences are related to differences in health services organisation and population factors such as socioeconomic differences, smoking rates, and use of vaccines against influenza or pneumococcal disease (polysaccharide vaccine use in adults or PCV use) [1]. The crude rate as assessed in this study is important since it represents significant resource utilisation. A similar study in the Netherlands estimated there were 295 hospitalised CAP cases per 100,000 inhabitants, with an associated 178 million euro financial burden each year, which equated to 51% of the annual healthcare expenses of hospitals on the management and prevention of infectious diseases [26]. In Poland, the total economic burden of CAP in ≥50-year-olds has been estimated in 2009 to be over almost 22 million euro [22].

Where studies included hospital-acquired pneumonia, published hospitalisation rates can be significantly higher. For example, in Denmark, the overall rate of hospitalisations was 809 per 100,000 in 2011 [27]. A review of European literature revealed the incidence of hospitalisation differed significantly between studies, ranging from 16 to 3581 per 100,000 adults dependent upon research methodology, country, patients' age, or time of study [1].

In total, across the 8-year study period, there were 1,038,810 cases of pneumonia-related hospital admission in Poland. The most common diagnoses were ICD-10 J18 and J15, 'Pneumonia, organism unspecified' and 'Bacterial pneumonia, not elsewhere classified'. Despite the advancements in medical technologies, the precise identification of the causative agent, if sought, remains difficult. A population-based study in older adults in Spain found aetiological analyses were only conducted in 76% of patients and, within these, the aetiological agent remained elusive in over 60% of cases [28]. In a Polish study in children up to 5 years, over 80% of confirmed IPD cases were culture negative [21].

In this study, most bacterial pneumonia cases were classed as J15 (Bacterial pneumonia, not elsewhere classified), with a hospital admission rate varying between 75.4 and 92.2 per 100,000 population over the study period. Although *Streptococcus pneumoniae* and *Haemophilus influenzae* are known to be important causes of bacterial pneumonia [29], a much smaller number were classified as

'Pneumonia due to *Streptococcus pneumoniae*' (rates of 1.9–2.6) or 'Pneumonia due to *Haemophilus influenzae*' (rates of 1.3–1.7). The number of pneumonia hospitalisations due to *Streptococcus pneumoniae* was seen to rise over time in children under 6 years. This could be due to an increase in testing for pneumococcal pneumonia as a result of increased disease awareness prior to the introduction of PCV. Conversely, the number of hospitalisations in children with a diagnosis of 'Pneumonia due to *Haemophilus influenzae*' was seen to fall. Mandatory and reimbursed Hib mass vaccination was introduced in 2007 in Poland, with an uptake of 98.8% by 2009 [30]. Prior to its introduction, Hib accounted for 25% of all bacterial meningitis especially among children aged 6–24 months old. As seen in other countries, mass vaccination resulted in an almost complete elimination of Hib-related diseases [31]. The decrease in pneumonia due to *Haemophilus influenzae* observed in this study could, therefore, be related to the introduction of Hib vaccination [32,33], although there is no direct evidence of Hib vaccination affecting pneumonia rates.

The risk of death due to pneumonia has been shown to increase significantly with age [4]. Between 2009 and 2016 in Poland, the proportion of people aged 60+ years in the general population increased steadily each year, from 19.1% in 2009 to 23.6% in 2016 [16]. In addition, the proportion of pneumonia patients among this age group increased since 2011, from 32.3% in 2011 to 38.8% in 2016. The proportion of 60+ year-olds among hospitalised pneumonia patients was, therefore, higher (by 12–16 percentage points) than the proportion in the general population over the study period. As a result, the number of pneumonia deaths, as well as pneumonia hospital mortality, has risen. Over the course of the study period, there were 52,266 in-hospital deaths following hospitalisation for pneumonia. The number of deaths per year increased and the proportion of patients aged 60 + years among the patients who died increased from 85.7% in 2009 to 90.1% in 2016. An analysis of the World Health Organization European detailed mortality database, using ICD-10 codes, found a decrease in pneumonia mortality across EU countries between 2001 and 2014, with the exception of Poland and males in Lithuania. Pneumonia mortality in Poland was found to have increased by 33.1% in males and 10.2% in females, with the gender difference possibly due to higher smoking rates in males versus females. Some EU countries also reported a rise in pneumonia hospitalisations, especially among older people, which could reflect changes in hospital admission thresholds, and could, thus, contribute to the rise in pneumonia mortality in hospitals [34].

Mandatory and reimbursed universal PCV vaccination for children (with a 2 + 1 schedule for infants and 3 + 1 schedule for children at risk) was introduced in January 2017 in Poland [10,25,35], following the positive experience in Kielce where a municipal pneumococcal vaccination programme was introduced in 2006. Vaccination uptake was positive with 94% of children born in 2017 vaccinated by the end of 2018 [36]. In Kielce, where hospitalisation rates for CAP were higher than in other areas of Poland [9], vaccination was financed by the Municipal Office, administered in 3 doses (2 + 1 schedule) covering 99% of the population of children aged 3–14 months [12]. Before the introduction of PCV vaccination, hospitalisation rates were 4132 and 611/100,000 children aged 1 year and 2–4 years respectively [13]. The rate of hospitalisation decreased in the first year by 65% and 23% respectively [13]. Further research revealed that seven years after the introduction of the vaccination programme, there were also considerable

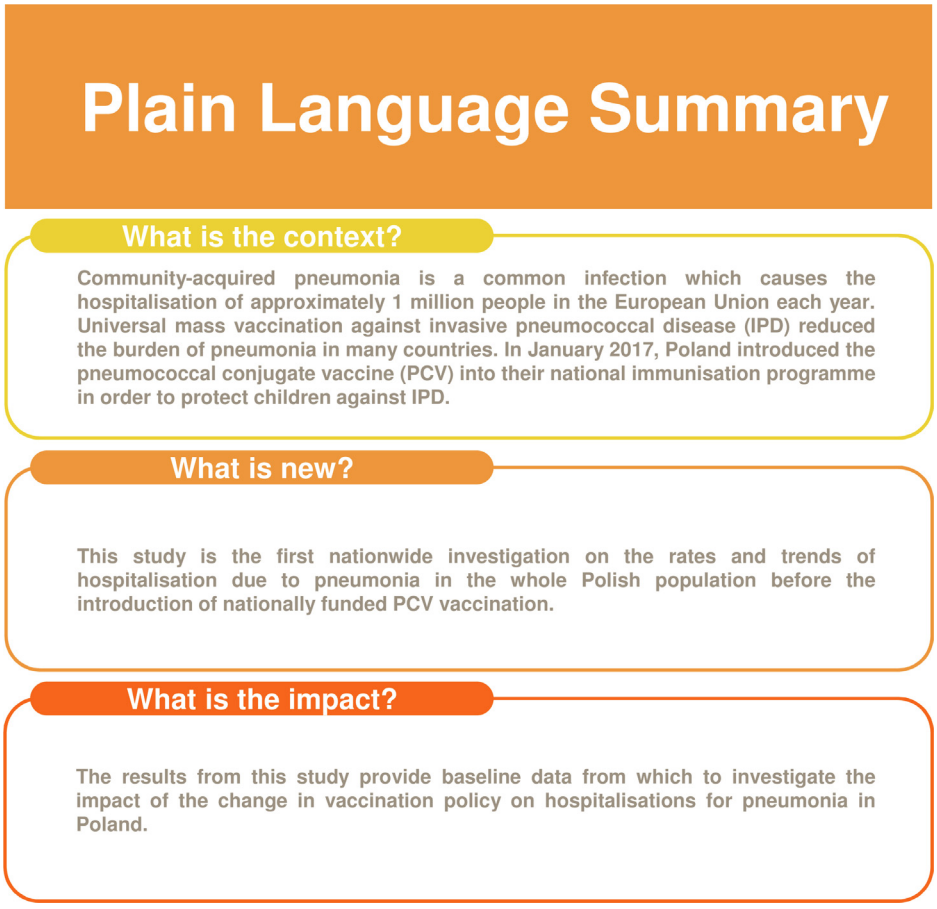

Fig. 6. Plain language summary.

reductions in the numbers of pneumonia cases in older age groups [12]. The present study should provide a benchmark for the investigation of the national impact of the change in vaccination policy. Fig. 6 summarises the context, outcomes, and impact of this study for healthcare professionals.

The study is limited to the hospitalised patients and therefore does not provide a full picture of the disease epidemiology. The privacy of individuals is protected in the hospital data, as such absolute numbers of hospitalisations were available, meaning that an individual could be counted more than once in the event they were admitted with pneumonia more than once per year or were transferred from hospital to hospital. Crude rates however remain relevant as these represent resource utilisation. Additionally, the bias resulting from this effect could be stable year to year. Time-trend analysis was performed within age groups as data were not age-standardised for investigation of population trends. Also, as is inherent with this type of study, any trend observed could reflect changes in medical practice, access to healthcare or most importantly changes in use of diagnosis codes. There is no explicit confirmation of diagnoses, as such the study is limited to providing indications rather than proof of underlying epidemiological changes. Nevertheless, this national study will be a useful benchmark for the evaluation of future trends should the methodology be replicated in years to come.

5. Conclusions

Over the eight years analysed in the study, the absolute number of pneumonia hospitalisations in Poland remained fairly stable. The patients most often undergoing hospital treatment due to pneumonia were children and older adults. Rates of pneumonia due to *Streptococcus pneumoniae* in young children were seen to rise, whilst rates of *Haemophilus influenzae* pneumonia in the same age groups fell. Universal Hib vaccination in Poland was introduced in 2007 and universal pneumococcal vaccination for children was introduced in January 2017. Taking into account the positive effects of pneumococcal vaccination seen in the Świętokrzyskie region of Poland, one can predict that the number of CAP hospitalisations in Poland will decrease in the future. Further analyses should be conducted to validate these predictions.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Alicja Książek and Patricia Izurieta are employees of the GSK group of companies. Małgorzata Gajewska, Paweł Gorynski, Iwona Paradowska-Stankiewicz, Katarzyna Lewtak, Maria Piotrowicz, Ewa Urban, Dorota Cianciara and Mirosław J. Wysocki report no conflict of interest.].

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Contributions

Małgorzata Gajewska, Paweł Gorynski, Katarzyna Lewtak and Alicja Książek participated in the conception and design of the study. Małgorzata Gajewska and Paweł Gorynski participated in the collection or generation of the data. All authors were involved in the analysis or interpretation of the data, and provided substantial intellectual and scientific input during the manuscript development, critically reviewing the content, revising the manuscript and giving final approval before submission. All authors had full access to the data and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The work described was carried out in accordance to ICMJE recommendations for conduct, reporting, editing and publications of scholarly work in medical journals. The corresponding author was responsible for submission of the publication.

Ethical approval statement

This article does not contain any studies with human participants or animals performed by any of the authors. For this type of retrospective study, formal consent is not required.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2019.10.031.

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