Antimicrobial stewardship program in China's tertiary hospitals in 2018: a nationwide cross-sectional online survey

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Research

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Abstract

Background

The study aimed to assess the development of antimicrobial stewardship (AMS) program in China's tertiary hospitals to identify the potential challenges for AMS program and provide references and benchmarks for strategic policymaking.

Methods

A nationwide cross-sectional study was conducted online by sending questionnaires to tertiary hospitals under China Antimicrobial Resistance Surveillance System (CARSS) between November 1, 2018 and December 10, 2018. The questionnaire included 5 sections regarding structure, technical support, antimicrobial use management, antimicrobial use surveillance and education. Descriptive statistics were used for data analysis.

Results

Of 1044 tertiary hospitals under CARSS, 13.4% (140) hospitals participated in the study. Among them, 99.3% (139/140) set up AMS program. Hospital president (82.1%, 115/140) and medical service department (59.3%, 83/140) were responsible for AMS outcomes in most hospitals. Structured antimicrobial formulary restriction management was adopted by 99.3% (139/140) hospitals. Infection disease department, infection control department and microbiological laboratories were established in 87.1% (122/140), 99.3% (139/140), and 100% (140/140) hospitals, respectively. Up to 85.6% (124/140) hospitals applied clinical pathways and 33.6% (47/140) hospitals implemented hospital-specific guidelines for infectious diseases. Outpatient prescription audit, inpatient prescription audit and prophylactic antimicrobial prescription audit of aseptic operation were performed in 99.3% (139/140), 98.6% (138/140) and 95.7% (134/140) hospitals, respectively. Up to 97.1% (136/140) hospitals participated in antimicrobial use surveillance network and 99.3% (139/140) hospitals established the specialized management of carbapenem and tigecycline. Staff education and AMS-related popular science education were provided with different ways and frequency in 100% (140/140) and 88.6% (124/140) hospitals, respectively.

Conclusions

AMS in China's tertiary hospitals were primarily headed by hospital presidents and involved collaboration among various disciplines and administrative departments. More efforts should be put into further promoting and strengthening the development of hospital-specific guidelines and the establishment of progress and outcome evaluation system.

Background

Antimicrobial resistance (AMR) has been identified as a critical crisis to public health around the world [1, 2, 3]. Inappropriate antimicrobial use fosters the emergence and spread of new resistance organisms [4]. In an era of serious AMR and a diminishing pipeline of new antimicrobial development, antimicrobial stewardship (AMS) program has been introduced to hospitals as a way to optimize antimicrobial use [2, 5, 6]. AMS program has been defined as a comprehensive and coordinated interventions designed to improve and measure appropriate antimicrobial use through optimizing drug selection including dosing, therapy duration as well as administration route [7]. Guidelines for establishing and implementing AMS program have been developed, such as a checklist including core elements of hospital AMS programs by the US Centers for Disease Control and Prevention and a checklist on structure and process indicators for hospital AMS program by the Transatlantic Taskforce on Antimicrobial Resistance [8, 9].

China is one of the largest consumers of antimicrobials [10, 11, 12]. To promote antimicrobial rational use and confine AMR, several administrative regulations and technical specifications, such as the Regulations for Antimicrobials Clinical Use, National Action Plan to Contain Antimicrobial Resistance (2016–2020), have been issued in the past decade [13]. However, the extent to which AMS program has been implemented in China's tertiary hospitals is a lack of study. The present study aimed to assess the development of AMS program in China's hospitals, as well as to identify the potential challenges for AMS program establishment, and to provide references and benchmarks for strategic policymaking.

Methods

The questionnaire was designed based on literature review of previous studies for AMS program, the published guidelines and checklists as well as relevant Chinese policies [6, 8, 11, 13, 14, 15]. Potential survey questions were extracted and classified. After three rounds of face-to-face consensus meetings with professionals from governments, hospitals and academic institutions, the final survey questionnaire was determined by including 5 sections regarding structure, technical support, antimicrobial use management, antimicrobial use surveillance and education. The questionnaire was sent to the tertiary hospitals under China Antimicrobial Resistance Surveillance System (CARSS) [16]. The hospitals participated in the survey voluntarily. To ensure the accuracy of the information, only the staff involved in AMS program were eligible to complete the questionnaire. The completed questionnaire was required to affix the hospital's seal before being sent back. Only one questionnaire could be accepted for each hospital. The nationwide cross-sectional study was conducted between November 1, 2018 and December 10, 2018.

We conducted descriptive analyses of sample characteristics and the establishment of AMS program. The variables were summarized with frequencies and proportions using Microsoft Excel 2016 and R version 3.3.3.

Results

A total of 140 out of 1045 hospitals under CARSS were investigated, and the response rate was 13.4%. The hospitals participating accounted for 5.5% of all tertiary hospitals (140/2548) [17], and geographically covered all provinces and municipalities in mainland China except Fujian, Gansu, Ningxia, Qinghai, and Tibet. (Fig. 1)

Structure of AMS program

AMS program was established in 99.3% (139/140) hospitals. The members of the AMS programs were mainly from pharmacy department (99.3%, 139/140), intensive care unit (ICU, 97.9%, 137/140), respiratory department (95.0%, 133/140), microbiological laboratory (95.0%, 133/140), infection control department (95.0%, 133/140) and infectious disease department (90.0%, 126/140). For most hospitals, AMS program were headed by hospital presidents (82.1%, 115/140), followed by vice hospital presidents who were in charge of healthcare service (15.0%, 21/140). AMS program fell under the responsibility and control of medical service departments in 59.3% (83/140) hospitals, followed by pharmacy department in 30.7% (43/140) hospitals. (Table 1)

Table 1
Structure of AMS program

Elements	Number of hospitals N = 140 n (%)
Time of AMS program establishment	
Not yet	0 (0)
Before 2006	36 (25.7)
2006–2010	42 (30.0)
2011–2015	56 (40.0)
After 2015	5 (3.6)
N/A	1 (0.7)
Number of AMS team members	
0	0 (0)
1–3	1 (0.7)
3–6	0 (0)
≥ 7	139 (99.3)
Number of AMS team members - full time	
0	41 (29.3)
1–3	52 (37.1)
3–6	30 (21.4)
≥ 7	16 (11.4)
N/A	1 (0.7)
Number of AMS team members - part time	
0	2 (1.4)
1–3	13 (9.3)
3–6	21 (15.0)
≥ 7	103 (73.6)
N/A	1 (0.7)

AMS, antimicrobial stewardship, ICU, intensive care unit.

Elements	Number of hospitals N = 140 n (%)
Clinical departments participating in AMS program	
Pharmacy department	139 (99.3)
ICU	137 (97.9)
Microbiological laboratory	133 (95.0)
Infection control department	133 (95.0)
Respiratory department	133 (95.0)
Infectious disease department	126 (90.0)
Others	137 (97.9)
Administrative departments participating in AMS program	
Medical service department	140 (100)
Pharmacy department	140 (100)
Infection control department	139 (99.3)
Microbiological laboratory	127 (90.7)
Information department	119 (85.0)
Infectious disease department	107 (76.4)
Nursing Department	107 (76.4)
Quality control department	95 (67.9)
Medical record department	41 (29.3)
Others	11 (7.9)
Leader of AMS program	
Hospital president	115 (82.1)
Vice hospital president in charge of healthcare service	21 (15.0)
Leader of the medical department	1 (0.7)
Leader of the infectious disease department	1 (0.7)
Others	2 (1.4)

AMS, antimicrobial stewardship, ICU, intensive care unit.

Elements	Number of hospitals N = 140 n (%)
Department in charge of AMS program	
Medical service	83 (59.3)
Pharmacy department	43 (30.7)
Infection control department	7 (5.0)
Infectious disease department	0 (0)
Others	7 (5.0)
Measures taken to improve AMS program	
Professional training	138 (98.6)
Incentive reward mechanism	124 (88.6)
Staffing full-time employee	120 (85.7)
Electronic information technology	58 (41.4)
Others	15 (10.7)

AMS, antimicrobial stewardship, ICU, intensive care unit.

Technical support of AMS program

In terms of information technical support for AMS, structured antimicrobial formulary restriction management was adopted by 99.3% (139/140) hospitals, followed by antimicrobial use data crawling (94.3%, 132/140). Infectious disease departments were established in 87.1% (122/140) hospitals and the main responsibilities of them were bacterial infection prevention and treatment (76.4%, 107/140) and clinical consultation for infection diseases (71.4%, 100/140). Up to 99.3% (139/140) hospitals set up infection control departments before 2015 with variable measures adopted to reduce the hospital infection. The main responsibilities of the pharmacy departments were prescription audit for outpatient and emergency department (51.4%, 72/140), prescription audit for inpatient (60.0%, 84/140) and special prescription audit for antimicrobials (57.9%, 81/140). Microbiological laboratories were established in all hospitals (100%, 140/140) and the main responsibilities included bacterial infection test (100%, 140/140), fungal infection test (100%, 140/140) and clinical consultation for infectious diseases (77.9%, 109/140). (Table 2)

Table 2
Technical support of AMS program

Elements	Number of hospitals N = 140 n (%)
Information technology for AMS program	
Structured antimicrobial formulary restriction management	139 (99.3)
Structured antimicrobial duration restriction management	57 (40.7)
Intelligent prescription audit of antimicrobials	64 (45.7)
Antimicrobial use data crawling	132 (94.3)
Others	55 (39.3)
Time of infectious disease department establishment	
Not yet	16 (11.4)
Before 2006	75 (53.6)
2006–2010	16 (11.4)
2011–2015	26 (18.6)
After 2015	5 (3.6)
N/A	2 (1.4)
Responsibilities of infectious disease department	
Bacterial infection prevention and treatment	107 (76.4)
Fungal infection prevention and treatment	98 (70.0)
Communicable disease (e.g. hepatitis, tuberculosis) treatment	84 (60.0)
Clinical consultation for infection diseases	100 (71.4)
Clinical consultation for highly restricted antimicrobials [a]	97 (69.3)
Others	7 (5.0)
Time of infection control department establishment	

AMS, antimicrobial stewardship; ICU, intensive care unit.

[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.

Elements	Number of hospitals N = 140 n (%)
Not yet	1 (0.7)
Before 2006	94 (67.1)
2006–2010	32 (22.9)
2011–2015	13 (9.3)
After 2015	0 (0)
Measures to improve infection control	
Measures for "hand hygiene"	140 (100)
Outbreak investigation	138 (98.6)
Quarantine measures	137 (97.9)
Active screening	138 (98.6)
Environmental cleaning and disinfection	130 (92.9)
Post-exposure prevention	129 (92.1)
Multisectoral collaboration	139 (99.3)
Training and education	136 (97.1)
Surveillance and early warning of multi-drug resistant bacteria	110 (78.6)
Other	16 (11.4)
Number of pharmacists majoring in infectious diseases, respiratory and ICU	
0	3 (2.1)
1	12 (8.6)
2–3	71 (50.7)
4–6	49 (35)
7–9	4 (2.9)
≥ 10	1 (0.7)

AMS, antimicrobial stewardship; ICU, intensive care unit.

[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.

Elements	Number of hospitals N = 140 n (%)
Main responsibilities of pharmacy department for AMS program	
Prescription audit for outpatient and emergency department	72 (51.4)
Prescription audit for inpatient	84 (60.0)
Special prescription audit for antimicrobials	81 (57.9)
Selection of antimicrobial catalogue	20 (14.3)
Time of microbiological laboratory establishment	
Not yet	0 (0)
Before 2006	134 (95.7)
2006–2010	5 (3.6)
2011–2015	1 (0.7)
After 2015	0 (0)
Responsibilities of microbiological laboratory	
Bacterial infection test	140 (100)
Fungal infection test	140 (100)
Communicable disease test (e.g. hepatitis, tuberculosis)	49 (35.0)
Clinical consultation for infectious diseases	109 (77.9)
Medical record review	66 (47.1)
Selection of antimicrobial catalogue	71 (50.7)
Other	5 (3.6)
AMS, antimicrobial stewardship; ICU, intensive care unit.	
[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.	

Antimicrobial use management of AMS program

To strengthen appropriate antimicrobial use, about one third of (30.0%, 42/140) the hospitals developed 1–5 clinical pathways, and up to 14.3% (20/140) hospitals developed no less than 20 clinical pathways. In terms of hospital-specific guidelines related to antimicrobial use and specific infectious diseases, the

guidelines mainly focused on lower respiratory tract infection and acute exacerbation of chronic obstructive pulmonary disease (25.0%, 35/140), upper respiratory tract infection (22.9%, 32/140) and urinary tract infection (22.9%, 32/140). However, there were still 66.4% (93/140) hospitals with no guidelines established. (Table 3)

Table 3
Antimicrobial use management of AMS program

Elements	Number of hospitals N = 140 n (%)
Basis for assigning the privilege of antimicrobial prescribing	
Professional titles	13 (9.3)
Education and evaluation results	18 (12.9)
Annual prescription review results	1 (0.7)
Administrative level	1 (0.7)
Combination of technical titles and performance evaluation results	93 (66.4)
Other	1 (0.7)
Development of clinical pathways	
Not yet	14 (10.0)
1–5 clinical pathways	42 (30.0)
6–10 clinical pathways	27 (19.3)
11–15 clinical pathways	23 (16.4)
16–20 clinical pathways	12 (8.6)
≥ 21 clinical pathways	20 (14.3)
N/A	2 (1.4)
Hospital-specific guidelines about antimicrobial use	
No guidelines established	93 (66.4)
Urinary tract infection	32 (22.9)
Upper respiratory tract infection	32 (22.9)

AMS, antimicrobial stewardship; AMR, antimicrobial resistance.

[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.

[b] Clean incision surgery means no inflammation is encountered in a surgical procedure, without a break in sterile technique, and during which the respiratory, alimentary and genitourinary that are not entered [18].

Elements	Number of hospitals N = 140 n (%)
Lower respiratory tract infection, acute exacerbation of chronic obstructive pulmonary disease	35 (25.0)
Soft tissue infection	24 (17.1)
Central nervous system infection	28 (20.0)
Gastrointestinal tract infection	31 (22.1)
Genital infection	24 (17.1)
Bloodstream infection	30 (21.4)
Eye, ear, nose and throat infection	26 (18.6)
Unexplained septicemia	19 (13.6)
Certain infections, e.g. MRSA, Clostridium difficile and tuberculosis	17 (12.1)
Myoendocarditis	23 (16.4)
Others	11 (7.9)
Types of antimicrobial prescription audit	
Outpatient prescription audit	139 (99.3)
Emergency department prescription audit	132 (94.3)
Inpatient prescription audit	138 (98.6)
Parenteral antimicrobial use in outpatient and emergency department	65 (46.4)
Prophylactic antimicrobial prescription audit of aseptic operation	134 (95.7)
Special prescription audit for highly restricted antimicrobials [a]	124 (88.6)
Special prescription audit for top ranking antimicrobials	88 (62.9)

AMS, antimicrobial stewardship; AMR, antimicrobial resistance.

[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.

[b] Clean incision surgery means no inflammation is encountered in a surgical procedure, without a break in sterile technique, and during which the respiratory, alimentary and genitourinary that are not entered [18].

Elements	Number of hospitals N = 140 n (%)
Antimicrobial prescription audit based on trend of AMR	28 (20.0)
Others	3 (2.1)
Outcome measures for AMS program	
Number of varieties and specifications of antimicrobials	140 (100)
Number of defined daily doses	140 (100)
Number of days of therapy	21 (15.0)
Antimicrobial prescription rate of outpatient and inpatient	140 (100)
Registration of highly restricted antimicrobial prescription	123 (87.9)
Proportion of prophylactic antimicrobial use for clean incision surgery [b]	133 (95.0)
Appropriateness of prophylactic antimicrobial use for clean incision surgery	125 (89.3)
Rate of conducting antimicrobial susceptibility tests before antimicrobial treatment for inpatient	132 (94.3)
Prescription audit	133 (95.0)

AMS, antimicrobial stewardship; AMR, antimicrobial resistance.

[a] Structured antimicrobial formulary restriction management has been established in China, which categorized antimicrobials into three classes (non-restricted, restricted and highly-restricted), with different prescription privileges to different level of physicians.

[b] Clean incision surgery means no inflammation is encountered in a surgical procedure, without a break in sterile technique, and during which the respiratory, alimentary and genitourinary that are not entered [18].

Antimicrobial use surveillance of AMS program

Up to 97.1% (136/140) hospitals participated in antimicrobial use surveillance network. The main indicators adopted for antimicrobial use included antimicrobial use intensity by departments (measured by number of defined daily doses, DDDs, 90.7%, 127/140), ranking by usage volume (83.6%, 117/140) and ranking by usage expenditure (85.7%, 120/140). To improve the prudent use of antimicrobials, up to 90.0% (126/140) hospitals included antimicrobial use quality to performance appraisal. Admonishing conversation (86.4%, 121/140) and financial penalties (84.3%, 118/140) were also commonly adopted. Most of the hospitals (96.4%, 135/140) established the targeted management of carbapenem and tigecycline after 2015. (Table 4)

Table 4
Antimicrobial use surveillance of AMS program

Elements	Number of hospitals N = 140 n (%)
Participation of antimicrobial use surveillance network (Center for Antibacterial Surveillance)	
Not yet	3 (2.1)
2005–2010	70 (50.0)
2011–2015	65 (46.4)
After 2015	1 (0.7)
N/A	1 (0.7)
What to report of antibiotic usage?	
Not yet	2 (1.4)
Antimicrobial use intensity by departments (measured by DDDs)	127 (90.7)
Ranking by usage volume	117 (83.6)
Ranking of usage expenditure	120 (85.7)
Others	11 (7.9)
Frequency of announcing antimicrobial use	
Not yet	2 (1.4)
1–2/year	6 (4.3)
3–4/year	41 (29.3)
≥ 5/year	90 (64.3)
N/A	1 (0.7)
Frequency of announcing AMR	
Not yet	0 (0)
1–2/year	14 (10.0)

AMS, antimicrobial stewardship; AMR, antimicrobial resistance; DDDs, number of defined daily doses.

[a] Hospitals are required to fill in a form to report the relevant information of patients who used carbapenems or tigecycline, including name, diagnose, generic name of the drugs, dosage, etc. Specific persons are assigned to collect the forms and analyze the data to propose effective ways of controlling carbapenems and tigecycline resistance [19].

Elements	Number of hospitals N = 140 n (%)
3–4/year	110 (78.6)
≥ 5/year	15 (10.7)
N/A	1 (0.7)
Penalties and rewards to improve AMS program	
Admonishing conversation	121 (86.4)
Deprivation of prescription privilege	89 (63.6)
Financial penalties	118 (84.3)
Linked to title assessment	53 (37.9)
Linked to promotion	56 (40.0)
Included to performance appraisal	126 (90.0)
Education	104 (74.3)
Material reward	22 (15.7)
Praise in hospitals	57 (40.7)
Others	2 (1.4)
Time of specialized management of carbapenem and tigecycline [a]	
Not yet	1 (0.7)
Before 2006	1 (0.7)
2006–2010	0 (0)
2011–2015	2 (1.4)
After 2015	135 (96.4)

AMS, antimicrobial stewardship; AMR, antimicrobial resistance; DDDs, number of defined daily doses.

[a] Hospitals are required to fill in a form to report the relevant information of patients who used carbapenems or tigecycline, including name, diagnose, generic name of the drugs, dosage, etc. Specific persons are assigned to collect the forms and analyze the data to propose effective ways of controlling carbapenems and tigecycline resistance [19].

AMS program education

Staff education was provided by all hospitals (100%, 140/140) with different ways and frequency. To guarantee the efficiency of education, attendance record (90.7%, 127/140) and examination (94.3%, 132/140) were mainly used. For patients, AMS-related popular science education was organized by 88.6% (124/140) hospitals. (Table 5)

Table 5
Education of AMS program

Elements	Number of hospitals N = 140 n (%)
Frequency of organizing AMS education and promotion	
Not yet	0 (0)
1–3/year	92 (65.7)
4–6/year	29 (20.7)
7–9/year	5 (3.6)
≥ 10/year	13 (9.3)
N/A	1 (0.7)
Frequency of sending staff to AMS-related conferences or courses	
Not yet	2 (1.4)
1–3/year	62 (44.3)
4–6/year	38 (27.1)
7–9/year	10 (7.1)
≥ 10/year	28 (20)
N/A	2 (1.4)
Frequency of inviting experts for AMS lecturing	
Not yet	3 (2.1)
1–3/year	84 (60.0)
4–6/year	34 (24.3)
7–9/year	8 (5.7)
≥ 10/year	9 (6.4)
N/A	2 (1.4)
Frequency of participating online AMS education	
Not yet	16 (11.4)
1–3/year	73 (52.1)

AMS, antimicrobial stewardship.

Elements	Number of hospitals N = 140 n (%)
4–6/year	20 (14.3)
7–9/year	9 (6.4)
≥ 10/year	20 (14.3)
N/A	2 (1.4)
Management approach of AMS education	
Attendance record	127 (90.7)
Certificate of completion	16 (11.4)
Examination	132 (94.3)
Other	0 (0)
N/A	1 (0.7)
Frequency of conducting AMS-related popular science education	
Not yet	14 (10.0)
1–3/year	79 (56.4)
4–6/year	10 (7.1)
7–9/year	0 (0)
≥ 10/year	35 (25.0)
N/A	2 (1.4)

AMS, antimicrobial stewardship.

Discussion

We systematically conducted a nationwide survey on the implementation and current status of AMS program in 140 tertiary hospitals, covering 26 provinces in China. In this survey, AMS program was implemented in 99.3% (139/140) of the responding hospitals, which was higher than that in the studies conducted in developed countries such as the US and Netherland [20, 21]. AMS program has been required to be implemented in China since 2011. Furthermore, in the past decade, a relatively systematical management system and advanced technical support framework have been established by the Chinese government, contributing to setting up AMS program in the hospitals. The hospitals surveyed were all tertiary hospitals which were likely to be larger, urban and have better access to medical resource and

financial support. As adequate manpower and funding are identified as main barriers to developing AMS program, tertiary hospitals surveyed were probably more capable of policy execution and AMS program implementation when comparing with other hospitals [22, 23, 24].

Leadership and teamwork are paramount prerequisites for successful and effective implementation of AMS program. The survey demonstrated that hospital presidents were heading AMS program in most hospitals. Different from our result, previous studies found that AMS team was more likely to be led by pharmacists or infectious disease physicians in the US [20, 25]. According to the management regulations and technical specifications issued by the Chinese government, hospital presidents were appointed as the leaders of AMS program. It is emphasized that a wide range of health professionals could provide unique support in achieving the over-all goal of AMS [26, 27, 28]. Obviously, the hospital presidents possess the supreme power, and it is beneficial for ordering commanding and dedicating necessary human resources for the program when the hospital presidents take charge of AMS program. Under this circumstances, financial support could be also guaranteed, which greatly augments the capacity and influence of the program. Furthermore, the survey confirmed that pharmacy departments exerted a critical role in AMS implementation. It is recommended that along with infectious disease physicians, pharmacists are considered as the core members as drug expertise in AMS team [8].

In the survey, most infectious disease departments were still occupied by the management of common communicable diseases such as hepatitis and tuberculosis. Also, infectious disease physicians played a limited role in AMS program implementation in most hospitals. This finding was similar with the result in a prior study [29]. The tertiary hospitals in China has been required to establish infectious disease departments since the outbreak of severe acute respiratory syndrome in 2013. The main duties of the departments are to treat various infectious diseases, address AMR and deal with infectious disease emergence. However, when comparing with the developed countries, our finding revealed that the effectiveness of infectious disease department in antimicrobial rational use promotion and AMR confinement needs to be strengthened. The limited privilege of infectious disease physicians would undoubtedly restrict the impact of AMS on antimicrobial rational use and AMR confinement in China. This may be partly attributed to the shortage of adequately trained physicians interested in infectious diseases and the lack of consciousness of AMR control of the physicians. Hence, it is imperative that the infectious disease department and the physicians should attach great importance to their commitment to AMS implementation.

Clinical pathways and hospital-specific guidelines for main infection syndromes are identified as an effective way to standardize antimicrobial prescription for specific infectious syndromes. In our survey, most hospitals developed clinical pathways. The Chinese government has made great efforts to implementing clinical pathways and establishing diagnosis related group system, which exert a catalyzing effect on the development of clinical pathways in AMS program [30, 31]. Unlike clinical pathways, hospital-specific guidelines were only developed in 33.6% (47/140) hospitals surveyed. The majority of the guidelines in the hospitals surveyed were for urinary tract infection and upper respiratory tract infection. This was basically in accordance with the morbidity of infectious diseases in China and

the guideline for AMS program by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America [6]. Previous studies showed that the implementation of hospital-specific guidelines was associated with optimal antimicrobial use by increasing the likelihood of sufficient initial therapy, narrower-spectrum antimicrobial use, shorter therapy duration and timely switch from intravenous to oral antimicrobials [32, 33, 34, 35, 36, 37, 38]. Hence, multi-discipline collaboration of AMS program in development of hospital-specific guidelines for infectious diseases should be emphasized.

Our findings highlighted the ongoing difficulties in antimicrobial usage measurement, which has long been considered as an essential opponent to promote AMS [39]. Although up to 138 hospitals surveyed reported antimicrobial usage on a regular basis, most of them tracked antimicrobial use using define daily dose (DDD) and ranked antimicrobials based on usage and expenditure. Neither indicator was appropriate and optimal for benchmarking [40, 41]. Specifically, although DDD is a direct and widely adopted metric for antimicrobial usage measurement and comparison, the limitations of DDD are obvious. Unlike number of days of therapy which is recommended as the first option for antimicrobial usage measurement in the US, DDDs is not an applicable measuring tool in pediatric setting and is not an optimal metric for individuals with renal and/or liver impairment because of the dose reduction [8, 42]. Previous study also showed that some hospitals in China might mechanically define DDDs by restricting the total dosage of antimicrobials during infectious disease treatment [29]. This would result in antimicrobial underuse and even possibly exacerbate AMR. The limited access to computerized pharmacy data may also narrow the options of tracking antimicrobial usage. We also found that there was a lack of evaluating AMS outcome from the clinical and the economic perspective. Of note, optimizing patient outcomes and confining AMR is the primary goal of AMS [6]. The outcome measurement would provide useful information on the effectiveness of strategies used and assist in adjusting AMS program. Moreover, cost savings could be achieved by optimized antimicrobial use, shorter duration and avoidance of unnecessary antimicrobials. This will in turn motivate the implementation of AMS program. Hence, there is a necessity to identify appropriate metrics for antimicrobial use, AMR outcome, patient outcome and expenditure and establish a comprehensive evaluation system for the program.

Our study has some limitations. Firstly, though up to 140 tertiary hospitals participated in the survey, they only accounted for 5.5% (140/2548) of all tertiary hospitals in China [17]. The relatively small sample size and low response rate may introduce non-response bias and affect generalizability given the extensive application of antibiotics and increasing emergence of AMR in tertiary hospitals in China. Secondly, the survey solely assessed tertiary hospitals on AMS implementation. In contrast to primary care setting, tertiary hospitals have better access to medical resource and more funding for AMS development, which may lead to over-estimation in our results. We aim to extend the survey to obtain information on this topic in primary care setting in the future. Furthermore, the hospitals participated in this survey voluntarily. Therefore, the respondents might be those most interested or active in AMS than non-respondents, which probably provided an optimistic view of the results.

Conclusions

In conclusion, this nationwide survey provided important information on the progress of AMS that was made in China's tertiary hospitals. AMS program in tertiary hospitals were mainly headed by hospital presidents and involved collaboration among a wide range of disciplines and administrative departments. More efforts are required to further promote and strengthen the development of hospital-specific guidelines. Furthermore, establishment of progress and outcome evaluation system should be strengthened to guarantee the feasibility or sustainability of AMS program.

Abbreviations

AMR
Antimicrobial resistance
AMS
Antimicrobial stewardship
CARSS
China Antimicrobial Resistance Surveillance System
ICU
Intensive care unit
DDD
Defined daily dose
DDDs
Number of defined daily doses

Declarations

Ethics approval and consent to participate

The study was approved and exempted for informed consent from Peking University Institutional Review Board, Beijing, China (No. IRB00001052-18027-Exampt).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

LWS conceived the study. YZ and HW designed the study. All authors acquired and analyzed the data. YZ, HW, and XZ interpreted the findings. YZ and HW wrote the first draft of the manuscript. LWS drafted subsequent versions. All authors critically reviewed this article and approved the final version.

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Figures

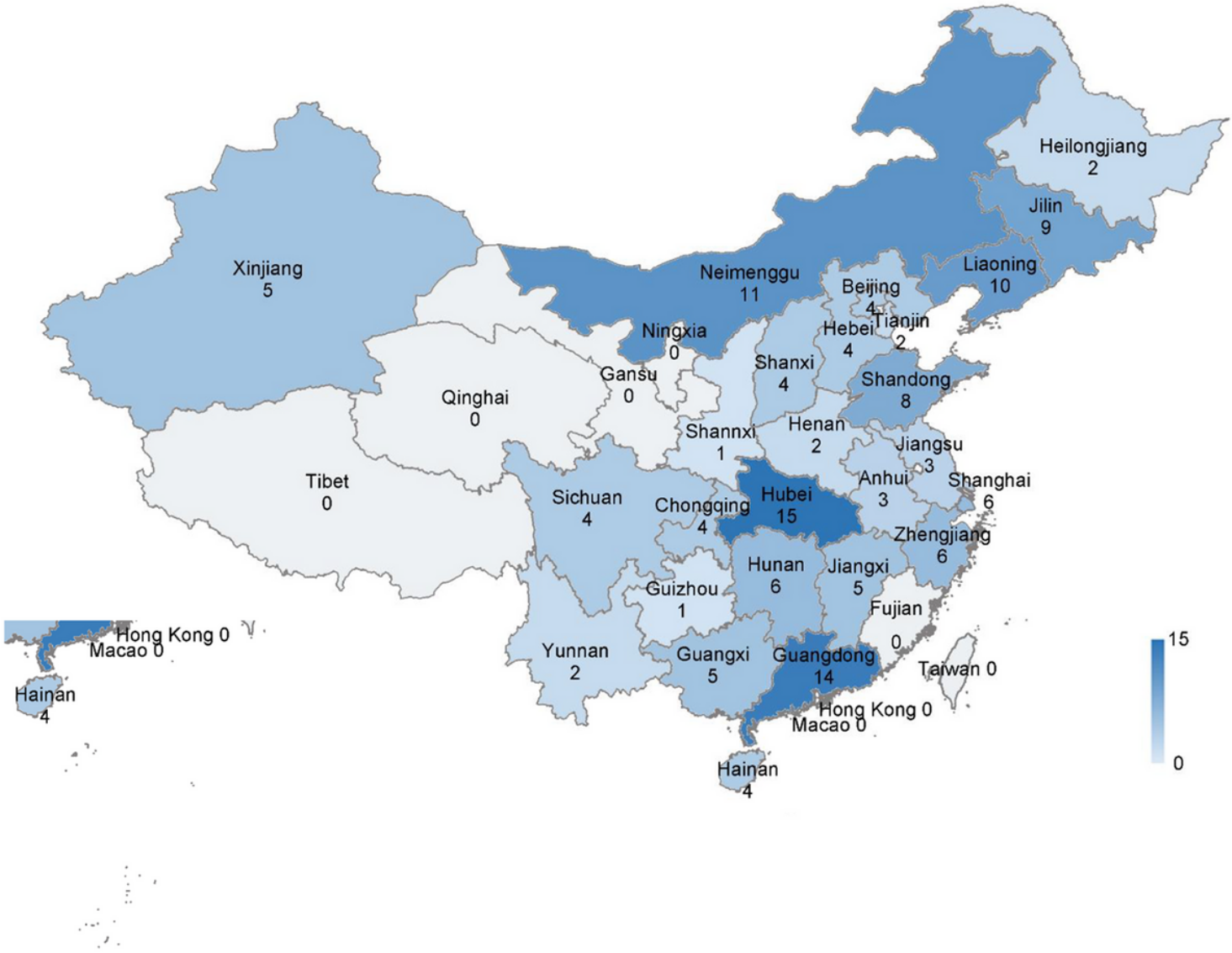

Figure 1

The distribution of sample hospitals. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.