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Published in:
Journal of Hospital Infection

DOI:
10.1016/j.jhin.2021.10.012

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Journal of Hospital Infection 119 (2022) 1–8

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Factors influencing the stewardship activities of Antimicrobial Management Teams: a national cross-sectional survey

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ARTICLE INFO

Article history:
Received 6 August 2021
Accepted 19 October 2021
Available online 26 October 2021

Keywords:
Antimicrobial stewardship
Health service research
Public health
Resource allocation

SUMMARY

Background: The link between inappropriate antibiotic prescribing and the global threat of antimicrobial resistance is well documented. International strategies recommend antimicrobial stewardship (AMS) programmes, with improvement interventions to safeguard antibiotics.
Aim: This study sought to systematically evaluate the impact of multi-professional Antimicrobial Management Team (AMT) staff resource availability on stewardship activities.
Methods: We conducted an on-line, cross-sectional survey of AMTs in each regional Health Board and the national specialist hospital in Scotland ($N = 15$). Responses were analysed descriptively, exploring observed relationships between variables to identify patterns.
Findings: Results highlighted apparent variation in the levels of AMT resource availability across Scotland, not directly influenced by Health Board size, with some larger Health Boards having proportionately poorer AMT resource allocation. However, the range and frequency of activities to support AMS was not directly linked to either Health Board size or staff resource allocation, indicating a more complex inter-relationship between factors.
Conclusions: There is apparent inequity in staff resource available for AMTs across Scotland, with significantly lower resource allocation in comparison with recommendations from other international studies. However, considering these survey findings with our earlier qualitative research indicates that leadership style and team member enthusiasm may be as, if not more, influential than resource availability on the scope of AMT activities. These findings have international relevance for hospital service managers considering the recruitment, training and ongoing support of AMTs, in order to maximize impact from a limited resource.

Introduction

Increasing antimicrobial resistance (AMR) is a key public health concern and efforts to stem its rise are a priority for the global community [1]. Antimicrobial stewardship (AMS), defined as "a coherent set of actions which promote the

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https://doi.org/10.1016/j.jhin.2021.10.012

responsible use of antimicrobials" [2], is one way to reduce the emergence of resistance in a variety of settings, by focusing on rationalizing the use of antimicrobials. As a consequence, policy makers at international and national levels now recommend the implementation of AMS strategies, delivered at a local level via designated Antimicrobial Management Teams (AMTs) [1—6]. Following the Scottish Government's 'Management of Antimicrobial Resistance Action Plan' (ScotMARAP) [4] in 2008, the national framework for AMS [6] has been led by the Scottish Antimicrobial Prescribing Group (SAPG), with the recommendation that each Health Board should support and maintain an active and effective AMT. The National Health Service (NHS) in Scotland comprises 14 regional Health Boards, covering both acute and primary care services, and one national special Health Board. The scale of acute care in-hospital services varies significantly, ranging from the smallest island hospital with 38 acute care beds to the largest city-based Health Board with 3863 acute care beds.

A recently updated Cochrane review by Davey *et al.* [7] found that stewardship interventions were effective in improving compliance with antibiotic policy and reducing the duration of antibiotic treatment. However, the authors concluded that further exploration of the barriers and facilitators to AMS implementation was warranted. Similarly, the World Health Organisation (WHO) also recommend that barriers and enablers to implementation AMS programmes need to be highlighted, to identify areas for improvement [8].

Responding to these recommendations, a recent qualitative study involving AMS implementation leads and frontline practitioners ($N = 99$) used Normalization Process Theory to explore barriers and enablers affecting the implementation of a national AMS programme in Scotland [9]. Findings showed that perceived barriers to implementation included organizational context and AMT resource availability, as well as AMT leadership influence. These qualitative findings resonate with several survey-based studies conducted in Australia, France, Canada, USA and Japan, which also highlight limited AMT resource availability as a barrier to AMS implementation [10—15].

This paper aimed to explore factors that may influence the scope of AMS activities conducted by AMTs in acute care hospitals in Scotland. Specifically: (1) What, if any, is the relationship pattern between (i) the AMT staff resource availability and size of the Health Board, and (ii) overall AMT staff resource availability and the scope of AMT activities? (2) What are the key factors that influence the scope of AMT activities across Scottish Health Boards?

Methods

The study was conducted in accordance with the Declaration of Helsinki and the protocol was approved by the Ethics Committee of Glasgow Caledonian University School of Health & Life Sciences (HLS/NCH/17/051). The Research and Development Department of each NHS Health Board provided permission to access participants and the SAPG Project Lead acted as gatekeeper, circulating an on-line questionnaire to participants. Participant information was included in the link and completion of the survey taken as informed consent to participate.

A 26-item questionnaire was developed using SurveyMonkey© on-line software. The cross-sectional survey explored AMT resource allocation and focused on potential AMS activities the AMT might engage with (Supplementary Material). The survey tool was reviewed by three clinical experts in the field of AMS and minor changes made to improve comprehension. The SurveyMonkey© link was distributed via e-mail to the AMT Pharmacist in each regional Health Board, who was asked to complete the survey in consultation with the AMT Lead, during September 2018.

Data were summarized descriptively for each question, illustrating the range of AMT resources and activities across the 15 Health Boards. Due to the necessarily small number of respondents, further statistical analysis was not possible. Instead, relevant data were extracted into tables for descriptive analysis by rank ordering results within each variable. This descriptive approach enabled identification of observed patterns between variables in relation to each of the research questions, but does not lay claim to any statistical correlation or causation. Key variables of interest were: AMT leadership category (infectious disease or microbiology consultant); medical and overall AMT resource availability; size of Health Boards based on bed numbers; type of AMS activities carried out in each Health Board.

Results

All 15 Scottish Health Board AMTs responded to the survey (Supplementary Material).

Q1. What is the relationship between the AMT staff resource availability and size of the Health Board?

Scottish Government policy requires that AMTs are led by a medical consultant who is an infection specialist, usually in infectious diseases or microbiology [4]. The other mandatory AMT member is the AMT pharmacist. Each Health Board may then co-opt other staff into the core AMT, for example, AMT nurse, pharmacy technician, data analyst, infection prevention control (IPC) lead, consultants from other specialties. Table I outlines the AMT lead consultant specialism, core membership of the AMT, and the funded full-time equivalent (FTE) resource allocated to each of these roles, presented horizontally in descending rank order of the Health Board size (acute bed numbers) [16].

Medical leadership of the AMT, in terms of specialism and allocated time, varies between Health Boards, with some influence of Health Board size evident. The five largest Health Boards all have an infectious diseases consultant as AMT Lead, all have 10—20% of their work-plan time allocated for AMT related activity. The remaining 10 Health Boards generally have a microbiology consultant as AMT lead ($N = 7$), with three smaller Health Board AMTs being led by a director-level specialist. Only three of the seven microbiology consultant AMT leads have specific time allocated in their work-plan for AMT activity (10—20%); this relates somewhat to Health Board size, with the sixth, seventh and 10th largest Health Boards funding time for the microbiologist AMT lead.

The type of medical infection specialist input to the AMT also varies across Health Boards (infectious disease, microbiology, or both). The 10 largest Health Boards all have infectious disease consultant input into the AMT; the five smaller Boards may not have an infectious disease specialist in their hospital provision, although they can access specialist advice from a larger Health Board. Thirteen of the 15 Boards have

Table I
Core Antimicrobial Management Team (AMT) resource availability related to size of the Health Board (bed numbers)

Ranked Health Board size/beds	1st 3863	2nd 2054	3rd 1331	4th 1067	5th 1047	6th 952	7th 723	8th 645	9th 524	10th 355	11th 225	12th 165	13th 70	14th 43	15th 38
AMT lead	ID	ID	ID	ID	ID	Micro	Micro	DPH	Micro	Micro	Micro	Med Dir	Micro	Med Dir	Micro/ Pharm
ID input/funded	Yes 0.2 FTE	Yes 0.2 FTE	Yes 0.1 FTE	Yes 0.1 FTE	Yes 0.1 FTE	Yes Not funded	Yes Not funded	Yes Not funded	Yes Not funded	Yes Not funded	No	No	No	No	No
Micro input/funded	Yes 0.05 FTE	Yes Not funded	Yes 0.1 FTE	Yes Not funded	No	Yes 0.2 FTE	Yes 0.2 FTE	Yes Not funded	Yes 1 h/month	Yes 0.1 FTE	Yes Not funded	Yes Not funded	Yes Not funded	No	Yes Not funded
Consultant resource ranking */FTE	1st 0.25 FTE	2nd 0.2 FTE	2nd 0.2 FTE	6th 0.1 FTE	6th 0.1 FTE	2nd 0.2 FTE	2nd 0.2 FTE	10th 0 FTE	9th 0 FTE	6th 0.1 FTE	11th 0 FTE	11th 0 FTE	11th 0 FTE	15th 0 FTE	11th 0 FTE
Pharm	Yes 5.9 FTE	Yes 1.4 FTE	Yes 2.5 FTE	Yes 0.7 FTE	Yes 1.2 FTE	Yes 2.0 FTE	Yes 0.4 FTE	Yes 0.6 FTE	Yes 1.0 FTE	Yes 15 h (0.4 FTE)	Yes	Yes	Yes	Yes	Yes
Nurse	No	Yes 1 FTE	No	No	Yes 1.0 FTE	No	No	No	No	Yes 21 h (0.6 FTE)	No	No	No	No	No
IPC	No	Yes Not funded	Yes Not funded	Does not attend	Yes Not funded	Yes Not funded	No	Yes Not funded	No	Yes Not funded	Yes Not funded	Yes No additional info	Yes No additional info	No	Yes Not funded
Pharm tech	No	No	No	No	0.4 FTE	No	No	No	No	0.6 FTE	No	No	No	No	No
Data analyst	Yes 0.8 FTE	Yes 0.8 FTE	No	No	No	Yes Not funded	No	No	No	No	No	No	No	No	No
Ranking for total FTEs	1st 6.95 FTE	2nd 3.2 FTE	3rd 2.7 FTE	8th 0.8 FTE	3rd 2.7 FTE	5th 2.2 FTE	9th 0.6 FTE	9th 0.6 FTE	7th 1.0 FTE	6th 1.7 FTE	11th 0 FTE	11th 0 FTE	11th 0 FTE	11th 0 FTE	11th 0 FTE
Overall FTEs/ 1000 beds	1.79 (6th)	1.56 (7th)	2.03 (4th)	0.74 (10th)	2.58 (2nd)	2.31 (3rd)	0.83 (9th)	0.93 (8th)	1.91 (5th)	4.79 (1st)	0	0	0	0	0

DPH, Director of Public Health; FTE, full time equivalent; ID, infectious disease; IPC, infection prevention and control; Med Dir, medical director; Micro, microbiology; Pharm, pharmacy.
* Standard competition rank order technique applied.

microbiology consultant input to the AMT. Nine of the 10 largest Health Boards have both infectious disease and microbiology consultant input to the AMT; however, only two, the first and third largest Health Boards, allocate dedicated time in the work-plans of both infectious disease and microbiology consultants for AMT work. Notably, the fifth largest Health Board is one of only two Boards which does not have microbiology input to the core AMT and might be considered an outlier in this context. Overall, the type of specialist medical input to the core AMT varies across the Health Boards, appearing to relate to Health Board size, with the smaller Health Boards having more restricted specialist medical input.

The pattern of relative resource availability across Health Boards shifts, however, when the additional AMT members are taken into account. Table I also shows the allocated FTE resource for the required AMT pharmacist and other members of the AMT. The final row in Table I demonstrates the overall AMT resource as a ratio of FTEs:1000 acute beds and suggests that Health Board size is not a good predictor of overall AMT resource, with the largest Health Board ranking sixth for overall resource availability per 1000 acute beds (1.79 FTEs per 1000 beds). The addition of funded time for an AMT nurse and 0.4 FTEs pharmacy technician moves the fifth largest Health Board, previously an outlier for lower medical resource, into second position in terms of overall AMT resource allocation per 1000 beds (2.58 FTEs per 1000 beds). Most notably, the 10th largest Health Board extends its positive outlier position, having the most generous overall AMT resource allocation per 1000 beds (4.79 FTEs per 1000 beds). Therefore, Health Board size does not have a linear relationship with overall AMT resource availability.

Q2. What is the relationship between overall AMT staff resource availability and the scope of AMT activities?

Table II lists each of the 24 possible AMT activities surveyed and summarizes the number of 'regularly', 'sometimes' and 'never' responses for each activity.

All Health Boards undertake 'Audits for SAPG prescribing indicators', this being a required AMT activity, reported nationally. The majority of Health Boards (14/15) regularly provide 'junior doctor induction' training. Most other activities vary in frequency irrespective of overall allocated AMT resource, i.e. whether the response is 'regularly/sometimes/never' does not appear to relate to the amount of AMT resource available.

Conversely, a tally of the number of activities that are 'regularly' carried out within a specific Health Board (Table III), shows that the top six overall FTE resourced Health Boards do carry out the highest number of different activities (15–20 regular activities) in comparison with all other remaining Health Boards (seven to 13 regular activities), suggesting that

Table II
Antimicrobial Management Team (AMT) activity frequency

Item	AMT activities	Regularly	Sometimes	Never
1	Formal AMT work-plan in place	11		4
2	Guideline development and revisions	13	2*	
3	Providing telephone advice to prescriber	12	3*	
4	Audits for SAPG prescribing indicators	15		
5	Other local audits: antibiotic usage	10	5	
6	Other local audits: surgical prophylaxis	7	6	1
7	Other local audits: point prevalence	10	5	
8	Feedback of audit data to clinical teams/prescribers in person at the time of audit	10	4	1
9	Feedback of audit data to medical teams via written report	7	8	
10	Feedback of audit data to ward areas via written report	7	8	
11	Feedback of audit data to specific clinical teams at team meetings	4	11	
12	Feedback of audit data to clinical teams in general, e.g., grand rounds	3	11	1*
13	Review of local surveillance data on antimicrobial use	13	1*	1*
14	Review of local data on antimicrobial resistance	6	7	2*
15	Quality improvement audits	7	5	2
16	Use of technology to prompt guidelines compliance, e.g., use of electronic prescribing	3	4	8
17	Other prompts to guideline compliance, e.g., prescribing chart stickers	9	4	2
18	Junior doctor induction	14	1	
19	Junior doctor tutorials/ongoing education	10	5	
20	Senior doctor education	3#	12	
21	Nursing staff education	7	8	
22	Clinical pharmacist education	8	7	
23	Develop of local online modules for medical staff	2	5	8
24	Antimicrobial ward rounds	7	3	5

SAPG, Scottish Antimicrobial Prescribing Group.
* Reported by the five least well-resourced Health Boards.
# Reported by three of the five best resourced Health Boards only.

Table III
Total number of 'regularly' completed activities mapped to overall Antimicrobial Management Team (AMT) resource ranking and overall full-time equivalents (FTEs):1000 beds

Overall AMT resource FTE (ranking)	6.95 (1^{st})	3.2 (2^{nd})	2.7 (3^{rd})	2.7 (3^{rd})	2.2 (5^{th})	1.7 (6^{th})	1.0 (7^{th})	0.8 (8^{th})	0.6 (9^{th})	0.6 (9^{th})	0 (11^{th})	0 (11^{th})	0 (11^{th})	0 (11^{th})	0 (11^{th})
Overall FTEs: 1000 beds (ranking)	1.79 (6^{th})	1.56 (7^{th})	2.03 (4^{th})	2.58 (2^{nd})	2.31 (3^{rd})	4.79 (1^{st})	1.91 (5^{th})	0.74 (10^{th})	0.83 (9^{th})	0.93 (8^{th})	0	0	0	0	0
Total number of 'regularly' completed activities	20	17	17	17	15	16	12	8	7	13	11	12	11	13	7

the better-resourced Health Boards may regularly carry out a wider range of activities.

Methods of feedback of prescribing indicator audits is an area where there appears to be considerable variability in activity levels across different Health Boards, irrespective of resource availability. Whilst 10/15 AMTs report providing verbal feedback to prescribers at the time of audit, other forms of feedback to the wider team have higher rates of 'sometimes'/'never' responses than other activities (eight to 12 responses/15). Only one Health Board, with the second highest overall AMT resource reports regularly providing all five forms of audit feedback surveyed. The joint third highest overall resource AMTs provide only direct feedback at the time of audit. Only one Health Board, with the eighth highest overall AMT FTEs did not regularly provide any form of feedback to prescribers on their audit results.

Ten Health Boards implemented antimicrobial ward rounds (regularly = 7, sometimes = 3) but how and when these were carried out differed. The AMT staff member involved in these outreach ward rounds also varied, with some being led by the AMT pharmacist and microbiologist and others by the AMT lead.

The activity least often carried out by Health Boards was the use of technology to prompt guideline compliance, primarily due to the lack of availability of electronic prescribing systems across most Health Boards. Other prompts were used regularly in nine Health Boards and sometimes in four; these included reminder stickers, monitoring forms, specific spaces on drug prescriptions, and pharmacist annotations.

Taken together, these findings suggest that AMT resource availability does not necessarily directly influence the frequency or scope of activities carried out. Although AMTs with higher overall FTEs are more likely to report 'regularly' carrying out a broader range of activities, the best resourced AMTs also only 'sometimes' or 'never' provide the full range of audit feedback mechanisms, prompts or education for a wider staff group.

Discussion

This discussion brings together the findings of this survey and our previous qualitative study to address the final research question: 'What are the key factors that influence the scope of AMT activities across Scottish Health Boards?'. A key strength is the use of our earlier qualitative findings [9] to develop a descriptive cross-sectional survey tool, looking in detail at AMT composition, leadership and resource allocation. By looking at these factors in light of Health Board size and associated AMT activities, interesting comparisons can be made. The inclusion of all Health Boards, rather than a sample, allows a more detailed national picture to emerge. The survey is, however, limited by the self-report and possibly subjective nature of the responses. In addition, in describing observed relationship patterns, we make no claims of statistical relationship or causation.

Scottish Government policy mandates the establishment of an AMT in each regional Health Board and specifies the broad Terms of Reference for the delivery of strategic objectives [4,5]. The AMT should be led by a consultant-level infection specialist, supported by an AMT pharmacist. Since 2008, each mainland Health Board has received Scottish Government funding for a single FTE antimicrobial pharmacist to support the local AMS programme, however, the level of staff resource otherwise dedicated towards AMT work is not mandated. Each Health Board can determine whether the AMT lead has any allocated time in their work-plan specifically for AMT work and the proportion of FTE AMT pharmacist contribution and the inclusion of other funded posts, such as an AMT nurse, pharmacy technician, or data analyst, is at the discretion of each Health Board.

This approach provides flexibility for Health Boards to determine AMT composition and resource allocation depending on their own needs and priorities. Whilst it might be assumed that Boards would allocate AMT staff resource commensurate with their size and complexity, our findings show this is not the case, with variation in both specialist medical and combined all-role FTE allocations to AMTs across Health Boards, irrespective of size. This is particularly noticeable when the overall FTEs per 1000 acute bed ratio is examined.

In addressing the question, 'What, if any, is the relationship between the AMT staff resource availability and size of the Health Board', two key points are apparent. Firstly, the size of the Health Board does appear to influence the type of infection specialist who leads the AMT, with the five largest Boards appointing an infectious diseases consultant. The seven largest Health Boards also designate 10—20% of the AMT lead's time for AMT activity. The five smallest Health Boards have more restricted specialist input and no allocated time for AMT lead medical consultants, however, their relative size (38—225 beds) probably means that there is less AMT-related activity required in comparison with larger Health Boards. Standing out however, the fourth and fifth largest Health Boards (1047—1067 beds) have lower allocated medical resource, compared with the sixth and seventh largest Boards (723—952 beds), and equivalent to the 10^{th} largest Health Board (335 beds). Therefore, the fourth, fifth and 10^{th} largest Health Boards might be considered outliers to the general pattern, with two appearing less well medically resourced and one more generously resourced in relation to their size. Overall, the lack of allocated time for the consultant AMT lead and lack of dual contribution from infectious diseases and clinical microbiology in several Health Boards is of notable concern.

However, when overall resource allocation of the various AMT members is considered, Health Board size does not seem to predict the amount of resource made available per 1000 acute beds. Notably, whilst the largest Health Board does have the highest overall FTEs (6.95 FTEs), it is only the sixth ranked FTEs per 1000 beds (1.79 FTEs per 1000 beds); the fifth largest Health Board has joint third largest overall resource availability (2.7 FTEs) and the second highest FTEs per 1000 beds (2.58 FTEs: 1000 beds). Most strikingly, the 10th largest Health Board has the fifth largest resource availability (1.7 FTEs) but the first highest FTEs per 1000 beds (4.79 FTEs: 1000 beds). Thus, there is apparent inequity in both specialist medical input and overall FTE resource availability per 1000 beds for the larger-to medium-sized Health Boards. This would endorse the qualitative finding we reported previously, that AMT resource availability is problematic, with apparent disparity across Health Boards [9]. Arguably, an ideal AMT composition would include input from both infectious disease and clinical microbiology consultants (or indeed a jointly trained infection specialist), each bringing their own specialist perspectives, as well as a specialist nurse in addition to the AMT pharmacist; however, this was not common.

Previous international studies have made recommendations on AMT staffing level allocations in relation to hospital bed numbers. In a cross-sectional study to evaluate the human resources needed to implement AMS teams in France [12], it was estimated that 3.6 FTE antibiotic/ID lead supervisors/1000 acute care beds, 2.5 FTE pharmacists/1000 acute beds, and 0.6 FTE microbiologists/1000 acute beds were required; that would equate to 6.7 FTEs/1000 beds for the full AMT. A Canadian consensus development study [13] recommended one FTE physician, three FTE pharmacists and also highlighted the need for 0.5 FTE admin and 0.4 FTE analyst per 1000 acute care beds. Similarly, a survey organized by the Infectious Diseases Society of America (IDSA) task force applied logistical regression modelling to investigate the relationship between AMT resource level and self-reported effectiveness, recommending 1.0 FTE physicians and 3.0 FTE pharmacists/1000 beds [14]. Furthermore, a recent Japanese nationwide survey on implementing AMS programmes and staff FTEs at 1358 healthcare facilities found that pharmacist and physician FTEs were significantly associated with the implementation of AMS programmes; they recommended 0.8 FTE physicians and 1.6 FTE pharmacists for >500 beds [15]. Comparing these internationally drawn recommendations, it is clear that the average Scottish allocation of 1.95 FTEs/1000 beds is significantly lower than that recommended elsewhere.

Interestingly, despite obvious inequity in AMT resource allocation in relation to Health Board size, our survey results indicate little relationship between AMT resource availability and the scope of AMT activities. Almost all Health Boards carry out the required AMT activities of audits for SAPG prescribing indicators and junior doctor induction. The frequency of each of the other individual activity varies irrespective of Health Board size or AMT resource, with the larger-medium-sized and better-medium-resourced Health Boards also contributing to 'sometimes' and 'never' responses for some activities.

However, given that Davey *et al.'s* Cochrane Review [7] of the effectiveness of AMS interventions highlights the value of feedback, as does Doernberg *et al.'s* [14] study, the wide variation in the mode and frequency of feedback of prescribing indicator audits in our findings is of concern. Whilst providing direct feedback at the point of audit is good practice, failing to share audit data with the wider team limits opportunities for learning and improvement through behaviour change. Only three Health Boards, one the highest FTE: 1000 bed ratio (4.79 FTEs: 1000 beds, 1.7 FTEs overall), the other the two the largest in size but ranked sixth and seventh in terms of FTE resource: 1000 beds, reported using at least four different forms of feedback provision.

Whilst the top six highest FTE resourced AMTs do 'regularly' carry out the highest number of different activities, this is not a linear relationship, with some of the smallest Health Boards/poorest resourced AMTs reporting 'regularly' conducting the same or higher number of activities than several larger and better resourced Health Boards. Therefore, factors influencing the scope and frequency of AMT activities are complex and can not be simply explained by AMT resource availability alone. Reflection on the findings of our qualitative work [9], the theme 'people matter' is relevant here, where the enthusiasm of individual AMT members and the leadership style of the AMT leads who engage in more 'outreach' type work, using personal relationships to influence prescribers, was reported to impact the implementation of stewardship (Supplementary Material). This suggestion is endorsed in the literature review reported by Steinmann *et al.*, who found that an empowering AMT leadership style may lead to higher engagement of physicians, allowing them to overcome reported barriers of AMS implementation [17]. Both these studies echo the guidelines from the Society for Healthcare Epidemiology of America, describing the key knowledge and skills required for AMS professionals, including skills focused on leadership [18].

In addressing our final research question, 'What are the key factors that influence the scope of AMT activities across Scottish Health Boards', our earlier qualitative work [9] indicated that organizational context (Health Board size and complexity) and resources constraints (FTE staffing levels of AMTs) were key barriers to the implementation of AMS. The ability of AMT members to engage in 'outreach'-type work such as AMS ward rounds, providing education to nurses, or delivering a broader range of timely feedback of prescribing data audits was highlighted as being resource dependent. This survey partially endorses these views, highlighting the inequity of AMT resource allocation in relation to Health Board size. However, analysis of the relationship between resource availability and the range of activities carried out by AMTs suggests that there is no linear pattern, with some less-well-resourced AMTs reporting regularly carrying out a wider range of activities than AMTs in other, better-resourced Health Boards. This finding is perhaps counter-intuitive and may reflect the dedication, specific skills and enthusiasm of those individuals within the AMT, rather than the FTEs available.

These findings require caution in interpretation, as the activities surveyed here do not necessarily reflect impact or effectiveness in improving antimicrobial prescribing in hospitals; analysis of prescribing data would also be required to evaluate effectiveness; currently, there is no mechanism for longitudinal evaluation of the quality of prescribing within hospitals and more sensitive indicators are required.

In conclusion, comparing the allocated AMT resource per hospital bed numbers in NHS Scotland with that recommended internationally, Scotland appears to be less favourably resourced. Our findings indicate that Health Board size, for large-to medium-sized Boards, is not a reliable predictor of the

likely allocated AMT resource. We recommend that further work to model the optimum ratio of AMT FTEs: 1000 acute bed numbers be undertaken in the Scottish context, to further counter the potential barrier to AMS presented by resource limitations.

Despite apparent inequity in resource allocation, some AMTs with objectively lower resource regularly undertake a wider range of AMT-related activities in comparison with some better resourced Health Boards. This points to other factors being at play. Our qualitative findings suggest that the leadership style of the AMT and enthusiasm and commitment of other team members is influential. We recommend that AMTs are made aware of good practices adopted by colleagues and that additional leadership training is considered by AMTs.

Finally, further work to evaluate the specific activities undertaken by AMT pharmacists, AMT nurses and pharmacy technicians is required, to explore more innovative ways of using the varied skill-mix in the AMT. Capitalizing on staff who can make different contributions, whilst potentially at a lower cost than an AMT pharmacist, may be an effective way to expand services.

Acknowledgements

The authors would like to acknowledge the ongoing advisory role of Health Protection Scotland and the Scottish Antimicrobial Prescribing Group which is part of Healthcare Improvement Scotland.

Author contributions

K.C. and V.N. are PhD qualified academic researchers working within the 'Safeguarding Health through Infection Prevention' research group at Glasgow Caledonian University. J.S., R.A.S. and W. Malcolm are senior clinical advisors to the project, working in NHS Scotland organisations leading on antimicrobial policy development via the Scottish Antimicrobial Prescribing Group. V.N. made a substantial contribution to design of the work; acquisition and analysis of data, drafting the work, and approved the submitted version. J.S. provided clinical advice on the background to the study; design of the work; acted as a gatekeeper to facilitate participant recruitment; contributed to the drafting of the work; and approved the submitted version. R.A.S. provided clinical advice on the background to the study; design of the work; contributed to the drafting of the work; and approved the submitted version. W.M. provided clinical advice on the background to the study and approved the submitted version. K.C. led the conception and design of the work; analysis, and interpretation of data; drafting the work, preparing the final manuscript, and approved the submitted version. Conceptualization: K.C. and V.N.; methodology, V.N., K.C., J.S., R.A.S.; validation, K.C., V.N., J.S., R.A.S.; formal analysis, V.N., K.C.; investigation, V.N., K.C.; resources, K.C.; data curation V.N., K.C.; writing – original draft preparation V.N., K.C., J.S.; writing – review and editing V.N., K.C., J.S.; supervision, K.C.; project administration, V.N., K.C.; funding acquisition, K.C. All authors have read and agreed on the published version of the manuscript.

Conflict of interest statement

The authors declare no conflicts of interest. The Clinical Lead from the funding body (W.M.) was involved in advising on background information, the clinical context of the findings, and commenting on drafts of the manuscript.

Funding sources

This study was funded by Health Protection Scotland, in order to generate evidence for policy development. The Clinical Lead from the funding body (W.M.) was involved in advising on background information, interpreting the clinical context of the findings, and commenting on drafts of the manuscript.

Appendix A: Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2021.10.012.

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