

Impact of Full-Time Equivalent Allocation on the Effectiveness of Antimicrobial

Stewardship Activities: A Multicenter Study in Okayama, Japan

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Abstract

Background: Optimized administration of antimicrobial agents is critical for mitigating the emergence of antimicrobial resistance. This study aimed to elucidate the relationship between antimicrobial stewardship (AS) activities and antimicrobial prescription trends and patterns.

Methods: This retrospective, multicenter, longitudinal study was conducted between April 2014 and March 2023 (9-year fiscal period). A structured, questionnaire survey, regarding institutional infrastructure and environmental parameters, service modalities provided by AS activities, resource allocation and systemic support, and data on the use of broad-spectrum antimicrobial agents, was distributed to co-investigators working at seven hospitals in Okayama, Japan. Full-time equivalent (FTE) allocation for each healthcare facility were calculated and subsequently compared among the hospitals. Temporal variations in the proportional distribution of broad-spectrum antimicrobial agents were statistically evaluated using joinpoint regression analysis.

Results: Two hospitals where pharmacists were exclusively dedicated to AS activities and met the recommended FTE allocation showed a statistically significant reduction in the proportion of broad-spectrum antibiotic administration, with average annual percentage changes of -8.0% (95% confidence interval [CI]: -10.5 to -5.8) and -3.1% (95% CI: -5.5 to -0.7), respectively. In contrast, two other hospitals with full-time AS members but insufficient FTE allocation exhibited inconsistent and statistically nonuniform trends. The remaining three healthcare institutions with

poorly resourced AS teams demonstrated no statistically significant trends in their broad-spectrum antimicrobial prescriptions.

Conclusion: Our findings uncovered that hospitals with adequate FTE staffing metrics for AS activities exhibited statistically significant downward trends in the consumption of broad-spectrum antimicrobial agents.

Keywords: Antimicrobial Resistance; Antimicrobial Stewardship; Full-time Equivalent; Infection Prevention and Control; Trend analysis

Introduction

The global burden of antimicrobial resistance (AMR) continues to escalate [1]; however, both the development of novel antimicrobial agents and the sustainable supply of existing therapeutic options have been significantly declining [2,3]. The optimization of antimicrobial therapy remains a critical and urgent priority for addressing AMR. In response to the Global Action Plan on AMR led by the World Health Organization, the Japanese Ministry of Health, Labour and Welfare implemented a 'National Action Plan on AMR' in 2016 [4]. Subsequently, in 2023, a revised framework was established to delineate strategic objectives across six principal domains: (i) public health awareness and education; (ii) epidemiological surveillance and monitoring; (iii) infection prevention and control measures; (iv) antimicrobial stewardship (AS); (v) research and development initiatives; and (vi) international collaborative efforts.

Reducing antimicrobial consumption represents a fundamental component of the Action Plan on AMR, with healthcare facilities strongly recommended to establish comprehensive AS programs [5,6]. Effective AS activities require a well-established multidisciplinary team comprising healthcare professionals with extensive expertise and specialized knowledge [7]. A 2016 systematic review and meta-analysis demonstrated that hospital-based AS interventions yielded significant improvements in both clinical and economic outcomes, including decreased overall antimicrobial consumption, reduced antimicrobial therapy costs, a lower incidence of

antimicrobial-resistant pathogens, and shorter hospital length of stay [8]. Furthermore, robust AS programs are associated with enhanced quality metrics for inpatient care delivery [9,10].

The 2018 revision of the Japanese medical reimbursement system introduced financial incentives for AS initiatives within the infection prevention and control framework, facilitating the establishment and expansion of national AS programs [11]. However, a 2020 national surveillance study revealed that approximately 80% of Japanese healthcare institutions rely on nursing staff to perform concurrent duties in both infection prevention and control and AS activities, indicating a suboptimal infrastructure for AS activities in Japanese hospitals [12]. Despite the original AMR Action Plan achieving partial success in reducing antimicrobial consumption, predetermined benchmarks remain unattained, emphasizing the need for enhanced AS interventions across the country [13].

The enhanced participation of physicians and pharmacists is essential for promoting the optimal use of antimicrobial agents through AS initiatives. However, evidence-based guidelines regarding the optimal staffing ratios and resource allocation for these complex interventions remain limited [14]. The recent literature suggests that full-time equivalent (FTE) allocation, which simply quantifies the time dedicated to AS activities, is an effective metric for comparative analysis [15]. A cross-sectional analysis of active AS practitioners from three U.S. Infectious Diseases professional societies demonstrated that a 0.5 FTE increase in either physician or

pharmacist support significantly correlated with enhanced AS program effectiveness [16]. Pharmacist-led prospective audits and feedback interventions have emerged as the most significant determinants of successful AS outcomes. Conversely, hospitals in which AS team members maintain concurrent responsibilities have demonstrated reduced FTE allocations for AS activities [15,16]. These findings suggest that ensuring adequate FTE staffing standards is crucial for optimizing antimicrobial use in hospitals.

To the best of our knowledge, there is a paucity of multicenter studies in Japan that have investigated the association between FTE allocation and antimicrobial prescription trends and patterns. This study aimed to evaluate the relationship between AS interventions and antimicrobial prescriptions by analyzing the association between AS team FTE allocation and temporal trends in broad-spectrum antimicrobial agent use across healthcare facilities.

Methods

Study Design and Settings

This retrospective, multicenter observational study was conducted from April 2014 to March 2023 (9-year fiscal period) in healthcare institutions in Okayama Prefecture, Japan. Inclusion criteria comprised healthcare facilities meeting the following requirements: Hospitals with bed capacity ≥ 300 accredited with category 1 of the Additional Healthcare Reimbursement for

Infection Prevention and Control, where AS initiatives are considered well-established. The requirement for individual informed consent was waived because this investigation utilized retrospective analysis of anonymized data. The study protocol was approved by the Institutional Review Board of the Okayama City Hospital (approval number: 5-200).

Institutional Characteristics and Demographics

Baseline institutional data were collected for participating facilities, encompassing the following parameters for Core Facility Metrics and Healthcare Personnel Resources: (i) medical function classification; (ii) annual patient volume (outpatient encounters and inpatient admissions); (iii) annual surgical case volume; (iv) annual emergency transportations; (v) infectious disease unit designated by the National Infectious Diseases Control Law; (vi) total bed capacity; and (vii) Number of Medical Departments, (viii) number of physicians, pharmacists, and clinical laboratory technicians. Additionally, the AS program characteristics were evaluated based on previously validated assessment criteria [15,16], which are categorized into three principal domains; (A) Infrastructure Assessment for AS activities, (B) AS Service Delivery Metrics, and (C) Institutional Support Framework for AS activities (**Table 1**) [15,16].

Broad-Spectrum Antimicrobial Agent Classification

Broad-spectrum antimicrobial agents were defined as those with documented activity against both *Pseudomonas aeruginosa* and methicillin-resistant *Staphylococcus aureus*, as specified in the Japanese regulatory product labeling (**Supplemental Table 1**).

Outcome Measures and Statistical Analysis

The primary outcome was the percentage of parenteral broad-spectrum antimicrobial agents relative to the total parenteral antimicrobial administration and analyzed for temporal trends. A stratified analysis was performed based on the FTE allocation calculated by dividing the total weekly AS-dedicated hours (physicians + pharmacists) by the standard 40-h workweek for full-time employees. The optimal FTE thresholds were adopted from previous validation studies and stratified by institutional bed capacity as follows; 1.4 FTE for 100–300 beds, 1.6 FTE for 301–500 beds, 2.6 FTE for 501–1,000 beds, and 4.0 FTE for >1,000 beds [16]. Institutional AS-associated factors were evaluated by calculating mean achievement rates across three previously described domains [15,17]. As the 2018 revision of medical reimbursement fees introduced a new financial incentive for AS activities, the data were compared between the periods before and after the policy change (2014–2017 vs. 2018–2022).

Temporal trend analysis was performed using the joinpoint regression methodology (Joinpoint Regression Program, version 4.9.0.1, February 2022; Statistical Research and

Applications Branch, National Cancer Institute, Bethesda, MD, USA). Annual percentage changes were calculated between the identified trend change points with corresponding 95% confidence intervals (CIs). Additionally, the average annual percentage change was computed for the entire study period to quantify overall temporal trends.

Results

Among the 12 eligible healthcare facilities in the Okayama Prefecture that met the inclusion criteria, seven were invited to participate. The reasons for exclusion were as follows: two institutions due to unavailability of relevant data, two due to lack of approval from the hospital authority, and one due to non-response. Data were obtained from seven participating institutions, including six acute care hospitals and one long-term care facility. The detailed institutional characteristics are presented in **Supplementary Table 2**.

Fig. 1 illustrates the temporal changes in the professional composition and time allocation of core AS team members across participating institutions, with five of the seven facilities (71.4%) designating pharmacists as the sole AS practitioners as of 2022. A notable staffing change was observed in Hospital C, where a dedicated physician participated in AS activities since fiscal year 2017. While Hospital A transitioned its dedicated AS role from

physician to nurse in fiscal year 2021.

The achievement rates across the three domains of AS implementation are shown in **Fig. 2**: infrastructure assessment, AS service delivery metrics, and the institutional support framework for AS activities. Differential patterns were observed, with three institutions (Hospitals B, D, and E) demonstrating substantial improvements following the 2018 reimbursement revision and four other facilities showing minimal improvement during the latter study period.

The longitudinal trends in the proportion of broad-spectrum antimicrobial administration across the participating institutions were demonstrated in **Supplementary Fig. 2**. Comparative analysis between initial data collection and fiscal year 2022 revealed decreased administration in three of the seven facilities (Hospitals E, F, and G), while four institutions (Hospitals A, B, C, and D) demonstrated stable or increasing patterns. **Fig. 3** and **Table 2** present the temporal trends in the broad-spectrum antimicrobial prescription with the results of joinpoint regression analysis. A significant change point was not identified at Hospitals A, B, C, E, and G. Average annual percentage changes varied considerably among institutions: Hospitals A, B, and C showed non-significant trends at 3.7% (95% CI: -0.7 to 8.5), -0.7% (95% CI: -1.5 to 0.1), and -1.9% (95% CI: -5.6 to 1.9), respectively. Hospital D demonstrated an initial decline (2016–2018) followed by a significant upward trend starting in 2018 (Annual percentage changes: 3.7% [95% CI: 0.6 to 9.1]). Hospital F exhibited a similar pattern with an initial decline (2016–2019)

followed by an increasing trend from 2019 (Annual percentage changes: 3.1% [95% CI: –10.9 to 22.5]), although neither institution showed significant overall changes. Notably, Hospitals E and G maintained consistent declining trends throughout the study period, with significant average annual percentage changes of –8.0% (95% CI: –10.5 to –5.8) and –3.1% (95% CI: –5.5 to –0.7), respectively.

Table 3 compares the recommended and actual FTE allocations for AS activities across the participating institutions. Based on institutional bed capacity, the recommended weekly time allocations according to the validated benchmarks were 160 h for Hospital A; 104 h for Hospitals B and C; and 64 h for Hospitals D, E, F, and G. Actual weekly time allocations in fiscal year 2022 varied considerably, with Hospital A at 62 h, Hospital B at 42 h, Hospital C at 94 h, Hospital D at 40 h, Hospital E at 93.9 hours, Hospital F at 2 h, and Hospital G at 80 h. Analysis of FTE differentials revealed significant shortages in five institutions (Hospital A: –98.0 h; Hospital B: –62.0 h; Hospital C: –10.0 h; Hospital D: –24.0 h; Hospital F: –62.0 h), whereas two facilities demonstrated fulfilled allocations (Hospital E: +29.9 h; Hospital G: +16.0 h).

A comprehensive synthesis of the analyses is shown in **Table 4**. Institutions with dedicated pharmacists and optimal FTE allocations for AS activities (Hospitals E and G) demonstrated significant decreases in the proportion of broad-spectrum antimicrobial administration. Conversely, hospitals with dedicated pharmacists but suboptimal FTE allocations

(Hospitals D and F) exhibited inconsistent patterns without clear directional trends. Finally, institutions with no full-time AS members and suboptimal FTE allocations (Hospitals A, B, and C) showed no significant changes.

Discussion

This study analyzed the relationship between AS-dedicated FTE allocation and the proportion of broad-spectrum antimicrobial consumption across middle to large hospitals in Okayama, Japan. Due to the insufficient number and geographical imbalance of infectious diseases physicians in our region [18, 19], we hypothesized that hospitals could not have been implementing optimal AS activities. However, significant decreasing trends in the administration of broad-spectrum antimicrobial agents were demonstrated in two of the seven facilities where AS activities were consistently implemented by dedicated pharmacists with sufficient FTE allocations meeting evidence-based benchmarks. Clinical pharmacists served as primary AS practitioners at more than half of the hospitals, either throughout or during discrete periods of the study timeline, underscoring their pivotal role in AS activities.

Our findings demonstrate that optimal FTE allocation for AS practitioners is crucial to achieving a sustained reduction in broad-spectrum antimicrobial administration. Hospitals E and G, which maintained the recommended weekly time commitments (calculated as $FTE \times 40$

h/week), exhibited consistent decreasing trends in broad-spectrum antimicrobial utilization rates. This observation supports the utility of FTE as a standardized metric for comparing AS programs across Japanese healthcare institutions [15,16]. At Hospital E, despite a notable increase in FTE allocation after 2018, the declining trend had already commenced after 2014. This suggests the possibility that the observed reduction merely reflects a natural decrease unrelated to the FTE increase. A later audit uncovered that a physician who, although not certified as an infectious disease specialist, informally contributed to AS activities at Hospital E from 2016 to 2017. Owing to his initiative, an institutional AS manual was developed, establishing a foundational framework for AS activities thereafter. This qualitative background information was not adequately incorporated into the quantitative analysis of the study.

Different from Hospital E, Hospital G did not demonstrate improvement in AS-associated three domains, suggesting that the observed reduction in antimicrobial use may be solely attributed to the increased FTE allocation. However, we were later informed that internal medicine physicians comprehensively manage patients with hospital-acquired infections at the hospital; *i.e.*, the promotion of appropriate antimicrobial use was more readily achievable. Additionally, a physician with specialized interest in infectious diseases commenced providing consultative support for AS activities in 2021, and the frequency of AS case conferences was increased, enabling earlier intervention. These contextual factors, which were not captured in the

quantitative data collection process, could additively contribute to the reductions in the proportion of broad-spectrum antibiotics prescribed at Hospital G.

Conversely, institutions with suboptimal time allocation (Hospitals A, B, C, D, and F) demonstrated either static patterns or transient fluctuations without sustained reductions. Recent literature has identified ten essential structural indicators for evaluating institutional AS programs, including programmatic authority and the availability of expert consultation services [15]. Insufficient time allocation, as reflected by suboptimal FTEs, compromises the delivery of consultation services, even within institutions where such services are formally authorized and expected. Notably, the two institutions (Hospitals E and G) achieving a continuous downward trend in broad-spectrum antimicrobial usage were medium-sized facilities (300–400 beds). This suggests that hospital managers at mid-sized facilities in Japan may find it more feasible to approve the allocation of the required FTEs through the strategic deployment of existing clinical pharmacists.

Hospital B, the second largest institution surveyed, demonstrated a great advancement in AS-associated domains; however, antimicrobial consumption did not decline. A later interview suggested that this could be attributed to insufficient FTE allocation despite the assignment of a dedicated AS Team pharmacist in 2019, and inadequate submission of bacterial culture specimens to the laboratory. Furthermore, the per-dose administration of meropenem was previously

suboptimal and the Antimicrobial Use Density increased as a consequence of promoting appropriate dosing regimens. These points are considered potential underlying factors for the unchanged antimicrobial administration pattern at Hospital B.

Compelling evidence encompassing both economic benefits and contributions to global AMR mitigation efforts is required to secure institutional support for dedicated staffing resources. Our previous analyses documented significant disparities in the distribution of infectious disease specialists in Okayama, Japan [18], which can be correlated with the elevated prevalence of AMR pathogens in the region [20]. International guidelines emphasize prospective audits and feedback interventions as fundamental strategies in AS programs aimed at standardizing antimicrobial therapy and minimizing adverse outcomes [21]. While infectious disease physicians play a leading role, clinical pharmacists are supposed to have essential functions in program development, policy formulation, guideline creation, and optimization of antimicrobial therapy through prospective monitoring and interventions [22]. Pharmacist-led AS programs are particularly efficacious in regions with shortages and geographic imbalances of infectious disease specialized physicians. While pharmacists lack the credentials and ability to make medical diagnosis, they can leverage their pharmaceutical expertise to conduct patient assessments and evaluate therapeutic outcomes from a perspective complementary to that of physicians, thereby facilitating the recommendation of optimal antimicrobial regimens to enhance patient outcomes.

For the successful implementation of pharmacist-led AS programs, it is imperative that these initiatives receive official institutional approval and an enabling environment by securing adequate FTE allocation.

This study had several notable methodological limitations. First, due to the research design, it is impossible to evaluate a causal relationship between FTE and the reduction in broad-spectrum antimicrobial administrations. As introduced above, each hospital possesses unique qualitative contextual factors that are difficult to fully incorporate into the quantitative analysis. The influence of other potential factors that may impact the use of broad-spectrum antimicrobials requires further elucidation in future research. Second, the FTE calculations employed in previous studies [15,16] exclusively considered physician and pharmacist time allocations, omitting the contributions of other essential healthcare professionals, including clinical microbiologists and infection control nurses. Third, the inclusion of a long-term care facility in our analysis presents a potential limitation as FTE benchmarks were originally developed and validated for acute care settings, suggesting that alternative metrics may be more appropriate for evaluating AS programs in such hospitals. Fourth, data points for the joinpoint analysis were insufficient in three hospitals (Hospitals A, D, and F). The limited number of data points presents a significant challenge for precise trend estimation. The unavailability of historical data itself reflects a shortage in human resources allocated to AS programs at Japanese hospitals, posing difficulty in managing relevant

longitudinal data. Finally, our data included the period of the novel coronavirus disease 2019 pandemic. Although its impact would vary among institutions depending on hospital functions and staffing structures for the AS program, all facilities were presumably affected to some extent. Incorporating the pandemic's influence into the study analysis is highly challenging. Thus, a follow-up investigation in the post-pandemic period is warranted to establish comparative data.

In conclusion, this study demonstrated that healthcare institutions maintaining optimal FTE allocations for AS activities achieved significant reductions in the proportion of broad-spectrum antimicrobials. These findings suggest that adequate time allocation for AS activities rather than the nature of specific programmatic interventions may be the primary determinant of AS effectiveness. Moving forward, strategic personnel allocation and resource optimization are indispensable for successful AS initiatives, necessitating sustained administrative support and institutional commitment. Within the Japanese healthcare context, where demographic shifts toward an aging population with declining birth rates have exacerbated healthcare workforce shortages, evidence-based staffing models that support effective AS activities are essential. Future research that provides robust evidence for optimal resource allocation is critical to guide these organizational decisions.

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Availability of data and materials

Detailed data are available upon request from the corresponding author.

Conflict of interest

The authors declare no competing interests.

Author contributions

SK and HH conceived the study; AO, YH, and HY advised on the study design; SK, YH, HY, YI, TH, KS, FT, TK, SI, MY, YY, and HK collected the data; HH performed the statistical analyses; SK drafted and HH revised the manuscript; and AO, HY, SS, YF, FI, CY, SA, and TS supervised the study. All the authors interpreted the results and approved the submission of the manuscript.

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333 **Clinical trial number**

334 Not applicable

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Figure Legends

Fig. 1. Temporal changes in the profession and engagement time of the AS leader and the associates through fiscal year 2014–2022

AS, antimicrobial stewardship

MD, medical doctor. Ph, pharmacist. Ns, nurse.

Fig. 2. Comparison of achievement rates of three AS-associated domains from 2014–2017 and 2018–2022

AS, antimicrobial stewardship. (A) Facility environment for AS activities (four items), (B) Services provided by AS activities (11 items), (C) Underlying institutional support for AS activities (six items). The details of the items evaluated in each category are provided in Supplemental Table 1, with the numbers of calculated items indicated in parentheses.

Fig. 3. Trendlines in the proportion of intravenous broad-spectrum antibiotics

Data points were insufficient in four hospitals (Hospitals A, D, and F) due to the unavailability of historical data.