Five-year point prevalence survey of healthcare-associated infections and antimicrobial use in a Japanese university hospital

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A R T I C L E   I N F O

S U M M A R Y

Background: Periodic point prevalence surveys (PPSs) provide a method for assessing changes in healthcare-associated infections (HAIs) and antimicrobial use over time. Following the introduction of an antimicrobial stewardship programme at Nagoya University Hospital (Aichi, Japan) a five-year PPS study was performed to highlight any epidemiological changes.

Methods: One-day PPSs were performed annually in July at Nagoya University Hospital. Data on patient characteristics, medical devices, active HAIs and antimicrobial use were collected using a standard data-collection form.

Results: A total of 4339 patients were included. Over the five-year study period the median patient age was 62 years, median duration of hospital admission was nine days, 9% of patients had an HAI and 35.2% received at least one antimicrobial. Overall there were 406 HAIs (95% confidence interval, 369–447) with surgical site infection, pneumonia and febrile neutropenia occurring most frequently. Enterobacterales were the most common pathogens ($N = 78$, 28.6%) and 32.1% were third-generation cephalosporin-resistant. Meropenem was the most frequently prescribed antimicrobial for HAIs. Surgical antimicrobial prophylaxis changed drastically, with shorter durations and a marked reduction

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in oral cephalosporin use. However, antimicrobials for medical prophylaxis gradually increased.

Conclusions: This five-year PPS study shows consistent data for patient background, HAIs and causative pathogens and highlights changes in antimicrobial use during the era of the National Action Plan on Antimicrobial Resistance. To describe the epidemiology of Japanese hospitals by PPS, multicentre PPSs including in community hospitals should be performed annually.

Introduction

Emerging antimicrobial-resistant pathogens and the lack of newly developed antibiotics have become global concerns. The World Health Organization highlighted these problems in 2011, and subsequently many countries started to tackle these issues [1]. In April 2016, the Government of Japan released the *National Action Plan on Antimicrobial Resistance*. This plan aimed to achieve the following by 2020: lower the MRSA rate to ≤20%; reduce the use of intravenous antimicrobials per day per 1000 inhabitants by 20% from 2013 levels; and reduce the use of oral cephalosporins, quinolones, and macrolides per day per 1000 inhabitants by 50% [2]. For hospitals, monitoring antimicrobial use, healthcare-associated infections (HAIs) and antimicrobial-resistant pathogens is essential, but it is hard to acquire this data at one point in time.

A point prevalence survey (PPS) is a widely performed cross-sectional surveillance study allowing description of hospital data, especially for HAIs, causative pathogens and antimicrobial use [3–6]. Periodic PPSs can also provide a method for assessing the change in HAIs and antimicrobial use over time. In addition, periodic PPSs looking at antimicrobial use are useful for infection control teams to gain a precise overview of hospital epidemiology and to help create intervention policies [7,8]. The European Centre for Disease Prevention and Control (ECDC) performed large-scale multilateral PPSs in 2012 and 2016 and annual PPSs have been reported globally [4,5,9].

To achieve an overview of hospital epidemiology and to identify potential problems, we performed a PPS in 2014 at Nagoya University Hospital in Aichi, Japan [10]. The data collected identified several issues including long-term hospitalization, high HAI prevalence and unnecessary antimicrobials for surgical antimicrobial prophylaxis. To confirm the repeatability of these results we performed a PPS again in 2015. Based on those results we realized that "no action, no change" applied, especially with regard to surgical antimicrobial prophylaxis. We therefore started discussions with surgical departments in 2016 to optimize surgical antimicrobial prophylaxis. To check on trends in hospital epidemiology after this intervention we performed PPSs annually over a five-year period. Herein, we show our accumulated five-year annual PPS data from Nagoya University Hospital.

Methods

Study design

One-day PPSs were performed annually at Nagoya University Hospital, a 1080-bed (1035 beds until December 2017) tertiary-care university-affiliated cancer centre for children and adults. Each PPS from 2014 to 2018 took place on a Thursday in July. PPS protocols for 2014−2018 were created by modifying the 2012 protocol of the ECDC [11]. All patients at 08:00 on the day of the survey were included in the study, with a patient list taken from electronic patient records. Data was collected by doctors and pharmacists who reviewed medical records; whilst nurses collected data on medical devices.

Each annual PPS adhered to Japanese ethical guidelines for epidemiological studies and all study protocols were approved by the institutional review board of Nagoya University Graduate School of Medicine (approval no. 10,599).

Collected data

For all patients, data on background characteristics and medical devices were collected. For those receiving antimicrobials on the survey day (or in the 24 h before for surgical antimicrobial prophylaxis) additional data (e.g., indication, route of administration and day of surgery) were collected. Antimicrobial uses were categorized by indication including treatment for HAIs and community-acquired infections and both medical and surgical antimicrobial prophylaxis. Surgical antimicrobial prophylaxis was defined as antimicrobial use to prevent surgical site infection and infection related to invasive procedures. Medical prophylaxis was defined as antimicrobial use to prevent infection not related to surgery (e.g., fluconazole for patients with leukaemia, co-trimoxazole for patients with corticosteroids).

Definition of HAIs

During the five years of PPSs, HAI was consistently defined as infection occurring 48 h or more after admission to hospital. Community-acquired infections were defined as all infections other than HAIs. HAI categories were classified based on ECDC 2012 protocols [11]. In 2016, the definitions of pneumonia and surgical site infection changed to match the definitions set by the National Healthcare Safety Network (NHSN) 2016; these changes included fewer categories of pneumonia (ECDC: 5, NHSN: 3) and shorter durations for prosthetic device infection (ECDC 2012: 1 year; NHSN: 3 months) [12]. Febrile neutropenia was added as an HAI during the study period [13]. In this protocol, catheter-related blood stream infection, catheter-associated urinary tract infection, and ventilator-associated pneumonia were defined as device-related HAIs. When a clinical diagnosis did not satisfy the relevant HAI definitions this was reviewed by the study manager and the applicable HAI category applied.

Table I
Overview of five-year point prevalence survey.

Year (number of patients, N)	2014 (841)	2015 (920)	2016 (852)	2017 (878)	2018 (848)	Total (4339)	P
Gender, male, N (%)	462 (54.9)	493 (53.6)	465 (54.6)	463 (52.7)	449 (51.1)	2332 (53.7)	0.37
Age, median (IQR)	61 (37−72)	63 (39−73)	61 (39−72)	61 (39−72)	62 (39−73)	62 (39−73)	0.48
Duration of hospital stay, days, median (IQR)	10 (3−29)	10 (3−24)	9 (3−23)	9 (3−24)	9 (3−22)	9 (3−24)	<0.01
Underlying diseases, N (%)							
Malignancy	335 (39.8)	374 (40.7)	375 (44.0)	348 (39.6)	378 (43.1)	1810 (41.7)	0.12
Haematological malignancy	73 (8.7)	52 (5.7)	57 (6.7)	62 (7.1)	58 (6.8)	302 (7.0)	0.44
Bone marrow transplantation	19 (2.3)	27 (2.9)	30 (3.5)	29 (3.3)	26 (3.1)	131 (3.0)	0.29
Solid organ transplantation	8 (1.0)	9 (1.0)	16 (1.9)	9 (1.0)	13 (1.5)	55 (1.3)	0.32
Diabetes mellitus	138 (16.4)	176 (19.1)	151 (17.7)	153 (17.4)	137 (16.2)	755 (17.4)	0.57
Dialysis/CAPD	12 (1.4)	16 (1.7)	20 (2.3)	18 (2.1)	18 (2.1)	84 (1.9)	0.25
Patients with devices in place, N (%)							
PVC	251 (29.8)	294 (32.0)	269 (31.6)	267 (30.4)	291 (34.3)	1372 (31.6)	0.15
CVC/CV port/PICC	131 (15.6)	130 (14.1)	130 (15.3)	129 (14.7)	131 (15.4)	651 (15.0)	0.92
Urinary catheter	99 (11.8)	110 (12.0)	96 (11.3)	95 (10.8)	90 (10.6)	490 (11.3)	0.31
Tracheal-tracheostomy tube	31 (3.7)	32 (3.5)	47 (5.5)	35 (4.0)	33 (3.9)	178 (4.1)	0.66
Patients with HAI, N (%)							
Total HAIs	85 (10.1)	86 (9.3)	81 (9.5)	64 (7.3)	73 (8.6)	389 (9.0)	0.10
Device-related infections	14 (1.7)	12 (1.3)	13 (1.5)	15 (1.7)	10 (1.2)	64 (1.5)	0.68
Patients with any antimicrobial, N (%)	308 (36.6)	334 (36.3)	298 (35.0)	289 (32.9)	304 (35.8)	1533 (35.3)	0.43
Prescribed antimicrobials, N (per 100 patients)							
Total	494 (58.7)	550 (59.8)	480 (56.3)	471 (53.6)	499 (58.8)	2494 (57.5)	0.25
Treatment of HAIs	118 (14.0)	127 (13.8)	104 (12.2)	85 (9.7)	90 (10.6)	524 (12.1)	<0.01
Treatment of community-acquired infections	69 (8.2)	81 (8.8)	57 (6.7)	78 (8.9)	58 (6.8)	343 (7.9)	0.36
Medical prophylaxis	182 (21.6)	233 (25.3)	215 (25.2)	220 (25.1)	252 (29.7)	1102 (25.4)	<0.01
Surgical antimicrobial prophylaxis	119 (14.1)	105 (11.4)	102 (12.0)	84 (9.6)	88 (10.4)	498 (11.5)	<0.01
Timing of the survey day							
Postoperative day 0	6 (0.7)	3 (0.3)	12 (1.4)	13 (1.5)	23 (2.7)	57 (1.3)	<0.01
Postoperative day 1	51 (6.1)	51 (5.5)	47 (5.5)	36 (4.1)	33 (3.9)	218 (5.0)	0.01
Postoperative day 2	25 (3.0)	34 (3.7)	27 (3.2)	30 (3.4)	22 (2.6)	138 (3.2)	0.57
Postoperative day 3 or later	37 (4.4)	17 (1.8)	16 (1.9)	5 (0.6)	10 (1.2)	85 (2.0)	<0.01

CAPD, continuous ambulatory peritoneal dialysis; CV, central venous; CVC, central venous catheter; HAI, healthcare-associated infection; IQR, interquartile range; PICC, peripherally inserted central catheter; PVC, peripheral venous catheter.

Statistical analysis

Categorical variables are expressed as total numbers and percentages, and trends in categorical variables were tested using the Cochran−Armitage trend test. Continuous variables are expressed as mean and interquartile range, and tested using the Jonckheere−Terpstra trend test. HAIs by categories and the top five antimicrobials by indications during the five years were tested using the Cochran−Armitage trend test.

All statistical tests were two-sided, and P-values less than 0.05 were considered statistically significant. All statistical analyses were performed using R (version 3.6.3; The R Foundation for Statistical Computing, Vienna, Austria).

Results

A total of 4339 patients were included in this study. Table I shows overall data for the five years of PPSs. Median age and duration of hospitalization in the study period were 62 years (interquartile range (IQR): 39−73) and nine days (IQR: 3−24), respectively; 41.7% of patients had a non-haematological malignancy (95% confidence interval (CI): 40.2−43.2) and 7.0% had a haematological malignancy (95% CI: 6.2−7.8). Device insertion rates for peripheral venous, central venous, urinary catheters, and tracheal/tracheostomy tubes were 31.6% (95% CI: 30.2−33.0), 15.0% (95% CI: 14.0−16.1), 11.3% (95% CI: 10.4−12.3) and 4.1% (95% CI: 3.5−4.7), respectively. Percentages of patients with at least one HAI, device-related HAIs and antimicrobial uses were 9.0% (95% CI: 8.1−9.9), 1.5% (95% CI: 1.1−1.9) and 35.2% (95% CI: 33.8−36.7), respectively. Excluding duration of hospital stay, this data did not change significantly over the study period. Of the 2494 antimicrobials prescribed, 524 (12.1/100 patients, 95% CI: 11.1−13.1) and 343 (7.9/100 patients; 95 %CI: 7.1−8.7) were as treatment for HAIs and community-acquired infections, and 498 (11.5/100 patients; 95% CI: 10.5−12.5) and 1102 (25.4/100 patients; 95% CI: 24.1−26.7) were prescribed for surgical antimicrobial prophylaxis and medical prophylaxis, respectively. Antimicrobials for medical prophylaxis gradually increased (P<0.01), while antimicrobials for HAI and surgical antimicrobial prophylaxis gradually decreased (P<0.01). For surgical antimicrobial prophylaxis, antimicrobials prescribed on day 1 and 3 postoperatively reduced (P<0.01) but those prescribed on day 0 increased (P<0.01).

Table II shows five-year trends for HAI prevalence. A total of 406 HAIs (95%CI: 369–447) developed in 4339 patients. Surgical site infection was the most frequent in the five-year period. Pneumonia and febrile neutropenia were also common. *Clostridioides difficile* infection developed in only nine patients in five years. No significant changes in HAIs were observed during the five years.

A total of 274 pathogens were identified during the five years (Table III). In each year Enterobacterales, *Staphylococcus aureus*, *Enterococcus* spp., and *Pseudomonas aeruginosa* comprised the majority of pathogens. Of Enterobacterales, 32.9% (24/73) were third-generation cephalosporin-resistant and two were carbapenemase-producing (metallo-β-lactamase-producing *Enterobacter cloacae* complex and KPC-producing *Klebsiella pneumoniae*). Meticillin-resistant

S. aureus (MRSA) comprised 37.8% (17/45) of *S. aureus* species. Neither vancomycin-resistant *Enterococcus* spp. nor *Acinetobacter baumannii* with additional resistance were detected over the five years.

The top five antimicrobials by indication during the five years are shown in Table IV. The top five antimicrobials for HAIs included three β-lactams with anti-pseudomonal activity. In contrast, β-lactams without anti-pseudomonal activity made up the majority of antimicrobials used to treat community-acquired infections. Prescriptions of micafungin for HAIs and cefmetazole for community-acquired infections changed significantly over the five years. For medical prophylaxis co-trimoxazole was the most frequently prescribed, followed by oral fluconazole. Uses of co-trimoxazole, oral fluconazole and valacyclovir significantly increased over the study period.

Table II
Healthcare-associated infections during five years.

Year (total patients)	2014 (841)	2015 (920)	2016 (852)	2017 (878)	2018 (848)	Total (4339)	P
Surgical site infection, N (%)	15 (1.8)	25 (2.7)	13 (1.5)	15 (1.7)	19 (2.2)	87 (2.0)	0.91
Pneumonia, N (%)	18 (2.1)	7 (0.8)	8 (0.9)	12 (1.4)	15 (1.8)	60 (1.4)	0.95
Febrile neutropenia, N (%)	10 (1.2)	15 (1.6)	14 (1.6)	6 (0.7)	12 (1.4)	57 (1.3)	0.66
Laboratory-confirmed bloodstream infection, N (%)	10 (1.2)	7 (0.8)	8 (0.9)	8 (0.9)	7 (0.8)	40 (0.9)	0.59
Intra-abdominal infection, N (%)	6 (0.7)	7 (0.8)	7 (0.8)	4 (0.5)	4 (0.5)	28 (0.6)	0.36
Urinary tract infection, N (%)	5 (0.6)	3 (0.3)	7 (0.8)	4 (0.5)	1 (0.1)	20 (0.5)	0.27
Catheter-related bloodstream infection, N (%)	4 (0.5)	2 (0.2)	4 (0.5)	2 (0.2)	2 (0.2)	14 (0.3)	0.46
Skin and soft-tissue infection, N (%)	2 (0.2)	2 (0.2)	3 (0.4)	2 (0.2)	3 (0.4)	12 (0.3)	0.67
Clostridioides difficile infection, N (%)	4 (0.5)	1 (0.1)	1 (0.1)	2 (0.2)	1 (0.1)	9 (0.2)	0.24
Others, N (%)	16 (1.9)	20 (2.2)	19 (2.2)	10 (1.1)	14 (1.7)	79 (1.8)	0.28

Table III
Micro-organisms detected from healthcare-associated infections.

	2014 (N = 59)	2015 (N = 63)	2016 (N = 49)	2017 (N = 39)	2018 (N = 64)	Total (N = 273)
Enterobacterales						
3GC S, meropenem S, N	13	11	9	5	11	75
3GC R, meropenem S, N	3	3	8	3	5	
Carbapenem-resistant, N	0	1	0	0	1	
Unknown susceptibility, N	1	0	0	0	1	
Staphylococcus aureus						
MSSA, N	4	9	5	6	4	46
MRSA, N	5	5	2	2	3	
Unknown susceptibility, N	0	1	0	0	0	
Enterococcus spp.						
Vancomycin S, N	6	3	8	5	8	30
Pseudomonas aeruginosa						
Native resistance only, N	4	4	2	3	6	26
Meropenem R, N	0	2	0	1	1	
Multi-drug resistant, N	0	0	0	1	1	
Unknown susceptibility, N	1	0	0	0	0	
Streptococcus spp., N	4	2	2	3	4	15
Candida spp., N	1	6	2	4	2	15
Coagulase-negative *staphylococci*, N	3	1	1	1	4	10
Anaerobes, N	4	2	1	1	1	9
Clostridioides difficile, N	4	1	1	2	1	9
Acinetobacter baumannii, N	2	0	1	0	1	4
Others, N	4	12	7	2	10	35

3GC, 3rd-generation cephalosporin; R, resistant; S, susceptible; MRSA, meticillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

Antimicrobials for surgical antimicrobial prophylaxis changed markedly, with oral cephalosporins and flomoxef diminishing, and cefazolin and cefmetazole increasing to make up the majority of surgical antimicrobial prophylaxis prescribed in 2018.

Discussion

The National Action Plan on antimicrobial resistance prompted infection control teams in Japanese hospitals to apply their own methods to reduce HAI and unnecessary anti-microbial use [2]. Trends in total consumption of antimicrobials have been reported, but trends in device insertion rates, prevalence of HAIs and details of antimicrobial use remained unclear [14–17]. To the best of our knowledge, this study is the first to report multiple annual PPSs in a Japanese hospital and it shows the real hospital epidemiology of Nagoya University Hospital over the five years. The prevalence of HAIs and patients receiving antimicrobials remained at around 9.0% and 35.2%, respectively. Details of HAIs changed little. The number of antimicrobials prescribed for medical prophylaxis have been increasing for five years, but antimicrobials prescribed for HAIs and surgical antimicrobial prophylaxis have been decreasing. Antimicrobials for surgical antimicrobial prophylaxis have changed drastically both in terms of the antimicrobial pre-scribed and the duration. Compared with 2014, oral cepha-losporins were shown to be reduced by more than 50% in 2018. However, other indices (reductions of intravenous anti-microbials, quinolones, and macrolides) were difficult to evaluate by these PPSs.

These annual PPSs demonstrate the epidemiological trends of HAIs and antimicrobial use in a Japanese hospital for the first time. Surgical site infection and pneumonia were the most frequent HAIs; this is probably secondary to the high number of invasive surgeries performed and elderly patients with impaired swallowing. Compared with reports from other countries, urinary tract infections and *C. difficile* infections were less frequent HAIs at Nagoya University Hospital [3,4]. Annual trends in the prevalence of HAIs showed no significant changes; this is in keeping with eight years of PPSs in Chinese hospitals (5.03% in 2010—2011, and 5.04% in 2016—2017) [8]. A European PPS study found that country-weighted HAI preva-lence before validation correction in acute-care hospitals were 5.7% in 2011—2012, and 5.5% in 2016—2017 [4,9]. Considering these reports, HAI prevalence itself might not have changed much, but we consider two reasons for the unchanged preva-lence at Nagoya University Hospital. Firstly, a hand hygiene campaign combined with direct observation was implemented in August 2017. Adherence rates in the third quarter by direct observation in 2017 and 2018 were 31% and 47%, respectively, finally reaching 62% in the first quarter in 2019. The effects of hand hygiene improvement on reductions in HAIs at the time of the 2018 PPS were thus unclear. Secondly, there are limitations to cross-sectional studies and PPSs show one-time epidemiol-ogy which may be affected by several factors. Targeted sur-veillance may be superior to PPS to reveal trends in specific HAIs.

The PPS in 2014 and 2015 revealed unnecessary use of oral antimicrobials and excessively long prescriptions for surgical antimicrobial prophylaxis. As a result, from April 2016

Table IV
Top five antimicrobials by indication during five years.

Year (total patients)	2014 (848)	2015 (920)	2016 (852)	2017 (878)	2018 (848)	5-year (4339)	*P*
Antimicrobials for HAIs							
Meropenem, IV, *N* (%)	13 (1.5)	9 (1.0)	11 (1.3)	7 (0.8)	16 (1.9)	56 (1.3)	0.68
Micafungin, IV, *N* (%)	10 (1.2)	13 (1.4)	6 (0.7)	6 (0.7)	2 (0.2)	37 (0.9)	<0.01
Piperacillin tazobactam, IV, *N* (%)	7 (0.8)	12 (1.3)	5 (0.6)	8 (0.9)	4 (0.5)	36 (0.8)	0.24
Vancomycin, IV, *N* (%)	10 (1.2)	8 (0.9)	6 (0.7)	4 (0.5)	7 (0.8)	35 (0.8)	0.24
Panipenem betamipron, IV, *N* (%)	7 (0.8)	10 (1.1)	6 (0.7)	5 (0.6)	4 (0.5)	32 (0.7)	0.17
Antimicrobials for community-acquired infections							
Ceftriaxone, IV, *N* (%)	6 (0.7)	9 (1.0)	5 (0.6)	12 (1.4)	5 (0.6)	37 (0.9)	0.88
Ampicillin sulbactam, IV, *N* (%)	7 (0.8)	9 (1.0)	5 (0.6)	5 (0.6)	4 (0.5)	30 (0.7)	0.20
Piperacillin tazobactam, IV, *N* (%)	4 (0.5)	6 (0.7)	5 (0.6)	4 (0.5)	4 (0.5)	23 (0.5)	0.78
Cefazolin, IV, *N* (%)	7 (0.8)	4 (0.4)	2 (0.2)	6 (0.7)	1 (0.1)	20 (0.5)	0.12
Cefmetazole, IV, *N* (%)	1 (0.1)	3 (0.3)	3 (0.4)	4 (0.5)	9 (1.1)	20 (0.5)	<0.01
Meropenem, IV, *N* (%)	2 (0.2)	6 (0.7)	3 (0.4)	3 (0.3)	6 (0.7)	20 (0.5)	0.41
Antimicrobials for medical prophylaxis							
Co-trimoxazole, PO, *N* (%)	74 (8.7)	90 (9.8)	80 (9.4)	92 #####	100 #####	436 #####	0.04
Fluconazole, PO, *N* (%)	32 (3.8)	54 (5.9)	49 (5.8)	48 (5.5)	55 (6.5)	238 (5.5)	0.05
Polymyxin B, PO, *N* (%)	19 (2.2)	27 (2.9)	22 (2.6)	25 (2.8)	27 (3.2)	120 (2.8)	0.33
Acyclovir, PO, *N* (%)	23 (2.7)	11 (1.2)	14 (1.6)	9 (1.0)	24 (2.8)	81 (1.9)	0.97
Valacyclovir, PO, *N* (%)	0 (0)	17 (1.8)	11 (1.3)	17 (1.9)	16 (1.9)	61 (1.4)	<0.01
Antimicrobials for surgical antimicrobial prophylaxis							
Cefazolin, IV, *N* (%)	37 (4.4)	33 (3.6)	44 (5.2)	36 (4.1)	48 (5.7)	198 (4.6)	0.17
Cefmetazole, IV, *N* (%)	13 (1.5)	12 (1.3)	14 (1.6)	14 (1.6)	24 (2.8)	77 (1.8)	0.04
Cefdinir, PO, *N* (%)	22 (2.6)	22 (2.4)	12 (1.4)	13 (1.5)	3 (0.4)	72 (1.7)	<0.01
Flomoxef, IV, *N* (%)	9 (1.1)	11 (1.2)	10 (1.2)	4 (0.5)	1 (0.1)	35 (0.8)	<0.01
Cefpodoxime proxetil, PO, *N* (%)	6 (0.7)	5 (0.5)	4 (0.5)	5 (0.6)	0 (0)	20 (0.5)	0.06

ATC, anatomical therapeutic chemical; HAI, healthcare-associated infection; IV, intravenous; PO, per os.

conferences discussing the antimicrobial stewardship programme, National Action Plan on antimicrobial resistance and surgical antimicrobial prophylaxis were held with each surgical department. A total of 20 meetings with 13 surgical departments were held up to December 2017. Concurrent with these conferences, we had suggested methods to optimize antimicrobial use in clinical pathways. Based on the Japanese surgical antimicrobial prophylaxis guidelines, consideration of the following was suggested: first, appropriate selection; second, optimal duration; and third, costs of antimicrobials of similar classes [18]. Almost all surgical departments accepted the suggestions and these approaches led to reduced durations of surgical antimicrobial prophylaxis (increased use day 0 but decreased use day 1 and 3 or later postoperatively) and reduced use of oral cephalosporins.

Compared with surgical antimicrobial prophylaxis, details of antimicrobials for HAI and community-acquired infections were unchanged, with the exception of micafungin and cefmetazole. One reason for the decrease in micafungin was more appropriate use of febrile neutropenia, because some clinicians tended to prescribe micafungin earlier than the recommended timing of guidelines before 2016. Reasons for the increased use of cefmetazole for community-acquired infections were unclear, but cefmetazole may have been substituted for broad-spectrum antibiotics (e.g., cefoperazone/ sulbactam). Considering the causative pathogens for HAIs, it may be possible to reduce the use of broad-spectrum antimicrobials. During the five-year PPSs, we did not start any active intervention to address broad-spectrum antimicrobial use and as such no significant changes in their use were seen. To optimize antimicrobial use, in 2019 we started focused intervention and feedback to clinicians using broad-spectrum antibiotics. For example, we recommend the use of cefmetazole for extended spectrum beta lactamase-producing *Escherichia coli* or *K. pneumoniae* infections in place of carbapenems, discontinuation of antimicrobials where appropriate and collection of relevant cultures for undiagnosed fever.

We did not find clear reasons for the increase in medical prophylaxis. The increasing number of paediatric patients with malignancies, patients taking immunosuppressive agents, such as corticosteroids and biologics may have contributed. Guidelines for Pneumocystis pneumonia prophylaxis in patients with HIV infection, haematopoietic cell transplant recipients, and solid organ recipients have been published [19—21]. Japanese guidelines are similar to these recommendations [22,23]. However, indications for Pneumocystis pneumonia prophylaxis in patients with immunosuppressants should be judged on a case-by-case basis [24]. To understand the indications for and promote appropriate antimicrobial use for medical prophylaxis, we need to start liaising with medical departments.

Some limitations were identified in this five-year PPS in Nagoya University Hospital. First, the annual PPS was performed only in this single university hospital, and the data thus do not reflect conditions in other Japanese hospitals during the same period. Second, each PPS was performed only in July and seasonal variations in patient background, HAI and antimicrobials and pathogens thus were not described. To discuss the exact epidemiology, repeated PPSs of short-term periods should be conducted in combination with other forms of surveillance. Third, we could not judge whether the antimicrobials prescribed were appropriate. However, daily antimicrobial use by clinicians is now being audited and as such the quality of antimicrobial prescriptions can be judged. To describe the epidemiology in Japanese hospitals by PPS, multicentre PPSs including community hospitals need to be performed annually.

In conclusion, this study shows consistent data for patient background, HAIs and causative pathogens, whilst demonstrating a change in surgical and medical antimicrobial prophylaxis at Nagoya University Hospital during the era of the national action plan on antimicrobial resistance. This data highlights potential targets for intervention. Periodic PPS data can provide large amounts of useful information about HAIs, and antimicrobial stewardship and PPSs should be widely performed in Japanese hospitals in the future.

Acknowledgements

Author contributions

H.M.: design of the study, data collection, analysis of this study, and drafting manuscript; M.I., N.T., Y.T., D.K., A.H., A.M., K.O., H.K., T.I., Y.K., K.K., K.I., Y.K., N.K., Y.T., N.A., Y.I.: data collection and drafting the manuscript; F.K.: data analysis and interpretation of the results; T.Y.: coordination of the study and drafting the manuscripts; all authors: review of the manuscript. All authors have approved this article.

Conflict of interest statement

None declared.

Funding sources

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