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An international cross-sectional survey of antimicrobial stewardship programmes in hospitals

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Objectives: To report the extent and components of global efforts in antimicrobial stewardship (AMS) in hospitals.

Methods: An Internet-based survey comprising 43 questions was disseminated worldwide in 2012.

Results: Responses were received from 660 hospitals in 67 countries: Africa, 44; Asia, 50; Europe, 361; North America, 72; Oceania, 30; and South and Central America, 103. National AMS standards existed in 52% of countries, 4% were planning them and 58% had an AMS programme. The main barriers to implementing AMS programmes were perceived to be a lack of funding or personnel, a lack of information technology and prescriber opposition. In hospitals with an existing AMS programme, AMS rounds existed in 64%; 81% restricted antimicrobials (carbapenems, 74.3%; quinolones, 64%; and cephalosporins, 58%); and 85% reported antimicrobial usage, with 55% linking data to resistance rates and 49% linking data to infection rates. Only 20% had electronic prescribing for all patients. A total of 89% of programmes educated their medical, nursing and pharmacy staff on AMS. Of the hospitals, 38% had formally reviewed their AMS programme: reductions were reported by 96% of hospitals for inappropriate prescribing, 86% for broad-spectrum antibiotic use, 80% for expenditure, 71% for healthcare-acquired infections, 65% for length of stay or mortality and 58% for bacterial resistance.

Conclusions: The worldwide development and implementation of AMS programmes varies considerably. Our results should inform and encourage the further evaluation of this with a view to promoting a worldwide stewardship framework. The prospective measurement of well-defined outcomes of the impact of these programmes remains a significant challenge.

Keywords: antibiotic prescription, antibiotic policy, antibiotic management

Introduction

Antimicrobial resistance is growing and the pipeline for new antibiotics is running dry.[1,2] This is especially a problem with multiresistant Gram-negative bacteria.[1] Two main approaches are suggested to address this problem, namely an investment in new antibiotic discovery and improved antimicrobial stewardship (AMS).[1–3] The earliest described organized AMS activities go back to the early 1970s.[4] The term 'antimicrobial stewardship' was first coined in 1997 as describing a collection of strategies, policies, guidelines or tools that could improve antimicrobial prescribing with the aim of decreasing antimicrobial resistance and use.[5] Many definitions have been suggested for AMS across the world, but agreement has not been reached on one definition. While studies to investigate AMS have previously been undertaken, the vast majority have only been conducted on a national scale (e.g. in the USA,[6,7] the UK[8] and Belgium[9]) and good quality information from all continents is lacking. Nonetheless, all the studies to date describe varying levels of maturity of stewardship, different priorities or strategies and a different impact on measured outcomes. A European survey of 32 countries[10] focused around hospital antibiotic consumption and information about the presence of policies and practices again revealed much variation across countries. The aim of this global cross-sectional survey was to investigate the depth and penetration of AMS across the world. The survey collected outcome data for the relevant strategies

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employed and information about the main perceived barriers found in different regions. Learning about these barriers and facilitators for stewardship may identify opportunities for improving practice globally.

Methods

In March 2011, the ESCMID Study Group for Antibiotic Policies (ESGAP) launched a global survey of AMS. To achieve worldwide coverage, agreement was reached to form a joint working party with the AMS group of the International Society of Chemotherapy (ISC).

A literature search was undertaken of published standards and surveys on AMS using Medline, Embase and Google Scholar (articles published in English). Search terms were 'antimicrobial' or 'antibiotic' and 'stewardship' or 'control'.[5,11–49] The working party also shared surveys not identified within the literature search.

From the literature, a draft questionnaire was developed using the components of AMS that had been identified, and from questions asked in other surveys that would capture the breadth of activities undertaken.[7,10,50–60] Published recommendations for the development and implementation of web-based surveys were applied prospectively to the design of our research survey.[61–63]

A web-based survey tool (SurveyMonkey®) was used. The initial survey was distributed in October 2011 to key opinion leaders in AMS in all six continents to test the readability and clarity of the questions, especially in countries where English was not the main language, and to reach consensus on the questions. It was decided to restrict the survey to hospital AMS activities and exclude ambulatory care.

The survey was piloted in 11 countries in six continents.[63,64] The final survey was 18 pages long with 45 questions (the questionnaire is available as Supplementary data at *JAC* Online). In order to decrease the time taken to complete the survey, it used page and question logic that missed out pages or questions asking for more information depending on the answers.

An invitation letter was sent to regional and country contacts within the ISC and ESCMID for distribution via their infectious diseases, microbiology and antimicrobial pharmacy networks for each continent and country in March 2012. Further advertising took place during the 2012 ECCMID conference, through newsletters and the use of Twitter and other infection-related intranet sites. An interim review of data in April 2012 identified limited penetration to the African, Asian and South American continents. It was agreed to extend the original 5 week collection period to 6 months from March to September 2012 to maximize the response rate.

Only one IP address was allowed per hospital, but the survey could be accessed again to update the answers if not all the information was complete at the time of entry.

Descriptive data analysis was undertaken using IBM SPSS version 19 (Chicago, IL, USA). Duplicates were identified by duplicate hospital names and addresses. Where there were duplicate entries, these were amalgamated. Due to the size and complexity of the questionnaire, it was decided to use all entries that contained information about AMS activities, even if there were missing answers for some questions.

Results

There were 722 survey returns but 62 entries had to be excluded: 10 did not record any demographic information and 52 were duplicated entries from the same hospital. There were 660 eligible responses (67 countries from six continents): Africa, 44; Asia, 50; Europe, 361; North America, 72; Oceania, 30; and South America, 103 (Table 1). A total of 507/660 (77%) hospitals fully completed the questionnaire. Tertiary teaching hospitals accounted for 48% (319/660) of the returns, district or general hospitals for 24% (161/660) and community or private (not state-funded) hospitals for 8% (56/660) each. Hospitals with up to 500 overnight beds accounted for 48% (314/660), those with 501–1000 beds for 33% (217/660) and those with over 1000 beds for 20% (129/660) of the total.

AMS standards and structures

National AMS standards existed in 52% (35/67) of the countries, and a further 4% (3/67) planned to introduce them. Of the hospitals, 58% (367/636) had a local AMS programme with a median duration of 3 years and 22% (143/636) planned to introduce one. The AMS programmes of European hospitals had been running longer (Table 2).

Although the majority of hospitals reported the existence of drug and therapeutic committees (85%, 543/637), only 62% (396/637) had a specific AMS committee, with variation across the continents: from 12% (5/43) in Africa to 77% (267/348) in Europe. A total of 46% (293/637) of hospitals reported a specific overarching AMS strategy or code of practice. Only 38% (232/616) published an annual report on AMS and 29% (179/612) had a published AMS work plan.

AMS programme objectives, resources and barriers to effective implementation

Hospitals were asked the three main objectives of their AMS programmes. Reducing antimicrobial resistance was the most frequent reason across all continents. Improving patient outcomes, reducing antimicrobial prescribing, reducing *Clostridium difficile* infections and other healthcare-acquired infections and then

Table 1. Summary of validated returns by continent

	Africa, *n* (%)	Asia, *n* (%)	Europe, *n* (%)	North America, *n* (%)	Oceania, *n* (%)	South and Central America, *n* (%)	Total, (*n*)
Number of countries returning questionnaires	10 (15)	14 (20)	26 (38)	5 (7)	2 (3)	12 (17)	67[a]
Hospital returns by continent	44 (7)	50 (8)	361 (55)	72 (11)	30 (5)	103 (16)	660
Mean hospital returns by country (range)	4 (1–13)	3 (1–9)	12 (1–104)	15 (1–35)	15 (13–17)	7 (1–39)	8 (1–104)
Median hospital returns by country	2	2	8	9	15	4	3

[a]Russia and Turkey had hospitals in both Europe and Asia.

reducing costs were the next reasons, with a variation in the order by continent.

The resources available for AMS programmes varied by continent (Table 3). In Asia, Europe, North America and Oceania, the main manpower was antimicrobial or infectious diseases pharmacists, but stewardship was delivered by infection control staff in Africa. The main medical input was by infectious diseases doctors in most continents except for Africa and Europe, where medical microbiologists predominated. When asked about the funding of specific posts within the AMS programmes, 81% (820/1008) of posts were funded from general or hospital department budgets, 15% (150/1008) from dedicated funding [the highest proportion being antimicrobial or infectious diseases pharmacists—21% (61/292 posts)], and 4% (38/1008) of all AMS staff were funded from savings.

Figure 1 shows the top three barriers to delivering a functional and effective AMS programme in hospitals at the current time. These were a lack of funding or personnel and a lack of information technology or ability to get data, followed by prescriber opposition or other higher priorities. This was uniform across all continents except for Africa, which ranked information technology as the primary issue. In the 143/636 hospitals (22%) that planned to develop an AMS programme, the main barrier was lack of funding, except in South America, where a lack of awareness on the part of the hospital administration was the main reason stated.

AMS strategies

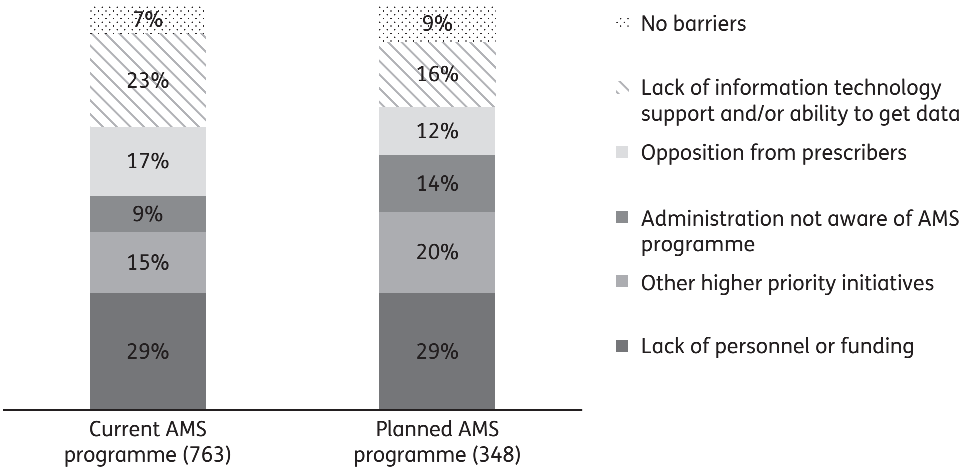
Various strategies were employed to deliver AMS (Table 4). Most hospitals throughout the world had specific guidance on the treatment of infections and on prophylaxis for surgical site infections, but there were marked differences for the authorization of restricted antibiotics—38% (5/13) in Asia compared with up to 88% in Europe (224/255). Advice by telephone was available from infectious disease or microbiology specialists but their advice was less available on ward rounds. The routine follow-up of patients with bacteraemia occurred more commonly in Oceania than the other continents. North America used Day 3 reviews, guidance on intravenous-to-oral switching, automatic stop or review policies and pharmacist pre-authorized to optimize the

Table 2. Summary of AMS standards and programmes

	Africa, *n*/*N* (%)	Asia, *n*/*N* (%)	Europe, *n*/*N* (%)	North America, *n*/*N* (%)	Oceania, *n*/*N* (%)	South and Central America, *n*/*N* (%)	Total, *n*/*N* (%)
Country AMS standards	2/10 (20)	5/12 (42)	21/26 (81)	1/5 (20)	1/2 (50)	5/12 (42)	35/67 (52)
Country AMS standards in preparation	0/10 (0)	1/12 (8)	1/26 (4)	0/5 (0)	0/2 (0)	1/12 (8)	3/67 (4)
Regional AMS standards	3/32 (9)	6/38 (16)	120/279 (43)	8/56 (14)	11/30 (37)	21/69 (30)	169/504 (34)
Hospital AMS standards	9/42 (21)	29/46 (63)	246/339 (73)	30/65 (46)	16/33 (48)	46/85 (54)	376/610 (62)
AMS programme in place	6/43 (14)	26/49 (53)	230/348 (66)	45/67 (67)	16/34 (47)	44/95 (46)	367/636 (58)
AMS programme in planning	10/43 (23)	14/49 (29)	70/348 (20)	15/67 (22)	10/34 (29)	24/95 (25)	143/636 (22)
Median duration of AMS programme (years)	1	3	5	3	2	3	3

Table 3. Average AMS programme resource hours per week, *n*=337

	Africa (*n*=12)	Asia (*n*=25)	Europe (*n*=190)	North America (*n*=49)	Oceania (*n*=14)	South and Central America (*n*=44)	Mean
Antimicrobial or infectious diseases pharmacist (*n*=320)	6	13	18	32	17	9	18
Infectious diseases doctor (*n*=284)	3	8	8	15	6	12	10
Medical microbiologist (*n*=308)	8	6	11	5	1	7	9
Infection control staff (*n*=220)	9	9	8	6	1	8	8
Nurse (*n*=199)	8	7	3	4	0	14	6
Administrative support (*n*=202)	4	6	2	6	2	7	4
Data analyst (*n*=201)	5	2	3	9	2	5	4
Other pharmacist (*n*=199)	8	3	2	7	0	9	4
Doctors in training (*n*=188)	5	3	3	5	8	4	4
Other medical specialty (*n*=199)	5	5	2	1	0	8	3
Pharmacy technician (*n*=188)	4	2	2	1	0	8	3
Scientist or laboratory staff (*n*=179)	7	3	1	2	0	7	3
Surgeon (*n*=201)	4	5	1	1	0	3	2



	Barriers to delivering a functional and effective AMS programme					
	Lack of personnel or funding, *n* (%)	Other higher priority initiatives, *n* (%)	Administration not aware of AMS programme, *n* (%)	Opposition from prescribers, *n* (%)	Lack of information technology support and/or ability to get data, *n* (%)	No barriers, *n* (%)
Current AMS programme (763)	219 (29)	118 (15)	68 (9)	128 (17)	175 (23)	55 (7)
Planned AMS programme (348)	100 (29)	69 (20)	48 (14)	43 (12)	57 (16)	31 (9)

Figure 1. Barriers to delivering a functional and effective AMS programme.

dose more often than elsewhere in the world. Care bundles (e.g. for community- or ventilator-acquired pneumonia) were quite frequently used in most hospitals across all continents except Europe and Oceania. Interventions used less often were separate antimicrobial prescriptions, the measurement of inflammatory markers such as procalcitonin to avoid starting antibiotics or facilitate stopping antibiotics earlier, restricting the access of pharmaceutical representatives and the cycling of antibiotics.

AMS rounds existed in 64% (261/408) of hospitals. Intensive care ward rounds were the most common in 74% (290/390) of hospitals and mostly occurred daily, followed by ward rounds on medical wards in 68% (248/366, mainly weekly), surgical wards in 63% (232/370, mainly weekly), paediatric wards in 43% (143/335, less than weekly) and less often emergency departments in 35% (120/345, less than weekly). The content of the antimicrobial guidelines ($n=402$) varied considerably. Most of the guidelines contained dosages (89%), alternatives for antimicrobial allergy (88%), preferred route (86%), duration of treatment (79%), guidance on intravenous-to-oral switching (70%), dosing in renal or liver impairment (60%) or diagnosis (60%). Less commonly covered were investigations (46%), guidance on directed therapy or a revision of therapy (43%), costs (24%) and dosing in obesity (23%). Some provided guidelines for antifungal (55%) and antiviral (38%) agents. Few hospitals could monitor guideline use (35%) or allow feedback direct from the guideline (38%). Most treatment guidelines were updated annually (41%) but guidance on surgical prophylaxis was most commonly updated every 2 years (38%). The antimicrobial formulary and restricted lists were usually updated annually.

Most hospitals (81%, 329/406) restricted some antimicrobials: 73% (282/384) restricted carbapenems, 64% (246/385) quinolones and 58% (223/383) cephalosporins. A post-prescription review of restricted antimicrobials by the pharmacy departments was carried out in 64% (219/340) of hospitals. A total of 31% (106/342) restricted before the first dose in all areas, 25% (87/342) restricted outside intensive care and 41% (132/319) restricted after the first dose, and only a few hospitals had no restrictions. Only 20% (102/516) had electronic prescribing for all their patients and a further 16% (80/516) had limited electronic prescribing. In the e-prescribing systems used, 51% (83/163) mandated the duration and 35% (56/160) mandated the indication. Approval for restricted antibiotics was required in 46% (72/158) of systems.

Electronic patient records existed for all or some patients in 43% (213/491). Few hospitals had full or limited automated antimicrobial dispensing (15%, 73/481) or data warehouse surveillance systems that linked prescribing to the laboratory results (17%, 78/458). Full or limited dispensing of antimicrobial agents to individual patients occurred in only 34% (163/480) of hospitals.

Table 4. AMS strategies—all or some wards (actual or planned AMS programme), $n=422$

	Asia (13) (%)	Africa (31) (%)	Europe (258) (%)	North America (54) (%)	Oceania (23) (%)	South America (43) (%)	Total (422) (%)
Treatment guidelines	85	84	98	89	96	84	94
Surgical prophylaxis guidelines	77	94	95	87	96	88	93
Approved antibiotics (formulary)	69	84	95	87	91	77	90
Reserve antibiotics needing authorization by indication	38	84	88	87	87	77	84
Infectious diseases/microbiology advice by telephone	85	84	92	81	96	84	89
Infectious diseases/microbiology advice on ward rounds	69	87	84	63	74	81	81
Systematic advice for bacteraemia by infectious diseases/microbiology	46	74	78	52	83	74	73
Dose optimization on request	92	71	80	87	96	67	80
Intravenous-to-oral switch guidance	62	65	82	91	78	67	80
Review of intravenous therapy at Day 3	62	61	78	89	61	70	76
Care bundles (e.g. ventilator)	85	90	59	76	30	72	64
Automatic stop/review policy	23	58	42	69	43	40	46
Pre-authorized pharmacy-driven dose optimization (e.g. automatic renal dose adjustments, intravenous-to-oral conversions etc.)	31	48	36	69	35	47	42
Separate antimicrobial chart or section	62	55	40	33	0	47	39
Inflammatory markers to prevent initiation of antibiotics, e.g. procalcitonin	69	65	37	22	13	51	39
Inflammatory markers to stop antibiotics early, e.g. procalcitonin	46	58	35	24	13	51	36
Restrictions on access by pharmaceutical representatives	31	45	26	56	43	40	33
Antibiotic cycling programme	23	19	14	11	4	42	17

Communication

The intranet was the most common method of communication, followed by booklets, email, posters and then newsletters. There were, however, differences across the continents, with Africa and South America preferring booklets and staff meetings rather than an intranet. There was little use of newer technologies such as smartphone applications or screensavers.

Evaluation of interventions: process and outcomes

Antimicrobial audit was undertaken in 80% (312/390) of hospitals. The most frequently undertaken audits were documentation of the indication for (66%, 228/344) and the duration of prescription (64%, 212/332) and compliance with infection care bundles (56%, 158/282), which were generally done monthly. Other audits were carried out mainly annually; these covered compliance with guidelines (74%, 253/341), audits of guidelines for surgical site infection (71%, 234/330) and aminoglycoside/glycopeptide level monitoring (51%, 163/318). Important audits undertaken less often were: time to first dose in severe sepsis (35%, 101/292), outcome of the Day 3 reviews (43%, 136/313) or cultures that were taken before antibiotics were given (41%, 121/295). Most specialties (58%, 160/278) never audited their own practice but relied on external audits. Two-thirds of respondents undertook point prevalence surveys (68%, 221/323).

Antimicrobial usage was monitored by 85% (334/391) of hospitals. Most reported expenditure (82%, 290/353), DDDs (80%, 251/315) and DDDs/occupied bed days (67%, 215/319) at hospital level but less so at specialty level [65% (206/317), 57% (180/315) and 53% (162/308), respectively]. A total of 55% (170/307) linked usage to resistance rates and 49% (146/299) linked usage to infection rates.

Of the 38% (119/317) of hospitals that formally assessed their AMS programme for return on investment or economic viability, most reported reductions in inappropriate prescribing (96%, 77/80), use of broad-spectrum antibiotics (86%, 83/96), direct expenditure (80%,70/87) and healthcare-acquired infections (71%, 47/66). A total of 65% (26/40) declared a reduction in length of stay or mortality and 58% (39/67) a reduction in antimicrobial resistance. Of the 270 hospitals that had assessed the impact of AMS ward rounds, 121 (45%) reported a reduction in antimicrobial consumption, and 41 (15%) an increase, with the largest impact on reduction in consumption being seen on surgical wards.

Education

Most hospitals (89%, 356/400) educated their healthcare staff. Overall, 96% of hospitals educated their senior and trainee doctors. Doctors most commonly received face-to-face training (trainees, 68%; and seniors, 46%) or written information (45% and 35%, respectively) at induction. Short courses were provided for trainees (31%) and seniors (27%). A small number of hospitals did not educate senior doctors (6%) or trainee doctors (2%). Fewer than 25% had mandatory updates every 1 or 2 years.

Nurses received less education; 27% received face-to-face training and/or 16% were given written information at induction, 21% undertook short courses and 15% received no specific education. Only 12% received mandatory updates.

Most pharmacists (94%) were educated, mainly at induction: 43% by face-to-face training and/or 25% by written information and 22% by short courses. Few centres (17% or fewer) used e-learning across the different staff groups.

Discussion

We present here data describing AMS practice in 660 hospitals in 67 countries across six continents. Our findings show a significant diversity and variation across the continents in relation to the organizational structures, range of interventions and impact of AMS programmes in hospitals. There were, however, some consistent approaches to AMS, especially across more developed countries.

Our survey has several limitations. First, respondents were self-selecting and there was no method of validating their data entry. Additionally, recruitment often occurred through contact sources of the authors or through their professional associations, thereby further contributing to a potential recruitment bias. Second, the interpretation of the questions and definitions used may not always have been clear or consistent between countries. For example, some may have no relevance or meaning in a local context, although help was available by email to minimize this bias. Third, there was an imbalance between the continents in terms of reporting results. The number of returns from Oceania and North America is clearly low and under-representative of significant and in some cases mature stewardship activity in these continents. Although the number of returns from Oceania and North America was low, these sorts of difference are inherent in this type of survey, especially where there is a country-wide invitation. A comparison to recently published AMS surveys from these countries demonstrated some consistencies and variation. An Australian state-wide survey of 155 hospitals undertaken in 2011[65] showed similar results for the existence of treatment guidelines but significantly lower rates for restriction and formularies. A 2009 survey of 406 USA hospitals[6] reported a lower rate of AMS programmes in place, antimicrobial restriction and guidelines for intravenous-to-oral switching but reported similar results for the type of staff delivering their AMS programmes and access to an infectious diseases specialist to review the patient. Europe accounted for more than half of the returns, and England for 15% of hospital returns. The impact of the data from England on those from Europe did not, however, cause significant changes in our results. For example, if the English data were removed from our analyses, the most important modifications would be a 7% reduction in AMS programmes in place but no difference in duration. Similarly, antimicrobial pharmacist time would decrease from 17 to 8 hours per week, and medical microbiologist input from 11 to 7 hours. We would observe a reduction in antimicrobial audit activity (from 82% to 71%) and a restriction of cephalosporins (from 66% to 46%) and to a lesser degree fluoroquinolones (from 72% to 61%). Therefore, we do not consider that the high participation of English hospitals represents a significant bias. Finally, this was a large-scale survey of institutions and we were unable to unravel or explore local circumstances, e.g. whether hospital policies had been adapted for the local setting or reflected regional or national antimicrobial resistance patterns. Prescribing will depend upon the hospital case mix and local experience with pathogens, which will be reflected in recommendations for empirical and definitive therapies. Another limitation is the proportion of respondents that completed the questionnaire to the end. Most continents achieved a 78%–83% completion rate. The outliers were Africa (89%, 39/44) and South America (59%, 61/103).

Regardless of these caveats, the study provides us with some important findings on standard approaches to AMS that are worth highlighting. While 52% of the countries had national AMS standards, there was a large variation across the continents: from 81% in Europe down to 20% in Africa and North America. There were also few countries that were planning to introduce AMS standards—mainly those in Asia. This may reflect the continental approach to antimicrobial resistance[66] and the size of the countries involved. To achieve more effective clinical engagement for stewardship in countries where national stewardship standards already exist, the recent development of national clinical stewardship standards for Australian hospitals[67] signifies possibly a mature and natural evolutionary process for the implementation of more effective stewardship in daily routine clinical care. These data suggest that there is still much to do to deliver the WHO Antimicrobial Resistance (AMR) strategy from 2001[68] and 2012[69] in which national AMS standards or guidelines are a core recommendation. As for AMS standards within hospitals, Europe again had the highest proportion, at 73%, followed by Asia and South America, whereas Africa had the lowest. This presumably reflects the relatively early stages of development of stewardship as a core activity for combating AMR within African hospitals. There is, however, evidence of emerging activity to address this in Africa through a collaborative approach with infection prevention teams[70,71] Such an approach has been commended in other systems as well.[72]

Two-thirds of the hospitals in North America and Europe had AMS programmes. This probably reflects strong and historical leadership on AMS from infectious diseases or microbiology organizations in the USA[12] and Europe.[73] The low- or middle-income countries (Africa and South America) had lower levels of AMS programmes, which may reflect the lack of infrastructure in these continents and a more recent political commitment.[74] Despite this variation, it is encouraging that stewardship programmes are being developed, and are successful, as in Vietnam,[75] or are being promoted as a key policy recommendation as in India: 'The Chennai Declaration' recommendations of 'A roadmap to tackle the challenge of antimicrobial resistance'.[76]

There has been little investigation in the literature into the barriers to the provision of AMS programmes. A review of barriers to AMS programmes,[17] an Australian study[67] and two American studies[6,50] have concurred that lack of finance is the major obstacle, and the reported drivers matched those found in our global study.[7]

Most hospitals had a drug and therapeutics committee, but it was mainly European and North American hospitals that had AMS committees. AMS policies and strategies were in place in fewer than half of all hospitals, and even fewer published an annual

AMS report. Currently, the WHO has a Strategic and Technical Advisory Group on antimicrobial resistance aiming to provide stronger leadership to improve this situation.[77] The type of staff delivering AMS activities seems to reflect the staffing within the healthcare system of that country. North America[78] and Oceania[57] primarily deliver their AMS service with specialist pharmacists and infectious disease specialist doctors whereas in Europe the delivery is mixed, mainly with pharmacists[8] and either medical microbiologists (UK and Ireland[79]) or infectious disease specialists[80] on mainland Europe. The skill mix of the stewardship team also reflects in the AMS strategies being delivered. For example, pharmacist skills are often deployed to optimize dosing, implement intravenous-to-oral switching or support post-prescription review, while infectious disease specialists are pivotal for ward rounds and diagnostic input.[81] The role of the microbiology laboratory and the medical microbiologist is fundamental to AMS, particularly through the interpretation, selective processing and reporting of culture and susceptibility results.[82–84] As laboratories move towards centralization and increasing efficiency, there is a real danger that specimens and culture results will no longer be interpreted by experts and that data will simply be reported without qualification to inexperienced clinicians, leading to overtreatment. There appears to be infrequent use of certain diagnostic or prescribing interventions that have been shown to reduce the volume of antimicrobial prescribing or improve patient outcomes, for example measurement of procalcitonin,[85] electronic prescribing with decision support or data warehousing.[16] On the other hand, AMS ward rounds were frequently used, particularly in low- or middle-income countries. Where their impact had been evaluated, there was about a 40% reduction in antimicrobial use.[86–88]

A restriction of broad-spectrum antibiotics was reported to occur routinely, often combined with a post-prescription review. The latter is generally regarded as a resource-intensive intervention but a key clinical and cost-effective intervention, particularly when linked to audit and feedback.[89] The focus on optimizing the use of certain antibiotic classes has been especially appealing, with a significant impact on resistance[16,90,91] and *C. difficile* infection rates.[92] Formal antibiotic diversity strategies were infrequently reported despite emerging evidence of their effectiveness in units with high levels of antimicrobial resistance.[93] Antibiotic cycling strategies were also infrequently reported, possibly reflecting the practical difficulties in doing this, including heavy resource use and a scarcity of evidence to support cycling as an effective means of controlling resistance.[94,95]

Audit and feedback is a core intervention in AMS. There is growing evidence that a regional or country-wide standardized approach can show sustained improvements in acute medical admission units in terms of both compliance with guidelines as well as prophylaxis for surgical site infections.[96] Outside measuring compliance with antibiotic treatment, however, or the duration and indication of treatment for inpatients or prophylaxis bundles, this approach did not frequently occur. Surprisingly, over half of all specialties never audited their own practice. This suggests that the significant impact of audit and feedback as a stewardship and educational tool is underestimated. A recent Cochrane review[16] supported its value, particularly in the context of a low baseline performance, when the source of feedback is a supervisor or colleague, when it is provided more than once, when it is delivered in both verbal and written formats, and when it includes both explicit targets and an action plan.[97] Therefore, this more focused evidence-based approach to feedback should be more widely commended. Additionally, the collection and feedback of consumption data is recommended,[12] as the engagement of prescribers is essential for antimicrobial management teams to make any impact.[98] Consumption metrics are a commonly used indicator of stewardship activity. Antimicrobial usage was monitored by most hospitals with an AMS programme as DDDs or expenditure, but fewer than half linked it to infection or resistance rates. In order to demonstrate positive outcomes of AMS programmes, there need to be improvements in the reporting of antimicrobial usage, and preferably benchmarking between similar hospitals.[99,100] Using such data for benchmarking is, however, subject to many difficulties.

While most hospitals provided AMS education, it was generally to doctors in training or to pharmacists at induction and with written materials. Nurses, however, appeared to receive little training despite their critical role in the monitoring and administration of treatment. The potential beneficial role of nurses in stewardship is underestimated.[101,102] A competency- and outcomes-based educational framework for stewardship is useful in planning such an implementation of stewardship education.[100,103] Few hospitals reported using e-learning and most did not mandate updates. Without a change in our education of prescribers and those who administer or monitor antibiotics, AMS will remain challenging.[17,102,104]

Overall, those hospitals that had carried out a formal evaluation of their AMS programme reported significant reductions in inappropriate prescribing, primarily the use of broad-spectrum agents, and a reduction in direct expenditure and healthcare-acquired infections, as well as to a lesser extent in the length of stay or mortality, and antimicrobial resistance. Respondents were not, however, asked to provide references to published reports and we acknowledge the limitations of self-reporting. These findings are nevertheless consistent with the literature[16,81,91,105,106] and argue for mandatory AMS programmes to be implemented worldwide. The model for AMS programmes and their implementation should offer flexibility to account for the local healthcare structure, geography, culture and resources, and could use published validated quality indicators.[18,105,107] The importance of measuring the impact of stewardship on outcomes has recently been emphasized with the competition for scarce financial resources, a key barrier identified in the survey.[104] We did not collect such outcome data, but large multicentre surveys exploring the relationships between different stewardship activities and outcomes (mostly antibiotic use and resistance data) are urgently needed. This could potentially facilitate prioritization from a menu of stewardship activities in resource-limited settings.

The results of this survey showed the depth of AMS across the world and the benefits that hospitals have reported from running an AMS programme. It also demonstrated that there has been some improvement in the implementation of AMS strategies compared with some of the more recent AMS surveys carried out in Europe in 2003,[10] Australia in 2012[65] and the USA in 2009,[6] 2003[52] and 1998.[108] We are unaware of published continent-wide surveys in Asia, Africa or South America[74] but one is currently being undertaken in Asia.[109] We hope that this work will inform local and international policy-makers about current stewardship activity and challenges with a view to fostering broader international collaboration as recommended by the recent WHO report on resistance.[110]

Practical impact of our findings and recommendations

Based on our findings, we would advocate: (i) an international AMS framework; (ii) international evidence-based AMS interventions/programmes; and (iii) mandatory public reporting of AMS process and outcome measures.

In summary, the development and implementation of AMS programmes varies considerably across the world. The study highlights the need to better understand current practices globally, not only in hospitals, but across all healthcare systems; this should include ambulatory care, for which such data are scarce. Our results should inform and encourage a further evaluation of this with a view to promoting a worldwide stewardship framework that is relevant to the context of the healthcare system, culturally pertinent and, above all, flexible and dynamic to meet the needs of the population. The prospective measurement of clear, well-defined outcomes of the impact of these programmes clearly remains a significant challenge if we are to persuade policy-makers and funders of the added and long-term clinical effectiveness and cost-effectiveness of these interventions aimed at combating antimicrobial resistance.

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Transparency declarations

None to declare.

Author contributions

D. N. conceived the study. P. H., C. P., G. L. H. and D. N. developed the survey. S. H. and I. M. G. provided feedback and direction. R. M. W. oversaw statistical reporting.

Supplementary data

The questionnaire is available as Supplementary data at *JAC* Online (http://jac.oxfordjournals.org/).

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