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Research article

Ten-year trends of antibiotics used for patients with pneumonia at long-term care hospitals in the Republic of Korea: An analysis based on national health insurance claims data

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ABSTRACT

Aim: To determine the trends in the usage of antimicrobial drugs by patients with pneumonia with prescriptions from long-term care (LTC) hospitals in the Republic of Korea.
Method: This retrospective study was conducted from 2011 to 2022 using the National Health Insurance Review and Assessment Service claim data in Korea. We calculated antibiotic usage expressed as a daily defined dose (DDD) per 1000 patients per day (DID).
Results: The number of patients with pneumonia in LTC hospitals increased by 2.7 times, from 30,000 in 2011 to 79,000 in 2022. Furthermore, antibiotic consumption per episode by patients with pneumonia in LTC hospitals increased from 17.14 DDD in 2011 to 18.11 DDD in 2022. Among the Access, Watch, and Reserve classification groups, the Watch group showed the highest usage; further, the Access group showed a decreasing trend, whereas the Watch and Reserve groups showed an increasing trend ($p < 0.01$). In the Watch group, the most commonly used antibiotic was J01CR05 (piperacillin and beta-lactamase inhibitor), followed in order by J01DD04 (ceftriaxone), J01MA12 (levofloxacin), and J01DH02 (meropenem). In the Reserve group, J01XB01 (colistin) and J01AA12 (tigecycline) were commonly used.
Conclusion: The antibiotics prescribed for pneumonia in LTC hospitals have continuously increased the use of broad-spectrum antibiotics. Accordingly, appropriate use of antibiotics in LTC hospital settings and assessment of antibiotics used are warranted.

1. Introduction

The overall antibiotic consumption in Korea has steadily increased over the past decade [1]; however, a slight decrease was observed in 2020 when the coronavirus 2019 (COVID-19) pandemic occurred [2,3]. Among the Organization for Economic

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Cooperation and Development countries, Korea has a relatively high number of antibiotic prescriptions [4]. Accordingly, the National Action Plan for Antibiotic Resistance in Korea, which was announced in 2016, prioritizes the prudent use of antibiotics and the reduction of unnecessary antibiotic prescriptions [5].

Previous studies have shown that antibiotic consumption is generally highest in older individuals [6]; moreover, there is high antibiotic use in long-term care (LTC) facilities. This could be attributed to the relatively high prevalence of infections among older adults and the overuse of antibiotics in LTC facilities [7,8]. LTC hospitals in Korea provide medical treatment and nursing care to individuals with chronic diseases or severe disabilities; further, they have a high proportion of older patients [9]. Similar to LTC hospitals in Korea, LTC facilities in Canada, Australia, and the United States also provide integrated treatment and nursing services [10].

Reported trends in antibiotic consumption within LTC facilities vary according to the study population, type of facility, and geographical location. Overall antimicrobial usage in LTC facilities was 81.8 daily defined dose (DDD) per 1000 residents per day (DID) in 2005–2016 (67.6–93.8) in Australia [11], 39.2 DID in 2007–2014 in Canada [7], and 28.9 DID in Singapore [12]. According to the National Health Insurance Service-national sample cohort group, antimicrobial use in Korea changed from 15.943 to 24.219 DID between 2002 and 2013 [1]. These wide differences in overall antibiotic consumption across countries could be attributed to various factors, including the type and organization of LTC facilities as well as the characteristics of the populations they serve; accordingly, antibiotic consumption is a complex issue [9,13,14].

In Korea, efforts are being made to reduce antibiotic overuse by regulating the use of systemic antibiotics as part of a broader strategy to combat antibiotic resistance and promote responsible use of antibiotics [5]. However, there are limited data regarding antibiotic use patterns in Korean LTC hospitals. As LTC hospitals have a fixed payment system, accurately estimating antibiotic use using Korea's claims data is difficult. However, for patients with pneumonia, the fee-for-service system allows for relatively accurate tracking of antibiotic usage. Therefore, this study aimed to investigate trends in antibiotic use among patients with pneumonia in LTC hospitals by analyzing Health Insurance and Reimbursements Agency claims data from 2011 to 2022.

2. Methods

2.1. Data source and study population

This study analyzes secondary data obtained from the National Health Insurance Review and Assessment Service claim data, encompassing approximately 98 % of the total population in Korea. These data were accessed with approval from the Health Insurance Review and Assessment Agency (IRB number: 2023-014) and were fully anonymized before access, ensuring no identifiable personal information was used. Our data handling processes were rigorously designed to adhere to ethical guidelines for secondary data research, in full compliance with the ethical standards of the Institutional Review Board of the Health Insurance Review and Assessment Agency. This adherence includes the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. As the study involved only de-identified secondary data and did not include direct interaction with human subjects, it was categorized as exempt from further review.

The study population comprised patients who claimed to have pneumonia among inpatients in LTC hospitals between January 1, 2011, and December 31, 2022. The amount of antibiotic consumption was calculated among these patients. The antibiotics used in the analysis were limited to the World Health Organization [15] anatomical therapeutic chemical (ATC) J01 class (antibacterials for systemic use).

Data from 4,967,152 patients admitted to LTC hospitals from 2011 to 2022 were extracted. Of these, 1,419,766 patients who used antibiotics were selected. Finally, 660,223 patients treated for pneumonia were included in the study (Supplementary material, Fig. S1). The amount of antibiotic consumption was calculated using WHO ATC DDD. The analysis unit of antibiotics was calculated as DDD/patients with pneumonia episodes.

DDD/episode was defined as the total antibiotic consumption in DDD for each episode of pneumonia, where an episode spans from the patient's admission to discharge. This definition enables accurate comparison of antibiotic use across individual pneumonia cases.

2.2. Statistical analysis

General characteristics of patients in LTC hospitals were analyzed by frequency analysis; further, the amount of antibiotic consumption was analyzed according to sex, age, Access, Watch, Reserve (AWaRe) classification, and ATC code level. Moreover, we performed univariate regression analysis of temporal changes in the amount of antibiotic consumption.

$$Y_t = \beta_0 + \beta_1 * time + e_t$$

The ATC code level was based on the classification system from the WHO Collaborating Center (2021) [16]. The AWaRe classification system was developed by the WHO in 2019 and comprises three groups: Access, Watch, and Reserve. The Access group includes antibiotics generally used to treat infectious pathogens. Antibiotics in the Watch group require monitoring since they have a higher risk of antimicrobial resistance than the Access antibiotics. The Reserve group comprises last-resort antibiotics used to treat infections caused by multidrug-resistant pathogens, which should only be used in certain patients under specific circumstances [17].

3. Results

3.1. Ten-year trend in patients with pneumonia

The number of inpatients in LTC hospitals increased from 255,000 in 2011 to 505,000 in 2019, followed by a decrease following the onset of the COVID-19 pandemic. The number of patients with pneumonia showed an increasing trend from 30,000 in 2011 to 74,000 in 2019, followed by a slight decrease to 67,000 in 2020 during the COVID-19 pandemic and a subsequent increase to 79,000 in 2022. Overall, the number of patients with pneumonia has increased by 2.7 times between 2011 and 2022. Patients with pneumonia accounted for 11.2%–16.8 % of all inpatients, with the percentage of patients with pneumonia showing an annual increase. <Fig. 1> In 2022, the number of patients with pneumonia per 100,000 population was 19, 207, 973, and 3523 among those aged 0–64, 65–74, 75–84, and ≥85 years, respectively, demonstrating an increase with increasing age. The number of patients with pneumonia continued to increase between 2011 and 2019, followed by a slight decrease in 2021 and an increase again in 2022. This pattern was observed in all ages. The absolute (non-population-adjusted) number of patients with pneumonia, excluding those aged ≥85 years, also showed a pattern of a slight decrease in 2021. Regarding the slope, the slope of the number of patients with pneumonia per 100,000 population was steeper and flatter for those aged ≤65 and 75–84 years, respectively, when adjusted for population. <Fig. 2(A-D)>

3.2. Antibiotic use according to age and sex

The amount of antibiotic consumption per episode among patients with pneumonia in LTC hospitals was 17.14 DDD in 2011 and 16.11 DDD in 2016, which had the lowest antibiotic consumption. Since 2016, antibiotic consumption increased to 18.67 DDD in 2021 during the COVID-19 pandemic and decreased again to 18.11 DDD in 2022. The annual trend was not significant. With respect to sex, both males and females showed an increase in antibiotic consumption; however, only males showed a significant trend ($p < 00.05$). With respect to age, there was a significant increase in antibiotic consumption across all ages, except ≥85 years. Among the AWaRe classification groups, the Watch group showed the highest antibiotic usage; moreover, the Access group showed a decreasing trend, whereas the Watch and Reserve groups showed a significantly increasing trend ($p < 0.01$). <Table 1>

3.3. Usage trend according to ATC and AWaRe classification

Regarding the amount of antibiotic consumption by ATC 3rd level, the antibiotics most commonly used in 2022 was J01D (other beta-lactam antibacterials) with 7.14 DDD, followed in order by J01C (beta-lactam antibacterials, penicillin) with 4.09 DDD, J01 M (quinolone antibacterials) with 3.45 DDD, and J01G (aminoglycoside antibacterials) with 1.07 DDD. Regarding the annual trend, the antibiotics with the highest increase in use were J01C, which increased by 2.8 DDD (from 1.29 DDD in 2011 to 4.09 DDD in 2022), followed by J01 M, which increased by 1.36 DDD between 2011 and 2022. Conversely, J01D and J01G, which were the antibiotics most commonly used, showed a decreasing trend. <Fig. 3> In the Access group, the most commonly used antibiotics in 2022 were in the following order: J01GB06 (amikacin), J01XD01 (metronidazole), and J01GB03 (gentamicin). Moreover, J01GB06 (amikacin) and J01DB12 (ceftezole) showed a decreasing trend in use, while J01GB03 (gentamicin) showed an increase in use after 2021.

In the Watch group, the most commonly used antibiotics in 2022 were in the following order: J01CR05 (piperacillin and beta-lactamase inhibitor), J01DD04 (ceftriaxone), J01MA12 (levofloxacin), and J01DH02 (meropenem). Further, J01CR05 (piperacillin and beta-lactamase inhibitor), J01MA12 (levofloxacin), and J01DH02 (meropenem) showed an increasing trend in use, whereas

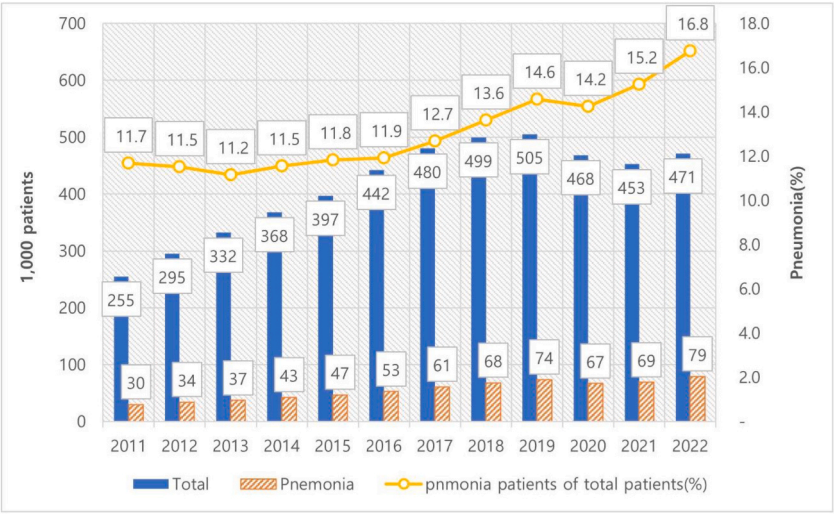


Fig. 1. Ten-year trend in inpatients and patients with pneumonia in long-term care hospitals.

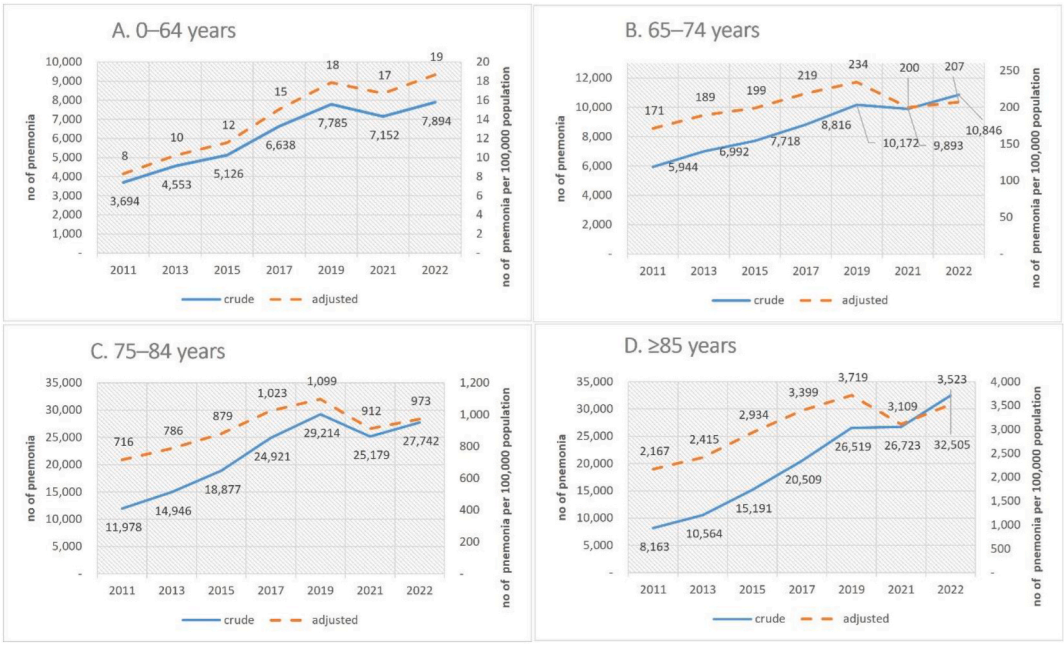


Fig. 2. Number of episodes and number of episodes per 100,000 individuals by age among patients with pneumonia in long-term care hospital.

J01DD04 (ceftriaxone) showed a decreasing trend in use. In the Reserve group, the use of J01XB01 (colistin) and J01AA12 (tigecycline) was confirmed. J01XB01 (colistin) showed a decreasing trend after peaking in 2020, while the use of J01AA12 (tigecycline) appeared after 2020. <Fig. 4(A-C)>

4. Discussion

This study investigated the trends in the use of antibiotics prescribed for pneumonia in Korean LTC hospitals over the past 10 years. This study has several major findings.

First, the findings showed a significant increase in the use of antibiotics prescribed for pneumonia, along with an increase in the number of patients with pneumonia in LTC hospitals over the past 10 years. This could be attributed to the rapidly aging population in Korean society. Specifically, there was a significant increase among individuals aged 75–84 and ≥ 85 years, with these age groups also showing a gradual increase in the number of inpatients over the past 10 years. Korea has rapidly become an aged society since 2000. The percentage of the population aged ≥65 years was 11.0 % in 2011, increasing to 13.2 % in 2016 and 17.5 % in 2022 [18]. As population aging continues, the percentage of the population aged ≥65 years is expected to exceed 25.7 % by 2030 and 34.4 % by 2040 [18]. Of note, the incidence of pneumonia is relatively high among older inpatients [19]. The average age of inpatients in LTC hospitals is increasing as a result of the aging population; additionally, our findings confirmed an increasing trend in antibiotics prescribed for pneumonia in LTC hospitals. Therefore, there is a need to establish appropriate use and control of antibiotics for pneumonia as well as prevention interventions for pneumonia among older patients in LTC hospitals. Moreover, several studies reported that patient comorbidities contribute to an increased risk of pneumonia [20]. Among LTC hospital patients, 65 % have difficulty in ADL function, such as using the restroom or moving outside their room. In addition, the average number of comorbidities in patients with pneumonia increased from 9.2 in 2011 to 12.1 in 2022 (Supplementary material, Fig. S2). These findings are consistent with prior studies that reported the characteristics of patients with pneumonia at LTC hospitals (such as advanced age, comorbid neurological conditions, and mobility issues) and their comorbidities, including neurological conditions, hypertension, dementia, cerebrovascular disease, and diabetes mellitus [20,21].

An increase in antibiotic consumption was identified from 2020 to 2021. This period coincides with the COVID-19 pandemic, which had a significant impact on pneumonia cases. COVID-19 can increase pneumonia risk, both as a primary respiratory disease and by weakening the immune system, making patients more susceptible to other infections. Previous research has shown that COVID-19 led to high antibiotic consumption, even in cases with minimal co-infection [2,22,23].

COVID-19 preventive measures and vaccinations have helped reduce the incidence of pneumonia in some contexts; however, this study found that antibiotic use still increased in Korean LTC hospitals. This trend may reflect the complex interplay between COVID-19, comorbidities, and the overall vulnerability of LTC hospital patients. The continued rise in pneumonia cases emphasizes the need for comprehensive strategies to manage pneumonia risk in LTC hospitals, including infection control, vaccination, and addressing comorbidities.

This study analyzes that patients with pneumonia accounted for 11.2–16.8 % of all inpatients, with the percentage of patients with

Table 1
Demographic characteristics of patients with pneumonia and the trend in antibiotic consumption according to the AWaRe classification (unit: DDD/episode).

			Total	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	β
ATC	Total		17.09	17.14	16.89	16.83	16.5	16.28	16.1	16.13	16.49	16.8	18.03	18.67	18.11	0.1298
	Sex	Male	17.76	17.77	17.4	17.44	16.97	16.66	16.66	16.61	17.17	17.41	18.9	19.42	19.12	0.1640*
		Female	16.35	16.47	16.34	16.15	16	15.89	15.49	15.6	15.74	16.12	17.02	17.78	17.03	0.0892
	Age group	<65	18.18	17.58	17.63	17.62	17.19	16.95	16.95	17.15	17.6	18.05	19.31	20.23	20.13	0.2438**
		65–74	17.67	17.54	17.06	17.29	16.71	16.42	16.29	16.55	17.24	17.48	18.94	19.81	19.39	0.2209*
		75–84	17.09	17.2	16.84	16.7	16.33	16.39	16.13	16.11	16.54	16.83	18.23	18.62	18.32	0.1468*
		85≤	16.49	16.56	16.53	16.36	16.34	15.85	15.67	15.64	15.77	16.14	17.14	17.87	17.01	0.0740
AWaRe	Access		3.72	5.64	5.18	4.65	4.24	3.94	3.53	3.46	3.32	3.32	3.57	3.29	3.04	−0.2089**
	Watch		13.23	11.41	11.61	12.07	12.15	12.24	12.44	12.53	13.03	13.33	14.25	15.18	14.93	0.3304**
	Reserve		0.07	0	0.01	0.03	0.03	0.04	0.06	0.06	0.07	0.08	0.12	0.12	0.09	0.0107**

AWaRe; Access, Watch, Reserve.
Beta values of the univariate regression analysis of temporal changes in the amount of antibiotic consumption.
*$p < 00.05$, **$p < 00.01$, and ***$p < 00.001$.

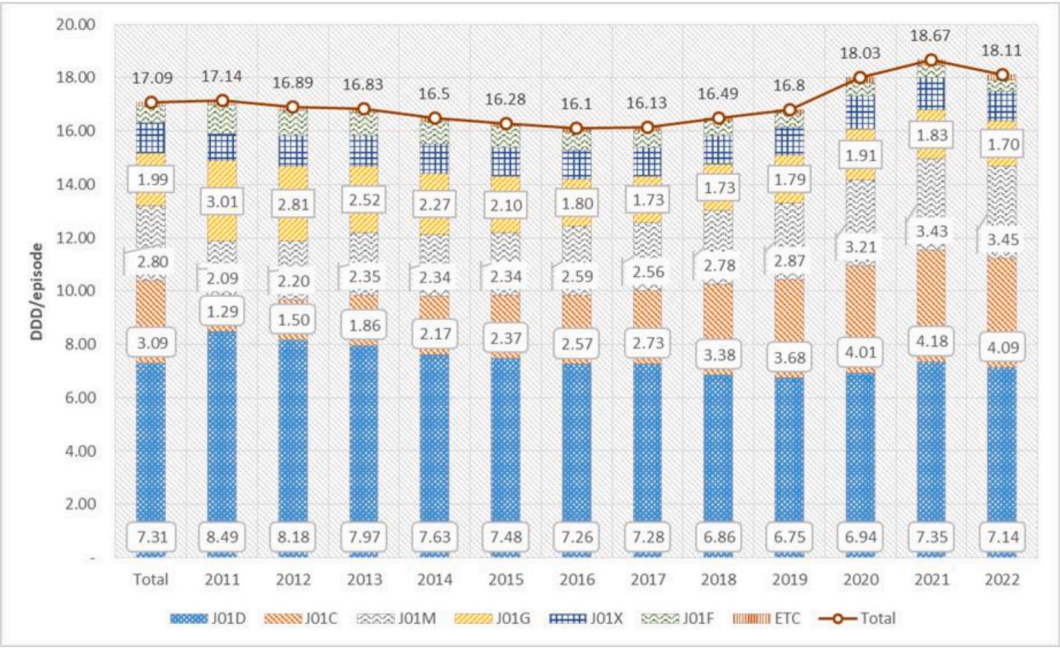


Fig. 3. Pattern of antibiotic consumption (DDD/episode) among patients with pneumonia J01D(Other beta-lactam antibacterials); J01C(Beta-lactam antibacterials, penicillins); J01 M(Quinolone antibacterials); J01G(Aminoglycoside antibacterials); J01X(Other antibacterials); J01F(Macrolides, lincosamides and streptogramins); ETC(Tetracyclines, Amphenicols, Sulfonamides and trimethoprim).

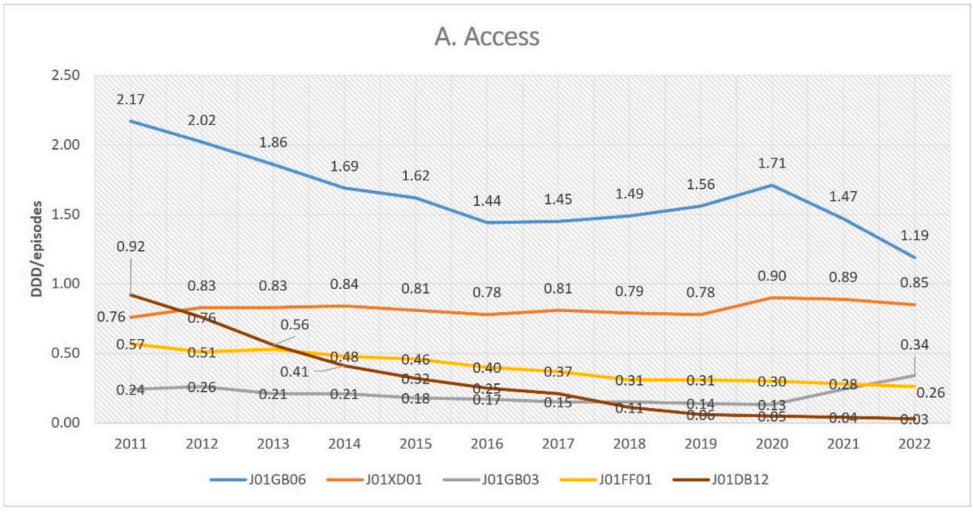
pneumonia showing an annual increase. This increase can be attributed in part to the aging population and related comorbidities, which contribute to higher susceptibility to pneumonia. Older adults often have weakened immune systems and are more likely to have chronic conditions such as COPD, heart disease, and diabetes, which increase their risk of pneumonia. Furthermore, LTC hospitals may face challenges in implementing effective infection control measures, especially when considering the close living quarters and mobility issues of many patients.

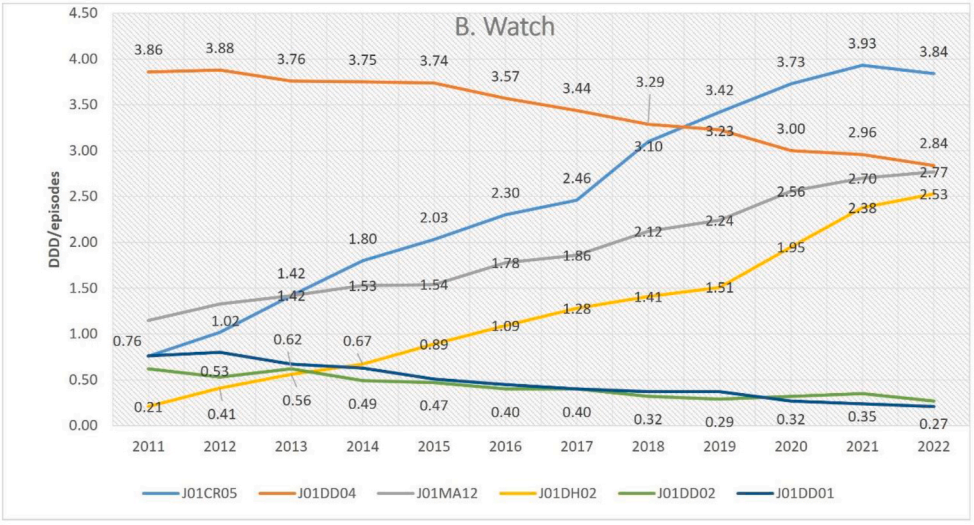
Second, there was a decrease in the number of inpatients in LTC hospitals and patients with pneumonia across all ages between 2020 and 2021. This could be attributed to the rationing of inpatients in LTC hospitals during the COVID-19 pandemic, as well as the increasing number of mortalities. Investigation of inpatients and mortalities using claims data revealed that the mortality rates among inpatients were 12.3 %. 13.7 %, 14.9 %. and 7.9 % in 2019, 2020, 2021, and 2022, respectively. This represented an increase of 1.5 % during the COVID-19 pandemic in 2020 compared with 2019; moreover, the number of inpatients in 2020 was less than half of that in 2019 (Supplementary material, Table S1). In 2022, when the COVID-19 pandemic had come to an end, the mortality rate increased by 2.99 %, as compared to 2021. The decrease in patients with pneumonia during this period might also be explained by these mortality rates, particularly among vulnerable patients.

The antiviral injection Veklury (main ingredient: remdesivir), which can be used on patients with COVID-19, was developed and approved as a special case in 2021. However, it was not widely used in the early phase following approval. Subsequently, in December 2022, the oral antiviral Paxlovid (main ingredient: nirmatrelvir and ritonavir) began to be used after receiving emergency use authorization [24]. Consequently, antibiotic consumption decreased following the use of these antiviral agents for COVID-19 or other infections. As such, antibiotic consumption was higher in 2021 than in 2022, which showed the highest percentage of patients with pneumonia.

Third, a gradually increasing trend was observed in the average amount of antibiotic consumption per episode among patients with pneumonia, which showed an overall average of 17.09 DDD per episode over the past 10 years. A study conducted by Kim et al. (2020) [6] on regular hospitals throughout Korea reported an antibiotic consumption of 15.5 DDD for community-acquired pneumonia (CAP), with the exclusion of hospital-acquired pneumonia (HAP). Although direct comparison is difficult since the present study did not differentiate between HAP and CAP, the findings suggest that antibiotic consumption in LTC hospitals is not less than that in regular acute care hospitals.

In our study, the overall antibiotic consumption for pneumonia in LTC hospitals over the past 10 years averaged 2.27 DDD per patient. The annual consumption ranged from 2.00 DDD per patient in 2011 to 3.03 DDD per patient in 2022 (Supplementary material, Table S2). This indicates that, on average, each inpatient in LTC hospitals received 2.27 DDD of antibiotics for pneumonia treatment during this period. Few studies have reported antibiotic consumption for pneumonia, which impedes direct comparisons with our findings. Nonetheless, Yoon (2015) used the 2008–2012 national health insurance claims data to analyze systemic antibiotic use and observed that antibiotic consumption was 4.26 DID [25]. However, since the value represented the average use of antibiotics prescribed in all hospitals throughout Korea, it can be assumed that the overall antibiotic consumption in our study was not low.





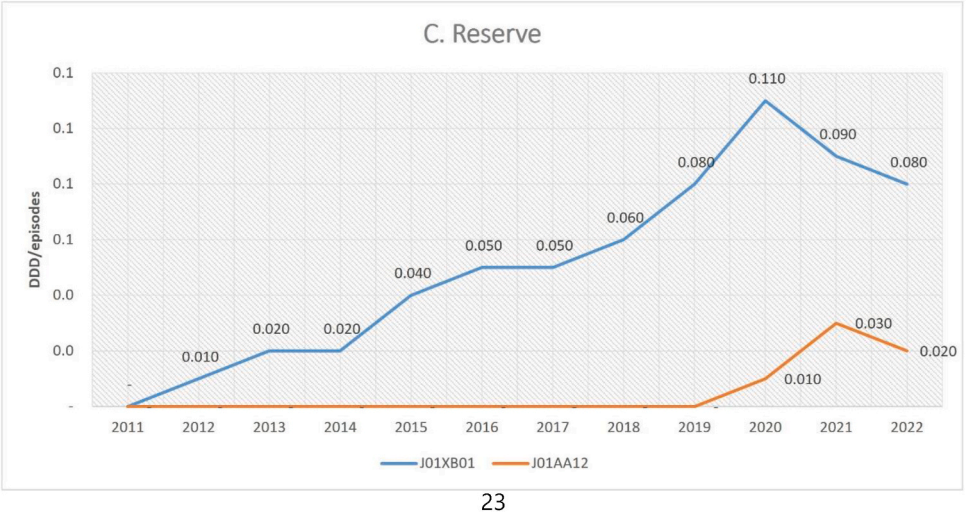


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Fig. 4. Antibiotic consumption (DDD/episode) according to AWaRe classification, AwaRe; Access, Watch, Reserve, (A) Access: J01GB06 (amikacin), J01XD01 (Imidazole derivatives), J01GB03 (gentamicin), J01FF01 (clindamycin), J01DB12 (ceftezole), (B) Watch: J01CR05 (piperacillin and beta-lactamase inhibitor), J01DD04 (ceftriaxone), J01MA12 (levofloxacin), J01DH02 (meropenem), J01DD02 (ceftazidime), J01DD01 (cefotaxime), (C) Reserve: J01XB01 (colistin), J01AA12 (tigecycline).

Moreover, in the National Health Insurance Service-National Sample Cohort study [1] conducted by Kim et al. (2018), 48 % of all antibiotic consumption was for respiratory diseases (11.683 DDD/1000 patients/day), which was higher than that reported by Yoon (2015) [25]. Further, 30 % of the antibiotic consumption for respiratory diseases was for upper respiratory infections, while the amount of antibiotic consumption for other respiratory diseases was 6.4 DID. A Canadian study on 381 LTC facilities [7] found that the amount of antibiotic consumption for respiratory diseases was 5.34 DID. Since the aforementioned studies used different study populations and analysis data, there are limitations in discussing the amount of antibiotic consumption for pneumonia relative to total antibiotic consumption. Accordingly, further monitoring and studies are warranted to compare the amounts of antibiotic consumption in LTC hospitals.

Regarding the trend in the amount of antibiotic use per patient with pneumonia (per episode) by age, patients aged <65 years showed the highest increase in antibiotic consumption, followed in order by those aged 65–74 and 75–84 years. Contrastingly, there was a non-significant increase among patients aged ≥85 years. This indicated an overall increase in antibiotic consumption for pneumonia among patients of all ages, except for those aged ≥85 years. Similarly, Kim et al. [1] reported a higher amount of use among patients aged ≥70 years as compared to those aged 60–69 years. Moreover, Kim et al. [6] reported that patients aged ≥65 years had a higher antibiotic consumption than those aged <65 years in acute care hospitals (15.7 vs. 15.3 DDD, $P < 0.001$), with antibiotic consumption increasing up to age 70 ($P = 0.005$), but decreasing after age 70. Consistent with these previous findings, a relatively low rate of increase was observed in antibiotic consumption in the older age groups; moreover, there was a non-significant increase in antibiotic consumption among those aged ≥85 years. This could be attributed to the fact that older patients in LTC hospitals may be transferred to an acute care hospital or have their treatment discontinued when their conditions deteriorate rapidly due to pneumonia [19].

The Access group showed a decreasing trend, while the Watch and Reserve groups showed a significant increasing trend ($p < 0.01$). This is consistent with the Korean National Action Plan on Antimicrobial Resistance (AMR) published in 2016, which aimed to contain antibiotic resistance through monitoring, prudent prescribing practices, and awareness-raising initiatives. Subsequent research by Chae et al. (2022) [26] reported a decrease in antibiotic use overall, with a decrease in the Access group and increases in the Watch and Reserve groups, a trend similar to this study. The findings suggest a continued reliance on broad-spectrum antibiotics, particularly in LTC hospitals, to address resistant pathogens.

The Watch group, which comprises antibiotics with a higher likelihood of antimicrobial resistance than those in the Access group, showed a continued decrease in the use of ceftriaxone but a substantial increase in the use of pipe/BLI, levofloxacin, and meropenem. Although these antibiotics are recommended in hospital guidelines for pneumonia treatment, there is an increasing number of resistant strains (e.g., carbapenem-resistant Enterobacterales). Therefore, these antibiotics should be used with caution. The observed pattern changes suggest the need for institutional measures to monitor the indiscriminate use of such antibiotics for pneumonia in LTC hospitals. In the Reserve group, there was a sharp increase in the use of colistin, which could be attributed to increased levels of multidrug-resistant *Pseudomonas aeruginosa* and A*cinetobacter* in LTC hospitals. The overall pattern of antibiotic consumption in LTC hospitals over the past 10 years was similar to that in a previous Korean national study on antibiotic prescription patterns [27]. A similar pattern of increased antibiotic consumption was observed in LTC hospitals; additionally, a nationwide survey indicated an increase in antibiotic-resistant pathogens in both acute care and LTC hospitals [27].

This study has several limitations. First, we analyzed claims data that do not include clinical outcomes. Consequently, the validity of the pneumonia diagnosis could not be confirmed; further, we could not determine whether the antibiotic prescribed was appropriate for the pathogen. Second, the measurement unit used was DDD/episode; therefore, antibiotic consumption may have decreased with disease due to early mortality after hospitalization among older individuals. Third, antibiotic consumption was only analyzed as DDD; additionally, since claims data do not provide detailed information such as duration of antibiotic prescription and concomitant therapies, the number of days may have differed from the actual number of treatment days. Nonetheless, this is the first study to clearly demonstrate the overall changes in the patterns of antibiotic consumption in all Korean LTC hospitals.

5. Conclusions

Our findings showed that the amount of antibiotics prescribed for pneumonia in LTC hospitals has been continuously increasing over the past 10 years; moreover, there is a gradually increasing trend in the use of broad-spectrum antibiotics. Accordingly, the findings suggest the need to manage antibiotics to ensure appropriate use in LTC hospital settings.

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Ethical approval statement

This study was approved by the Institutional Review Board from the Health Insurance Review and Assessment Agency (IRB number: 2023-014)

Data availability statement

The data that support the findings of this study are provided by the Health Insurance Review and Assessment Service (HIRA), *South Korea.* The datasets are not publicly available but can be obtained from the authors upon reasonable request and with permission from HIRA, *South Korea.*

CRediT authorship contribution statement

Jungmi Chae: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Dong-Sook Kim:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Jihye Shin:** Investigation, Formal analysis, Data curation. **Yong Chan Kim:** Writing – review & editing, Writing – original draft. **Seung Yeon Ji:** Investigation, Formal analysis, Data curation. **Yeseul Kim:** Investigation, Formal analysis, Data curation. **Mikyung Ryu:** Writing – review & editing, Writing – original draft, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e33047.

References

[1] Y.A. Kim, Y.S. Park, T. Youk, H. Lee, K. Lee, Changes in antimicrobial usage patterns in Korea: 12-year analysis based on database of the national health insurance service-national sample cohort, Sci. Rep. 8 (2018) 12210, https://doi.org/10.1038/s41598-018-30673-6.
[2] B. Kim, H. Hwang, J. Chae, Y.S. Kim, D.S. Kim, Analysis of changes in antibiotic use patterns in Korean hospitals during the COVID-19 pandemic, Antibiotics 12 (2023) 198, https://doi.org/10.3390/antibiotics12020198.
[3] S. Ryu, Y. Hwang, S.T. Ali, D.S. Kim, E.Y. Klein, E.H. Lau, B.J. Cowling, Decreased use of broad-spectrum antibiotics during the coronavirus disease 2019 epidemic in South Korea, J. Infect. Dis. 224 (2021) 949–955, https://doi.org/10.1093/infdis/jiab208.
[4] OECD Health Statistics, Pharmaceutical Market, OECD Publishing, Paris, 2023 [Internet]. [accessed 02 Aug 2023]. Available from: https://www.oecd.org/health/health-data.htm.
[5] S. Ryu, The new Korean action plan for containment of antimicrobial resistance, J Glob Antimicrob Resist 8 (2017) 70–73, https://doi.org/10.1016/j.jgar.2016.10.013.
[6] B. Kim, R. Myung, M. Lee, J. Kim, H. Pai, Trend of Antibiotic Usage for Hospitalized Community-acquired Pneumonia Cases in Korea Based on the 2010–2015 National Health Insurance Data, Jkms 35 (11AD) e390-0. https://doi.org/10.3346/jkms.2020.35.e390.
[7] F. Marra, M. McCabe, P. Sharma, B. Zhao, C. Mill, V. Leung, M. Chong, D.M. Patrick, Utilization of antibiotics in long-term care facilities in British columbia, Canada, J. Am. Med. Dir. Assoc. 18 (2017) 1098.e1–1098.e11, https://doi.org/10.1016/j.jamda.2017.09.018.
[8] M.Z. Raban, P.J. Gates, C. Gasparini, J.I. Westbrook, Temporal and regional trends of antibiotic use in long-term aged care facilities across 39 countries, 1985-2019: systematic review and meta-analysis, PLoS One 16 (2021) e0256501, https://doi.org/10.1371/journal.pone.0256501.
[9] H. Song, Long-term care hospital systems in developed countries and the implications for Korea, Journal of the Korean Geriatrics Society 16 (2012) 114–120, https://doi.org/10.4235/jkgs.2012.16.3.114.
[10] S.K. Park, Y.J. Lee, Categorization of long term care hospital in Korea using cluster analysis, Public Health Affairs 3 (2019) 71–81, https://doi.org/10.29339/pha.3.1.71.
[11] J.K. Sluggett, M. Moldovan, D.J. Lynn, L.E. Papanicolas, M. Crotty, C. Whitehead, S.L. Wesselingh, G.B. Rogers, M.C. Inacio, National trends in antibiotic use in Australian residential aged care facilities, 2005–2016, Clin. Infect. Dis. 72 (2020) 2167–2174, https://doi.org/10.1093/cid/ciaa436.
[12] A. Selcuk, C.B. Teng, S.Y. Chan, K.Z. Yap, Antimicrobial use and drug–drug interactions among nursing home residents in Singapore: a multicentre prevalence study, Int. J. Clin. Pharm. 40 (2018) 1044–1050, https://doi.org/10.1007/s11096-018-0683-z.
[13] M. Falcone, M. Paul, D. Yahav, G. Orlando, G. Tiseo, V. Prendki, R. Güerri-Fernández, G. Gavazzi, N. Mutters, B. Cookson, Antimicrobial consumption and impact of antimicrobial stewardship programmes in long-term care facilities, Clin. Microbiol. Infection 25 (2019) 562–569, https://doi.org/10.1016/j.cmi.2018.07.028.
[14] Y. Huang, W.I. Wei, D.F. Correia, B.H.M. Ma, A. Tang, E.K. Yeoh, S.Y.S. Wong, M. Ip, K.O. Kwok, Antibiotic use for respiratory tract infections among older adults living in long-term care facilities: a systematic review and meta-analysis, J. Hosp. Infect. 131 (2023) 107–121, https://doi.org/10.1016/j.jhin.2022.09.016.
[15] WHO. Anatomical Therapeutic Chemical (ATC) Classification: World Health Organization [accessed 12 June 2024]. Available from: https://www.who.int/tools/atc-ddd-toolkit/atc-classification.
[16] Anatomical Therapeutic Chemical (ATC)/defined Daily Dose (DDD) Index [Internet], World Health Organization Collaborating Center, 2021. Available from: https://www.whocc.no/atc_ddd_index. (Accessed 2 August 2021).
[17] WHO AWaRe Classification Database of Antibiotics for Evaluation and Monitoring of Use [Internet], World Health Organization, 2019. Available from: https://www.who.int/publications/i/item/WHOEMPIAU2019.11. (Accessed 2 August 2021).

[18] Statistics Korea, Future Population Projection, 2023 [cited 31 Aug 2023]. Available from: https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1BPA002&conn_path=I2.
[19] A.F. Simonetti, D. Viasus, C. Garcia-Vidal, J. Carratalà, Management of community-acquired pneumonia in older adults, Therapeutic Advances in Infectious Disease 2 (2014) 3–16, https://doi.org/10.1177/2049936113518041.
[20] J. Almirall, M. Serra-Prat, I. Bolíbar, V. Balasso, Risk factors for community-acquired pneumonia in adults: a systematic review of observational studies, Respiration 94 (2017) 299–311, https://doi.org/10.1159/000479089.
[21] J.Y. Lee, C.G. Yoo, H.J. Kim, K.S. Jung, K.H. Yoo, Disease burden of pneumonia in Korean adults aged over 50 years stratified by age and underlying diseases, Korean J Intern Med 29 (2014) 764–773, https://doi.org/10.3904/kjim.2014.29.6.764.
[22] G. Granata, F. Schiavone, G. Pipitone, F. Taglietti, N. Petrosillo, Antibiotics use in COVID-19 patients: a systematic literature review, J. Clin. Med. 11 (2022), https://doi.org/10.3390/jcm11237207.
[23] M.J. Nestler, E. Godbout, K. Lee, J. Kim, A.J. Noda, P. Taylor, R. Pryor, J.D. Markley, M. Doll, G. Bearman, M.P. Stevens, Impact of COVID-19 on pneumonia-focused antibiotic use at an academic medical center, Infect. Control Hosp. Epidemiol. 42 (2021) 915–916, https://doi.org/10.1017/ice.2020.362.
[24] S. NIoFaD, Questions and answers related to the safety and efficacy assessment of therapeutics for COVID-19(antiviral drug), National Institute of Food and Drug Safety, Chungcheongbuk-do, 06.30. https://www.mfds.go.kr/brd/m_1060/view.do?seq=15027&srchFr=&srchTo=&srchWord=&srchTp=&itm_seq_1=0&itm_seq_2=0&multi_itm_seq=0&company_cd=&company_nm=&page=1.
[25] Y.K. Yoon, G.C. Park, H. An, B.C. Chun, J.W. Sohn, M.J. Kim, Trends of antibiotic consumption in Korea according to national reimbursement data (2008–2012): a population-based epidemiologic study, Medicine 94 (2015), https://doi.org/10.1097/MD.0000000000002100.
[26] J. Chae, B. Kim, D.S. Kim, Changes in antibiotic consumption patterns after the implementation of the National Action Plan according to the Access, Watch, Reserve (AWaRe) classification system, Int. J. Infect. Dis. 122 (2022) 345–351, https://doi.org/10.1016/j.ijid.2022.06.013.
[27] D. Kim, J.Y. Ahn, C.H. Lee, S.J. Jang, H. Lee, D. Yong, S.H. Jeong, K. Lee, Increasing resistance to extended-spectrum cephalosporins, fluoroquinolone, and carbapenem in gram-negative bacilli and the emergence of carbapenem non-susceptibility in Klebsiella pneumoniae: analysis of Korean Antimicrobial Resistance Monitoring System (KARMS) data from 2013 to 2015, Annals of Laboratory Medicine 37 (2017) 231, https://doi.org/10.3343/alm.2017.37.3.231.