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The impact of antimicrobial stewardship ward rounds on antimicrobial use and predictors of advice, uptake, and outcomes

David W. Eyre [a,b,c,d,*,1], Gemma Pill [a,1], Bee Yean Ng [a], Caroline Herin [a], Bernadette O'Riordan [a], Douglas Izzard [a], Louise Dunsmure [a], Stephane Paulus [a], Katie Jeffery [a,e,2], Nicola Jones [a,2]

[a] Oxford University Hospitals NHS Foundation Trust, Oxford, UK
[b] Big Data Institute, Nuffield Department of Population Health, University of Oxford, Oxford, UK
[c] National Institute for Health Research Oxford Biomedical Research Centre, University of Oxford, Oxford, UK
[d] National Institute for Health Research Health Protection Research Unit in Antimicrobial Resistance and Healthcare-associated Infection, University of Oxford, Oxford, UK
[e] Radcliffe Department of Medicine, University of Oxford, Oxford, UK

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SUMMARY

Objective: To identify the impact of introducing antimicrobial stewardship (AMS) ward rounds.
Methods: We used an interrupted time-series approach to investigate the impact of implementing AMS ward rounds with in-person feedback from a multidisciplinary team in Hospital-1, also comparing to Hospital-2 in the same city where AMS ward rounds were not yet implemented. Regression models were used to identify predictors of advice given and of whether advice was followed, and associations between advice uptake and length of stay.
Results: Introducing AMS ward rounds was followed by new or accelerated declines in ceftriaxone, ciprofloxacin, amoxicillin-clavulanate, meropenem and piperacillin-tazobactam use at Hospital-1. Except for ceftriaxone, similar declines were not seen at Hospital-2. Half of reviews (3471/6878; 50%) recommended an intervention; 2003/2726 (73%) subsequently evaluated recommendations were implemented. Senior doctors were more likely than pharmacists or specialist doctors in training to recommend de-escalation/stopping antibiotics and to have their advice followed. The more prior AMS reviews completed, the more likely advice was to be followed. Following advice to de-escalate/stop antimicrobials was associated with a 0.58 day [95%CI 0.22–0.94] reduction in hospital stay.
Conclusions: Multidisciplinary AMS ward rounds reduced antibiotic use and likely reduced length of hospital stay. Senior clinician input and more AMS experience increased advice uptake.

Introduction

Antimicrobial resistance (AMR) is a major cause of mortality and morbidity globally. It is a growing and urgent problem[1] driven largely by use and overuse of antimicrobials in both humans and animals.[2] In response, in healthcare settings, antimicrobial stewardship (AMS) programmes have been developed to reduce and prioritise antimicrobial use. AMS aims to minimise the emergence/spread of AMR and reduce antimicrobial toxicity while also ensuring optimal treatment outcomes.[3] AMS programmes typically include a range of activities to improve the selection of antimicrobial agents, dose, duration, and route, additionally avoiding antimicrobial use where possible.

Some AMS programmes reduce antimicrobial use via restrictions or requirements for pre-authorisation. Another approach is the use of AMS ward rounds, reviewing all/selected antimicrobials, with in-person feedback from a multi-disciplinary team to the home team caring for each patient.[4,5] Uptake of advice given by this approach is relatively high, e.g. 70–80%,[6,7] with reductions in overall antibiotic use and specific agents in before-and-after and interrupted time-series studies[4,5,7,8] and improvements in the appropriateness of antibiotic use.[6] Systematic reviews of stewardship programmes in general show these can reduce antimicrobial use and decrease AMR-associated infections while avoiding increasing infection rates or mortality.[9]

* Correspondence to: Big Data Institute, Nuffield Department of Population Health, University of Oxford, Oxford OX3 7LF, UK.
E-mail address: david.eyre@bdi.ox.ac.uk (D.W. Eyre).
[1] Contributed equally.
[2] Contributed equally.

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However, only some AMS advice is followed. Qualitative studies of barriers to advice uptake have highlighted competing hierarchical influences between AMS and home clinical teams, challenges to clinical autonomy, tensions between evidence- and experienced-based learning and lack of continuity of care.[10–12] Successful AMS interactions may be underpinned by securing engagement across an organisation, relationship-building, and establishing a track record,[13] with electronic records supporting real-time decision-making.[14]

A potential criticism of many AMS intervention studies is the use of a before-and-after design without a contemporaneous comparator. Here we compare the impact of implementing AMS ward rounds in one hospital, while data from a second hospital in the same city and hospital group where AMS ward rounds were not yet implemented provides a comparison. We study predictors of the nature of the advice given and of the uptake of the advice. This has the potential to provide insights into how AMS ward rounds are acting and how they might be best implemented. We also assess the impact of AMS advice on mortality and subsequent length of stay.

Methods

Setting

We used data from Oxford University Hospitals NHS Foundation Trust (OUH), 4 teaching hospitals in Oxfordshire UK, collectively containing 1100 beds serving ~1% of the UK population and providing specialist regional referral services: Hospital-1 (oncology, haematology, renal, transplant and cancer surgery), Hospital-2 (acute/emergency medicine and surgery, paediatrics, obstetrics and gynaecology, neurology, specialist surgery, trauma, intensive care), Hospital-3 (district hospital), and Hospital-4 (an orthopaedic hospital, not studied further here).

The impact of AMS ward rounds was assessed and compared between Hospital-1, where AMS ward rounds were introduced, and Hospital-2, where AMS ward rounds were not yet introduced. Factors that influenced the nature of the AMS advice given and its uptake were analysed using data from Hospitals 1–3 after the introduction of the AMS intervention at each site (Table 1).

From 01 September 2021, weekly AMS ward rounds were held at Hospital-1, led by a multidisciplinary team including a senior infectious diseases doctor (a consultant with ≥9 years post-qualification experience), a specialist doctor in training (infectious diseases fellow/registrar, 4–8 years post-qualification experience), a specialist antimicrobial pharmacist, and AMS specialist nurse/advanced clinical practitioner (ACP). At Hospital-2 similar AMS ward rounds were rolled out gradually from 01 February 2023 in adult patients (≥16 y) but were not in place before this, except in neonatology and paediatrics where ward rounds led by specialist paediatric infection clinicians and pharmacists were already implemented. At Hospital-3 AMS ward rounds, led by a specialist AMS pharmacist and/or ACP, were conducted intermittently between 09 December 2021 to 30 November 2022 (data available from 01 January 2022), and consistently from 01 December 2022 onwards (Fig. S1).

All hospital inpatients with a current prescription for intravenous amoxicillin-clavulanate, piperacillin-tazobactam, ceftriaxone, ciprofloxacin (oral or intravenous), ertapenem, or meropenem were reviewed with ≥1 member of the team caring for each patient in a face-to-face meeting on each hospital ward. These AMS ward rounds were additional to regular ward rounds conducted by each clinical team. The target antibiotics were chosen based on frequency of use (Fig. S2) and their broad-spectrum activity. Reviews were based on clinical narratives from each patient's team, and an electronic review including the medical notes, drug charts, microbiology results, laboratory tests, and imaging results. In patients identified for review, prescriptions for other antimicrobials were also reviewed.

Other organisation-wide AMS initiatives in place at all 3 hospitals throughout the period studied included widely-used electronic antimicrobial guidelines available online and in a smartphone app, and integration of AMS into hospital education programmes. There was no requirement for pre-authorisation of any of the antibiotics studied. At all hospitals, there was an established microbiology and infectious disease consult service, available 24 h and 7 days a week, providing reviews on request, input at multidisciplinary speciality meetings, and routinely reviewing patients in person with positive blood cultures and other significant microbiology results.

Ethics

Deidentified individual patient records containing data on hospital admissions, antimicrobial use, and stewardship advice and uptake were obtained from Infections in Oxfordshire Research Database, which has approvals from the National Research Ethics Service South Central-Oxford C Research Ethics Committee (19/SC/0403), Health Research Authority and Confidentiality Advisory Group (19/CAG/0144) as a deidentified database without individual consent.

Analyses: impact of AMS ward rounds on antimicrobial use

Data from patients ≥16 years old from 01 January 2017 to 31 August 2021 were used to define initial levels of antibiotic use and trends before the introduction of AMS ward rounds, including changes arising during the COVID-19 pandemic. From 01 September 2021 to 31 December 2022, data from Hospital-1 where AMS ward rounds were introduced were compared to data from Hospital-2 where AMS ward rounds were not yet introduced using an interrupted time-series approach (see Supplement). Data from Hospital-3 was not included due to gaps in the implementation of AMS ward rounds.

For each drug, antibiotic use was summarised as total days of therapy, i.e. the sum of unique calendar days between the first and last dose received within each prescription.[15] Additionally, total use of any antibiotic was reported as the number of unique days that each patient received ≥1 dose(s) of an antibiotic, with each day only counted once regardless of the number of agents received (often referred to as length of treatment[15]). Total person time in hospital, was used as a denominator, i.e. the sum, over all patients (inpatients and day cases), of the time spent admitted to hospital from the date-time of admission to the date-time of discharge.[16]

Analyses: AMS advice given and uptake

We used all available data after implementation of AMS ward rounds, including from patients < 16 years old and from Hospitals 1–3 to investigate what AMS advice was given, and how this varied by the specialist leading the ward round, the drug reviewed, the indication for the drug, and the speciality caring for the patient. We used multivariable multinomial regression to identify predictors of advice to de-escalate/stop, escalate/start, or take other action, compared to recommending continuing current treatment. We also investigated rates of advice uptake and modelled predictors of uptake using multivariable logistic regression. We fitted regression models to investigate how 30-day mortality and subsequent length of stay varied according to whether advice was followed or not (see Supplement).

Table 1
Summary of hospital characteristics and interventions.

	Hospital 1	Hospital 2	Hospital 3
Specialities	Oncology, Haematology, Renal, Transplant surgery, Cancer surgery	Acute medicine, Emergency department, Acute surgery, Paediatrics, Obstetrics and gynaecology, Neurology, Specialist surgery, Trauma, Intensive care	District hospital: Acute medicine, Emergency department, Paediatrics
AMS ward round introduction	01-September-2021 onwards	Gradual roll-out from 01-February-2023 in adult patients (≥16 y). Paediatrics: 01-September-2021 onwards	Conducted intermittently 09-December-2021 to 30-November-2022. Consistently from 01-December-2022 onwards
AMS ward round team	Multidisciplinary team: senior infectious diseases doctor, a specialist doctor in training, a specialist antimicrobial pharmacist and AMS specialist nurse/advanced clinical practitioner	Multidisciplinary team: senior infectious diseases doctor, a specialist doctor in training, a specialist antimicrobial pharmacist and AMS specialist nurse/advanced clinical practitioner	A specialist antimicrobial pharmacist and AMS specialist nurse/advanced clinical practitioner
Included in time series analysis, 2017-2022	Yes (intervention hospital)	Yes, adult patients only (comparator hospital)	No (intermittent implementation of AMS ward rounds)
Included in analysis of predictors of advice and uptake, 2022-2024	Yes	Yes	Yes
Inpatient beds	~180	~750	~170
Total person time in hospital, days, 2017-2022	359,509	1,436,781	258,874
Length of stay in days: ordinary admissions, median (IQR)	1.9 (0.5–5.3)	1.1 (0.3–3.1)	0.6 (0.2–2.8)
Length of stay in hours: day case admissions, median (IQR)	3.0 (1.0–6.2)	3.1 (1.9–6.1)	2.9 (2.0–5.8)

Inpatient bed numbers are approximate as numbers of available beds varied during the study and depending on demand. Data were not available on bed occupancy, but this approached 100% of open beds throughout the study. Planned day case admissions are recorded as day case admissions, while planned admissions expected to last overnight and day/overnight emergency admissions are recorded as ordinary admissions.

Results

Impact of AMS ward rounds on antimicrobial use

Between 01 January 2017 and 31 December 2022, there were 163,652; 470,301; and 90,315 admissions of patients ≥16 years old to Hospitals 1–3 respectively involving 71,415; 236,049; and 50,324 patients. Median (IQR) patient ages were 63 (50–72), 55 (35–72), 61 (45–75) years, and 56%, 42%, and 46% were male.

At Hospital-1 rates of use of any antibiotic were 56.1/100 days of person time in hospital (201,526 days of therapy, 359,509 days), with lower rates at Hospital-3, 45.3/100 days (117,323/258,874) and Hospital-2, 44.2/100 days (635,338/1,436,781). The most frequently used antimicrobials were amoxicillin-clavulanate, ceftriaxone, metronidazole, and piperacillin-tazobactam (aciclovir, antifungal agents and co-trimoxazole were common as prophylaxis in the cancer centre at Hospital-1) (Fig. S2).

Compared to earlier use of antibiotics at Hospital-1, following introduction of predominantly senior doctor-led AMS ward rounds from 01 September 2021, there was an acceleration in declines in the use of ceftriaxone (post-intervention change in incidence rate ratio per year, IRR=0.68 [95%CI 0.62–0.75]) and ciprofloxacin (IRR=0.74 [0.68–0.81]), and new declines in amoxicillin-clavulanate (IRR=0.72 [0.70–0.74]), meropenem (IRR=0.78 [0.72–0.85]) and piperacillin-tazobactam (IRR=0.80 [0.76–0.85]) use (Fig. 1, Fig. 2, Fig. S3). In contrast, at Hospital-2 where stewardship ward rounds were not introduced, rates of ciprofloxacin (IRR=1.11 [1.05–1.17]) and meropenem (IRR=1.20 [1.11–1.29]) use increased compared to the underlying trend (leading to the previous downward trend being attenuated). Additionally, reductions in piperacillin-tazobactam (IRR=0.90 [0.86–0.95]) and amoxicillin-clavulanate (IRR=0.86 [0.85–0.87]) use were less marked at Hospital-2 than seen over the same time period at Hospital-1, while reductions in ceftriaxone use were similar (IRR=0.64 [0.62–0.66]).

Overall antibiotic use fell at Hospital-1 compared to the underlying trend (IRR=0.94 [0.93–0.96]) and at Hospital-2 (IRR=0.95 [0.94–0.96]). Within this overall reduction, there was some evidence that use of some antibiotics other than those targeted increased at Hospital-1 compared to Hospital-2, including antibiotics that might have been plausible substitutes for those targeted such as amoxicillin, co-trimoxazole, and nitrofurantoin (Fig. S4, Fig. S5).

AMS ward round activity and recommendations

Between 01 January 2022 and 30 April 2024, 6878 AMS reviews were documented across Hospitals 1–3 while a detailed database of advice given and uptake of the advice was kept by the AMS team.

The most common specialties interacted with during AMS ward rounds were neonatology and paediatrics, haematology, acute medicine, urology and general surgery (Fig. 3A). Piperacillin-tazobactam and amoxicillin-clavulanate accounted for half of all reviews, followed by ceftriaxone, meropenem, and ciprofloxacin (Fig. 3B). Indications for antimicrobial use documented by the original prescriber were most commonly non-specific, e.g. “sepsis”, “infection”, followed by neutropenic sepsis, respiratory, intra-abdominal and urinary tract infections (Fig. 3C). Most AMS reviews were consultant-led (4761; 69%), with 9% (609) led by a pharmacist, 7% (486) by a registrar (the AMS lead was not recorded for 1022 reviews when the database was first set up; 15%). The number of AMS reviews by each consultant ranged from < 20 to 1524 (Fig. 3D, Fig. S6).

Half of the reviews (3471/6878, 50%) recommended an intervention, with continuing current treatment supported in the remainder. The most common interventions suggested were stopping antibiotics (995, 14%), switching from iv to oral antibiotics (717, 10%), requesting further samples/additional investigations (414, 6%), stipulating/changing a duration (322, 5%), and other therapy de-escalations (272, 4%) (Fig. 4A).

Predictors of recommended AMS actions

We summarised the AMS actions recommended into 4 groups: continue current treatment (3407/6878, 50%), de-escalate/stop/iv to

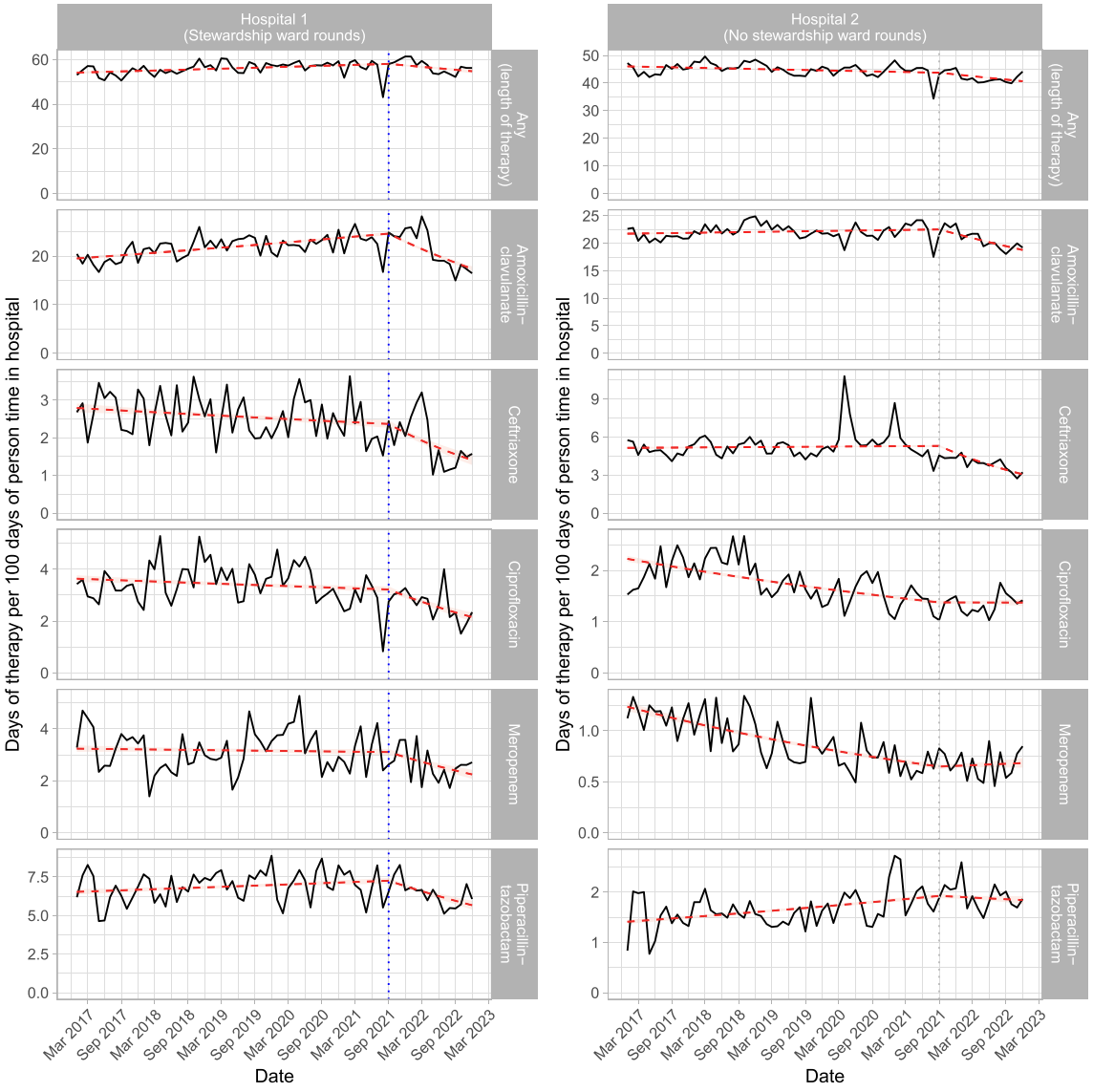

Fig. 1. Monthly rates of antibiotic use for targeted antibiotics in patients ≥16 years before and after introduction of regular AMS ward rounds, by hospital and antibiotic. Regular AMS ward rounds were conducted at the Hospital-1 from 01 September 2021 onwards (dotted blue vertical line). Data from Hospital-2 where there were no regular AMS wards are shown for comparison (dotted grey vertical line indicates the date AMS ward rounds were introduced in Hospital-1). Incidence rate ratios before and after 01 September 2021 are shown as dashed red lines, with the shaded area showing 95% confidence intervals. Findings were similar when allowing for a step-change when AMS ward rounds were introduced (Fig. S3). See Fig. S4 for non-targeted antibiotics. Across all hospitals, 661,636/1,454,034 (46%) of individual antibiotic therapy days were accounted for by the targeted antibiotics. Data presented include intravenous and oral prescriptions for ciprofloxacin and amoxicillin-clavulanate. The any group presented refers to all antibiotics, both those targeted by AMS ward rounds, and those not, and is shown as length of therapy, i.e. each day with receipt of ≥1 antibiotic is counted once regardless of the number of different antibiotic agents received.

oral switch (de-escalate, 1984, 29%), start/escalate (escalate, 148, 2%), and other (1339, 19%). We assessed how likely recommendations to de-escalate, escalate, and to undertake other actions were compared to recommending continuing current treatment (Fig. 5). Adjusting for all other variables, compared to consultant-led reviews, pharmacist-led and registrar-led ward rounds were less like to recommend de-escalation (adjusted odds ratio, aOR vs continuing, 0.36 [95%CI 0.26–0.50] and 0.78 [0.61–0.99]), and registrar-led reviews were also less likely to recommend escalation (0.26 [0.08–0.84]). Recommendations also differed by the individual clinician leading the AMS ward round (Fig. S7).

Compared to amoxicillin-clavulanate, ceftriaxone was more likely to be de-escalated, as were several drugs not initially targeted, but reviewed if co-prescribed with a target antibiotic, including clindamycin, metronidazole, vancomycin, and antivirals; ertapenem was less likely to be de-escalated potentially reflecting this was usually given after infection specialist advice. Broader spectrum drugs were less likely to be escalated, including meropenem and ciprofloxacin.

Treatment of urinary tract infection was more likely to be de-escalated than respiratory infection, while most other infections were less likely to be de-escalated. Compared to acute adult medicine, reviews of paediatric/neonatal/paediatric surgical patients were less likely to recommend de-escalation, as were reviews in several adult specialities.

Predictors of uptake of AMS advice

2726/3471 (79%) reviews leading to a recommended intervention had a note review conducted 24 h later by the AMS team (there was insufficient available AMS team time to review uptake of the remaining recommendations). Of recommendations reviewed, 2003

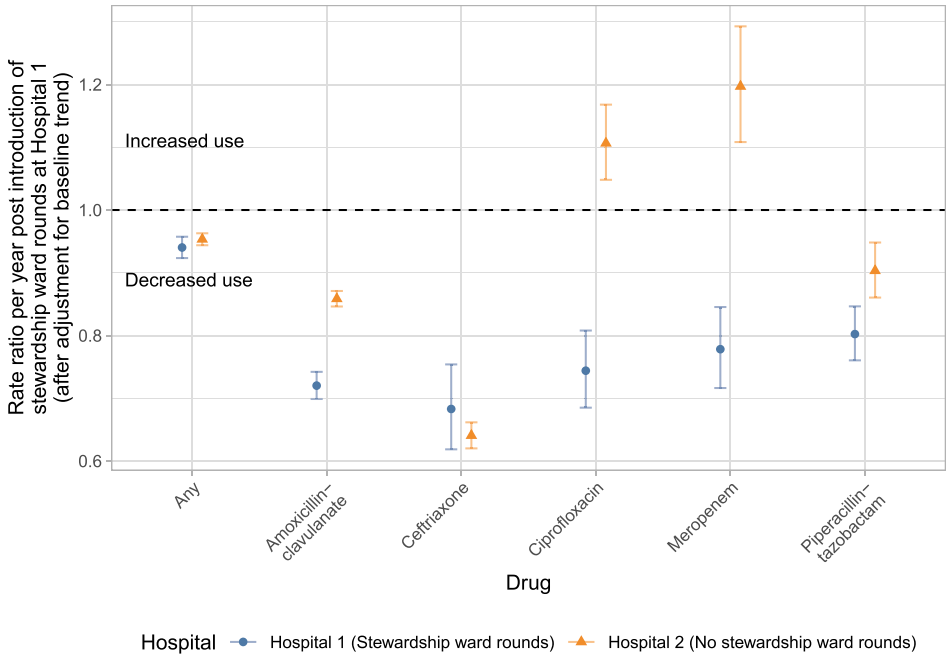

Fig. 2. Changes in antibiotic use for targeted antibiotics in patients ≥16 years after introduction of regular AMS ward rounds, by drug and hospital, after adjusting for underlying trend. Regular AMS ward rounds were conducted at Hospital-1 from 01 September 2021 onwards. Data from Hospital-2 where there were no regular AMS wards are shown for comparison. See Fig. S5 for non-targeted antibiotics. Error bars indicate 95% confidence intervals.

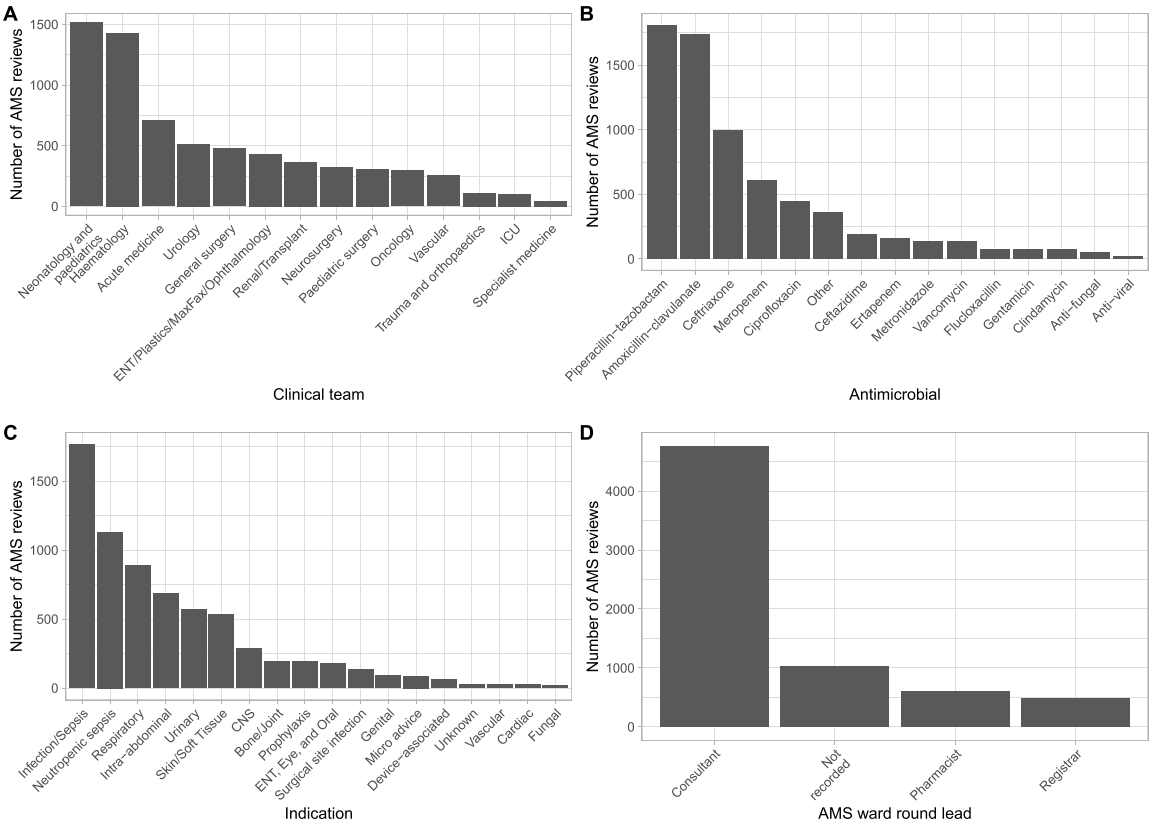

Fig. 3. AMS activity, by clinical team (panel A), antimicrobial (panel B), antimicrobial indication (panel C), and AMS ward round lead (panel D). Data are shown for 01 January 2022 to 30 April 2024 for all hospitals. See Fig. S6 for details by individual senior doctor (consultant).

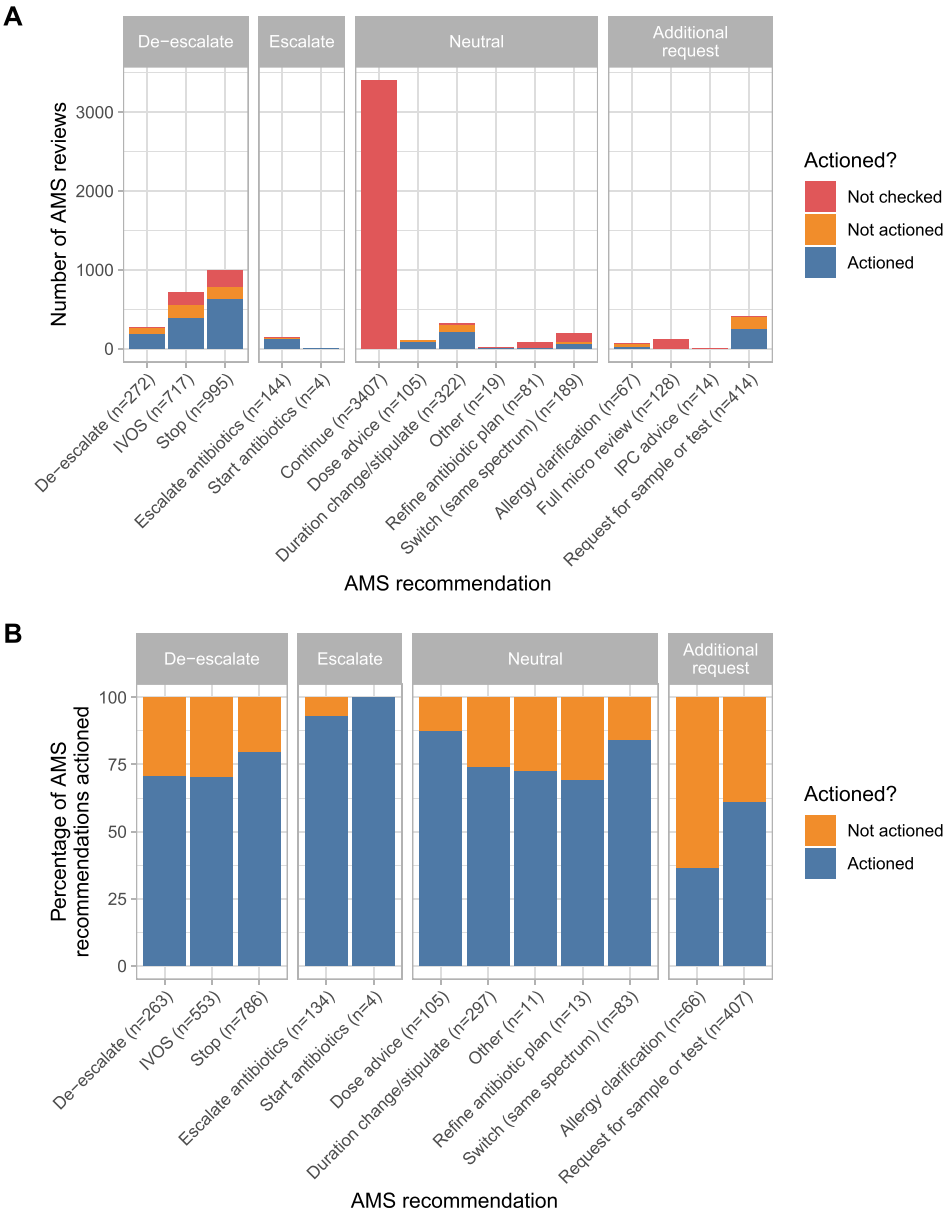

Fig. 4. AMS ward round recommendations and advice uptake rates. Panel A shows the number of AMS reviews resulting in each recommendation, by whether the advice was actioned or not actioned by 24 h later, or whether this not checked by the AMS team. The latter could arise because there was insufficient available AMS team time to review uptake of all recommendations, and after a recommendation to continue current treatment uptake of advice was not reviewed. Amongst AMS advice that was reviewed, panel B shows the proportion of recommendations actioned. Data are shown for 01 January 2022 to 30 April 2024 for all hospitals. IPC, infection prevention and control; IVOS, intravenous to oral switch.

(73%) were implemented. The most likely recommendations to be implemented were escalating or starting antibiotics (129/138, 93%), changes to doses (92/105, 88%), switching antibiotics but with a similar spectrum of activity (70/83, 84%) and stopping antibiotics (626/786, 80%). Advice which required more time-consuming action by the home team was less likely to be implemented, including clarification of allergies (24/66, 36%) and requests for additional samples or investigations (248/407, 61%) (Fig. 4B).

After considering potential predictors of uptake of advice, including the speciality caring for the patient, the antimicrobial reviewed, the indication for the antimicrobial, the recommended intervention, and the AMS lead, the best fitting model included only the proposed action and the AMS lead. Independently of nature of the recommendation made, reviews led by pharmacists or registrars/fellows were less likely to be implemented than consultant-led reviews (aOR=0.57 [95%CI 0.43–0.77] and 0.60 [0.44–0.82], respectively). Compared to recommendations to stop antibiotics, recommendations to escalate or start antibiotics were more likely to be followed (aOR=3.47 [1.73–6.99]) and there was marginal evidence that dose changes were more likely to be implemented (aOR=1.83 [0.99–3.36]). In contrast, recommendations to clarify allergies, de-escalate antibiotics, change or stipulate duration, switch from intravenous to oral antibiotics and request a further sample or investigation were all less likely to be followed (Table 2).

When we refitted the final multivariable model, adding an anonymised consultant identifier as an additional variable, there was no consistent relationship between years of consultant experience and advice being followed (Fig. 6A). In an alternative model, after adjustment for advice given, the greater the number of AMS reviews completed by a consultant prior to each review the more likely advice was to be followed (aOR=1.13 per 100 reviews [95%CI 1.05–1.22]) (Fig. 6B).

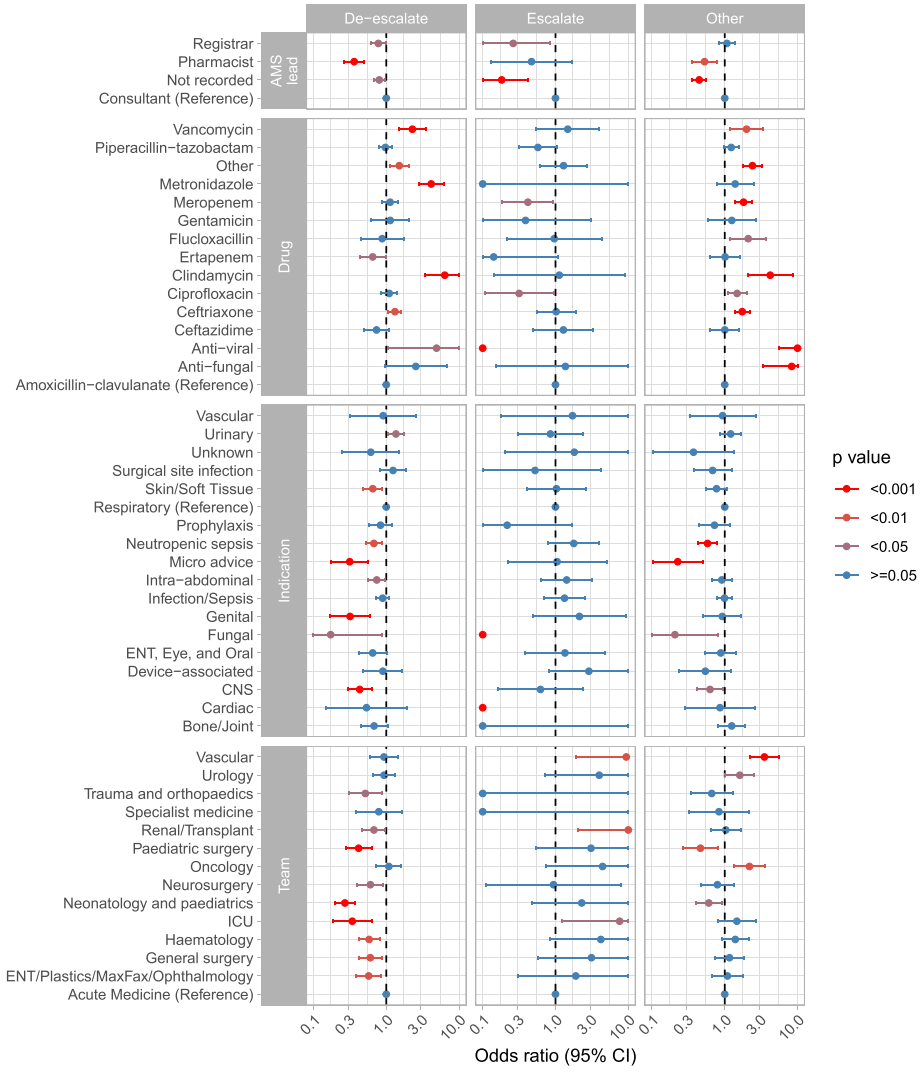

Fig. 5. Predictors of advice to de-escalate, escalate and other recommended actions compared to continuing current treatment. Odds ratios from a multivariable multinomial regression are shown, values < 0.1 and > 10 are truncated to aid visualisation. Hospital site is not included in the model due to collinearity with the specialties based at each hospital. See Fig. S7 for details by individual senior doctor (consultant). CI, confidence interval.

Impact of AMS advice on patient outcomes

816 instances of advice to de-escalate antibiotics had a documented review of advice uptake. Fifteen patients where identifiers in the AMS database could not be matched to the remainder of the electronic data were excluded. AMS advice was followed in 70% (563/801). 30-day all-cause mortality was 8% (45/563) where advice was followed and 8% (18/238) where it was not. Adjusting for age, sex, and specialty (as a proxy for the underlying diagnosis), there was no evidence that 30-day all-cause mortality varied by advice uptake (aOR=1.01 [95%CI 0.55–1.85]; Table S2). However, confidence intervals were wide reflecting insufficient power to exclude important effects in either direction.

There were 1535 AMS reviews with advice to de-escalate or stop antibiotics, an available review of advice uptake, and where patients were current inpatients. Of these, 12 were excluded that could not be matched to other hospital data. Advice was actioned after 1138/1523 (75%) reviews. Median (IQR) length of stay was 1.85 (0.68–4.72) days where advice was followed and 2.64 (1.10–5.85) where it was not. Adjusting for age, sex, and speciality, if AMS advice was followed patients had a shorter subsequent length of stay than if the advice was not followed (median 0.58 days shorter [95%CI 0.22–0.94]; Table S3).

Discussion

In a large UK teaching hospital setting, the introduction of weekly AMS ward rounds reduced use of target antibiotics when compared to a local comparator hospital where AMS ward rounds were not yet implemented. Reductions in use were seen across the main antibiotics targeted including amoxicillin-clavulanate, ceftriaxone, ciprofloxacin, piperacillin-tazobactam, and meropenem. Our experience adds to existing evidence that face-to-face AMS reviews, which have been referred to as “Handshake Stewardship”,[4,5] reduce total and inappropriate antibiotic use.[4–8] We observed additional reductions in use of some other antibiotics, e.g. clindamycin, metronidazole and vancomycin, which were only reviewed if co-prescribed with a target antibiotic, but may have also been impacted by learning from the AMS ward rounds more generally. There were some compensatory rises in alternative antibiotics, such as amoxicillin and co-trimoxazole.

Around half of AMS reviews generated suggested interventions. Advice to de-escalate antibiotics, including reductions in spectrum, switching to oral antibiotics, or stopping antibiotics, was given following 29% of reviews, while advice to escalate treatment was given in 2%. Reviews also generated other potentially valuable

Table 2
Multivariable predictors of AMR advice being actioned.

	Descriptive		Multivariable		
Characteristic	Not actioned, N = 723	Actioned, N = 2003	Adjusted odds ratio	95% confidence interval	p-value
AMS lead					
Consultant	562 (25%)	1728 (75%)	—	—	
Not recorded	4 (67%)	2 (33%)	0.13	0.02, 0.73	0.020
Pharmacist	86 (37%)	145 (63%)	0.57	0.43, 0.77	< 0.001
Registrar	71 (36%)	128 (64%)	0.60	0.44, 0.82	0.002
Action					
Stop	160 (20%)	626 (80%)	—	—	
Allergy clarification	42 (64%)	24 (36%)	0.15	0.09, 0.25	< 0.001
De-escalate	77 (29%)	186 (71%)	0.63	0.45, 0.86	0.004
Dose advice	13 (12%)	92 (88%)	1.83	0.99, 3.36	0.052
Duration change/stipulate	77 (26%)	220 (74%)	0.72	0.53, 0.99	0.041
Escalate or start antibiotics	9 (6.5%)	129 (93%)	3.47	1.73, 6.99	< 0.001
Full micro review	0 (0%)	2 (100%)			
IPC advice	2 (100%)	0 (0%)			
IVOS	164 (30%)	389 (70%)	0.62	0.48, 0.81	< 0.001
Other	3 (27%)	8 (73%)	0.73	0.19, 2.83	0.65
Refine antibiotic plan	4 (31%)	9 (69%)	0.49	0.15, 1.65	0.25
Request for sample or test	159 (39%)	248 (61%)	0.39	0.30, 0.51	< 0.001
Switch (same spectrum)	13 (16%)	70 (84%)	1.45	0.78, 2.70	0.24

Descriptive and multivariable estimates are shown (descriptive and univariable estimates for all variables are shown in Table S1). We used data from the 2726 AMS reviews with a documented outcome to investigate predictors of advice being actioned. Within these data, 2 requests for further microbiology consult were both actioned and neither of 2 requests for IPC interventions were actioned. As these two categories perfectly predicted the outcome, these observations were excluded from subsequent models. Similarly, all 8 recommendations made for cardiac indications were implemented and these records were also excluded, leaving 2714 observations for analysis. The variables included in the multivariable were determined by backwards selection, minimising AIC. Site was also excluded from the multivariable model due to collinearity with the team caring for the patient, as some specialties were based a single hospital.

interventions including clarifying antibiotic plans, reviewing allergies, and requesting additional investigations and microbiological work up of samples.

We found that senior doctor-led ward rounds were more likely than pharmacist-led or fellow/registrar-led reviews to recommend de-escalating antibiotics, with variation between individual clinicians too. Although the likelihood of advising de-escalation can depend both on the original quality of antibiotic prescribing and the individual leading the AMS review, these independent associations, after adjusting for the speciality, drug and indication, are likely to represent factors relating to the AMS decision-maker and the context in which they are working. Urinary tract infection was the clinical syndrome most likely to have de-escalation of antibiotics recommended. Advice to de-escalate antibiotics varied across specialities, with some of the highest rates of de-escalation suggested in acute adult medicine, which may reflect differences in how antibiotics are used in different settings, including the complexity of antibiotic decision-making and time available to clinicians.

A key strength of our data is the dedicated AMS database that allowed us to assess the likelihood of the advice given being actioned. Overall, 73% of recommendations to make a change were implemented, including 80% of all suggestions to stop antibiotics and 71% of suggestions to de-escalate antibiotics. The relatively high uptake of advice likely reflects the design of the AMS intervention, using face-to-face contact with a multidisciplinary team, underpinned by existing relationships between the infectious diseases consult service and teams throughout the hospital. Requests for clarification of allergies or additional tests were less likely to be actioned, representing an opportunity for improvement, particularly if implementing these suggestions can be supported by the AMS team, e.g. via AMS team and pharmacy-led allergy review and delabelling,[17] or direct requesting of investigations during the AMS ward round with the home team.

Although rates of advice uptake were high overall, advice was more likely to be followed after consultant-led AMS ward rounds (75%) than those led by pharmacists and registrars/fellows (63% and 64%). Potential explanations, that may well apply in other settings and could be explored further, include the perceived status of the lead by the home team, longer-term relationships between home team leads and AMS consultants, and possibly the way in which changes were suggested, explained or justified.[13] Empowering, upskilling and supporting the confidence of all members of the AMS team is now an important priority at our centre. Increased advice uptake after more reviews rather than based on years of post-qualification experience, suggests an opportunity for improvements through sharing of best practice and the value of relationships built over time.

Comparing when advice to de-escalate treatment was actioned to when it was not, we show following AMS advice was associated with a reduction in median length of stay of over half a day. This was after adjustment for patient age, sex and specialty, and likely represents a true reduction in length of stay but is also possible that advice was less likely to be followed in more complex patients who ultimately stayed longer for other reasons. Reductions in length of stay, antimicrobial costs, antimicrobial side effects, and future AMR are all likely to have reduced healthcare costs, although further work is needed to formally evaluate cost-effectiveness.

This study is limited by relying on an interrupted time series approach rather than a randomised design. However, the presence of a hospital within the organisation not yet implementing AMS ward rounds provides a local contemporaneous comparator, albeit one with different specialities and patient case mix. Additionally, some clinicians may have worked across multiple hospitals, which may have attenuated differences between hospitals 1 and 2 as learning from AMS ward rounds may have been shared. However, most clinicians worked at a single site. The study is also only of a single group of teaching hospitals and so may not generalise to all settings, for example, antimicrobial prescribing practices and the status and role of different healthcare professionals may vary across contexts. Not all AMS advice had outcomes documented due to limits in staff availability, but this is unlikely to have impacted representativeness of the data collected. We did not track how much time was spent on AMS reviews, and differences in workload between hospitals may have affected advice quality or uptake. However, this is unlikely to have impacted the key differences observed, as workload was similar within each site irrespective of who was leading the ward round, and available time was shared across the multiple specialties represented at each site.

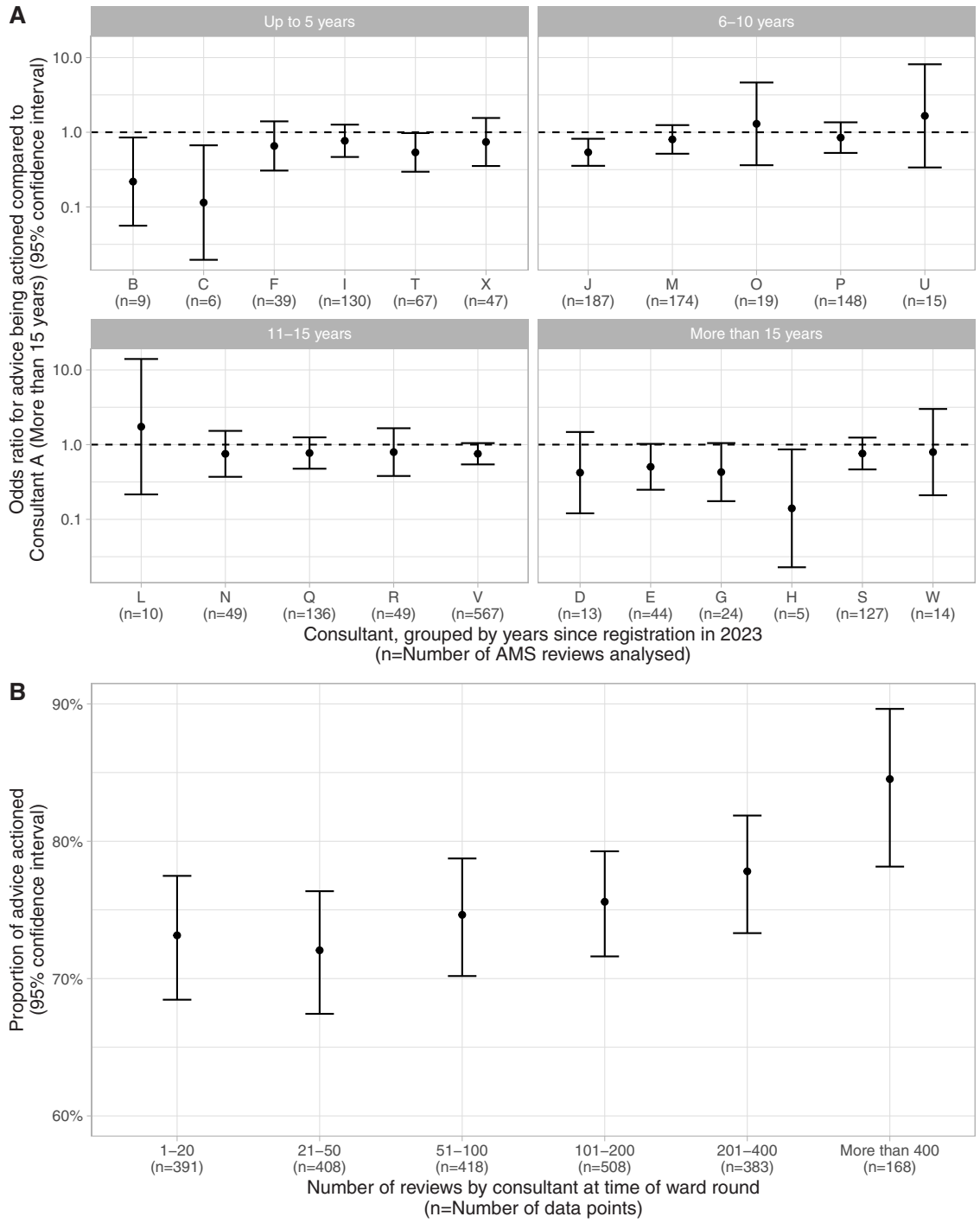

Fig. 6. Relationship between likelihood of AMS advice being actioned and years of experience as a consultant (panel A) and number of AMS reviews completed (panel B). In panel A, estimates shown are adjusted for the nature of the action recommended. Each letter represents a specific individual consultant (senior doctor). The total number of reviews conducted by each consultant is included in the x-axis labels. Observed data are shown in panel B. In panel A, all 4 reviews by consultant K with an outcome documented were actioned and were excluded from subsequent models, which together with the previous exclusions (see Table 2 footnote), left 2276 records for analysis.

There are several possible areas for further work. Considering more precise details of the clinical syndrome, clinical/vital sign/laboratory parameters, and microbiology results could allow differences in decision-making to be better understood. It may also be possible to use these data to predict what an average AMS reviewer would have suggested, both as an educational tool and potential clinical decision aid. This study, like many others, assessed measures of process including consult numbers and rates of advice to change antibiotics. We additionally measured immediate outcomes, including AMS advice uptake rates, length of stay and antibiotic consumption. Despite having data on several thousand AMS reviews, our study had insufficient power to rule out important differences in mortality depending on uptake of advice; a much larger dataset would be needed to do this.[18] Further studies are needed to ensure AMS advice is optimal, not only considering reductions in antibiotic use, but also impacts on a wide range of patient outcomes including readmission, re-operation, subsequent antibiotics, functional recovery, and patient experience. Additionally, further understanding

the personal, team, and cultural/organisational factors that promote effective stewardship interactions, and applying existing understanding, could enhance to effectiveness of AMS programmes.

In conclusion, introducing multidisciplinary AMS ward rounds reduced antibiotic use. In our setting half of reviews generated possible action. Uptake of advice was generally high and likely reduced length of hospital stay. Senior clinician input was associated with increased uptake of advice as was having previously completed more AMS reviews. Empowering and supporting other leaders of AMS reviews and sharing of best practice could further increase the impact of AMS reviews.

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Data availability

The datasets analysed during the current study are not publicly available as they contain personal data but are available from the Infections in Oxfordshire Research Database (https://oxfordbrc.nihr.ac.uk/research-themes-overview/antimicrobial-resistance-and-modernising-microbiology/infections-in-oxfordshire-research-database-iord/), subject to an application and research proposal meeting the ethical and governance requirements of the Database. For further details on how to apply for access to the data and for a research proposal template please email iord@ndm.ox.ac.uk.

Declaration of Competing Interest

No author has a conflict of interest to declare.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jinf.2025.106419.

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