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Electronic prescribing system design priorities for antimicrobial stewardship: a cross-sectional survey of 142 UK infection specialists

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3-5 keywords (very general terms such as 'bacteria' and 'human' and terms already present in the title should be avoided, as should non-standard abbreviations): CPOE, prescription, Clinical Decision Support Systems

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Synopsis

The implementation of electronic prescribing and medication administration systems (EPMAs) is a priority for hospitals and a potential component of antimicrobial stewardship (AMS).

Objectives

This study aimed to identify software features within EPMAs that could potentially facilitate AMS and to survey practising UK infection specialist healthcare professionals in order to assign priority to these software features.

Methods

A questionnaire was developed using nominal group technique and transmitted via email links through professional networks. The questionnaire collected demographic data, information on priority areas and anticipated impact of EPMA. Responses from different respondent groups were compared using the Mann Whitney U test.

Results

Responses were received from 164 individuals (142 analysable). Respondents were predominantly specialist infection pharmacists (48%) or medical microbiologists (37%). 59% of pharmacists had experience of EPMA in their hospitals compared to 35% of microbiologists. Pharmacists assigned higher priority to: indication prompt ($p<0.001$), allergy checker ($p=0.003$) treatment protocols ($p=0.003$), drug-indication mismatch alerts ($p=0.031$) and prolonged course alerts ($p=0.041$); and lower priority to a dose checker for adults ($p=0.02$) and an interaction checker ($p<0.05$), than microbiologists. A “soft stop” functionality was rated essential or a high priority by 89% of respondents. Potential EPMA software features were expected to have the greatest impact on stewardship, treatment efficacy and patient safety outcomes with lowest impact on *Clostridium difficile* infection (CDI), antimicrobial resistance and drug expenditure.

Conclusions

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63 The survey demonstrates key differences in health professionals' opinions of different healthcare
64 benefits of EPMA but a consensus of anticipated positive impact on patient safety and antimicrobial
65 stewardship.

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INTRODUCTION

Antimicrobial resistance (AMR) is a major threat to public health and a significant resource and cost burden on the United Kingdom (UK) National Health Service (NHS).[1] The Chief Medical Officer's 2013 report on infections and the rise of AMR called for action to preserve the effectiveness of existing antimicrobials through antimicrobial stewardship (AMS).[1] The 2013 UK Five Year Antimicrobial Resistance Strategy from the Department of Health (DH) also highlights AMS as one of seven key areas for action and NHS England has subsequently introduced antimicrobial prescribing reduction goals for English hospitals through the Commissioning for Quality and Innovation (CQUIN) programme for 2016/17.[2, 3]

In 2012, the UK Department of Health commissioned a study of the potential benefits to staff and patients of greater use of digital and information technology in the NHS and social care.[4] The study report identified four priority actions, one of which was to drive the rollout and use of electronic prescribing (e-prescribing) in secondary care. Implementation of e-prescribing systems in hospitals presents a unique opportunity to improve the quality of antimicrobial prescribing and to facilitate AMS.[5-10] Evidence for the benefits of AMS functionality within e-prescribing systems comes from published research studies demonstrating positive impact on outcomes including increased guideline adherence[11, 12] and effective initial therapy[13] or reductions in antimicrobial prescribing,[14, 15] resistance,[16, 17] dosing errors,[8] length of hospital or ICU stay[14, 18] and mortality.[12, 13, 19] However, many of these information systems were created on a small scale in individual hospitals or groups of institutions and few reports cover the full potential range of software features that enable AMS. Moreover there does not appear to be a recognised standard to guide the specification and commissioning of an optimal e-prescribing system that includes the required AMS functionality appropriate for the challenges that health systems currently face worldwide.[20]

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This report presents results from a cross-sectional survey of UK infection specialist health professionals. The specific objectives of this study were: to identify, using a convenience sample of local infection experts (the nominal group technique), software features within NHS hospital e-prescribing systems that could potentially facilitate antimicrobial stewardship; to assign a priority to these software features according to the opinions of practising infection specialist healthcare professionals; to identify any differences in priority setting according to professional group, hospital status (teaching or district general) or previous experience of e-prescribing systems; and to communicate research findings to e-prescribing software manufacturers and healthcare policy makers.

MATERIALS AND METHODS

Two focus group meetings of experienced infection health professionals from a local network of hospitals in the south central region of England were convened in order firstly, to identify software features within existing e-prescribing and medicines administration (EPMA) systems that facilitate AMS and secondly, to identify additional software features with the potential to facilitate AMS. The focus groups had representation from six infection hospital pharmacists (three with experience of EPMA systems), two consultant medical microbiologists (one with experience of EPMA systems) and one EPMA analyst. The focus group meeting output was a list of software features to be included in a questionnaire for wider circulation among UK infection specialist health professionals. Following the focus groups, two infection pharmacists designed a questionnaire using SurveyMonkey® software. The questionnaire included 42 questions, which were divided into 4 domains. The first domain collected respondent demographic data including professional group, experience in a specialist role, hospital setting and EPMA experience. In the remaining three domains, respondents were asked to assign a priority to individual software features grouped according to the categories of prescribing alerts/prompts (12 features), active prescription surveillance (11 features) and prescribing trend surveillance (8 features). At the end of each domain, respondents were asked to

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express their opinion of the anticipated collective impact of the software features from each domain on a number of clinical, microbiological and process outcomes. For the prescribing trend surveillance domain, respondents were asked to prioritise a number of technical aspects of the proposed surveillance reports. Finally, the questionnaire provided a freetext narrative section inviting respondents to suggest additional software features with potential to facilitate AMS, not mentioned earlier in the survey. The questionnaire was piloted in the local region, predominately with infection pharmacists and one medical microbiologist in October 2014. Feedback from the pilot led to the incorporation of one additional category (work efficiency) to the list of process outcomes. A copy of the finalised questionnaire and covering letter to respondents is available as an online Supplement (S1).

Respondents were advised that participation was voluntary and anonymous, that the questionnaire would take approximately 10-12 minutes to complete and that the results would be disseminated to e-prescribing software manufacturers, policy makers and the clinical infection community. The research team took the decision not to collect personal details of respondent names and employers in order to elicit candid responses; although respondent internet protocol (IP) addresses were collected, identifying responses from the same healthcare organisations. A hyperlink to the online questionnaire was distributed via health professional networks including the UK Clinical Pharmacy Association, the Royal College of Pathologists, the British Society for Antimicrobial Chemotherapy and Public Health England. The online questionnaire was closed in July 2015, 7 months from launch. Table 1 presents a glossary of key terms used in the questionnaire that will be referred to throughout this report.

Analysis methods

Questionnaire data were summarised with descriptive statistics and analysed using IBM SPSS v.22 with priority ranking of software features by different groups of respondents compared using the

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Mann Whitney U test. The respondent groups compared were: specialist pharmacists versus medical microbiologists (the number of respondents from other professional groups was too few for statistical analysis); respondents from hospitals with EPMA experience versus those without; and respondents from teaching hospitals versus district general hospitals (DGHs). A p-value of <0.05 was considered statistically significant. Finally, the freetext narrative comments were analysed by using a summative approach to qualitative content analysis, grouping responses into common themes according to frequency of reporting.[21]

This research did not require NHS Research Ethics Committee approval for sites in England, Scotland, Wales or Northern Ireland according to the Health Research Authority online decision tool (http://www.hra-decisiontools.org.uk/ethics/).

RESULTS

Respondent accountability

Responses were received from 164 individuals from 79 unique IP addresses. Twenty-two response sets were removed from the dataset (11 pharmacists, 6 medical microbiologists, one ID physician, 4 nurses and one trainee) due to failure to complete responses to survey questions beyond demographics. Responses from the remaining 142 individuals from 68 unique IP addresses were included in the analysis. Eleven of these 142 did not complete all sections of the questionnaire and missing data were ignored as they comprised less than 10% of responses.

Respondent demographics

The demographic profile of the 142 respondents included in the analysis is presented in Figure1. Infection pharmacists comprised almost half of respondents (48%; 68/142) from 39 IP addresses and the majority had at least 5 years' experience in a specialist infection role (47/68). Medical microbiologists represented over one-third of respondents (37%; 53/142) from 35 IP addresses and

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most had at least 5 years' experience (48/53). Six infectious diseases (ID) physicians responded to the survey and a further six respondents were grouped as other healthcare professionals (medical virologist, epidemiologist, junior doctor, infection prevention nurse, surveillance nurse and a consultant in public health).

Fifty-two per cent of respondents were from DGHs (71/136 responses) and 45% from teaching hospitals (61/136 responses). Figure 2 illustrates the distribution of experience of EPMA and e-prescribing systems amongst the questionnaire respondents. Half of respondents (49%; 68/139) reported experience of EPMA or e-prescribing; 59% of 68 infection pharmacists had experience of EPMA in their hospitals compared to 35% of 52 microbiologists. Forty per cent (56/139) expected implementation of EPMA within 5 years (25 from teaching hospitals and 29 from district general hospitals) but 11% (15/139) did not expect EPMA within 5 years (5 from teaching hospitals and 9 from district general hospitals).

Prescribing Prompt Software Features

Table 2 presents survey response data for priority attributed by respondents to 12 software features of EPMA systems grouped within the Prescribing Prompt category. With the exception of restriction features, all prescribing prompt software features were considered essential or high-priority by the majority (>50%) of respondents. The features considered essential by more than 50% of respondents were: an allergy checking function and a prompt to prescribers to record the clinical indication for prescribing an antimicrobial.

In comparison with medical microbiologists, specialist pharmacists assigned higher priority to: indication prompt ($p<0.001$); allergy checker ($p=0.003$); and treatment protocols ($p=0.003$) (Table 3). Medical microbiologists assigned higher priority to a dose checker for adults ($p=0.023$) and an

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interaction checker (p<0.05). Respondents from hospitals with EPMA experience assigned higher priority to an indication prompt (p=0.049); whereas respondents from hospitals without EPMA experience assigned higher priority to: restricted antimicrobial block (p=0.011); dose checker for children (p=0.024); and blood level monitoring alert (p=0.033). When responses from teaching hospitals were compared with responses from DGHs, there were no statistically significant differences in opinions of priority for any of the prescribing prompt software features. The majority of respondents considered that both patient safety (60%; 84/140) and ability to deliver antimicrobial stewardship (64%; 89/140) were extremely likely to be improved (Figure 3).

Active Prescription Surveillance Software Features

Table 4 presents survey response data for priority attributed by respondents to 11 software features of EPMA systems grouped within the Active Prescription Surveillance category. All but two of the 11 features (daily reports of new or ongoing prescriptions of all antimicrobials) were considered essential or high priority by the majority (>50%) of respondents. Only one feature was considered essential by more than 50% of respondents: daily report of new prescriptions for critical antimicrobials.

Specialist pharmacists assigned higher priority to a daily report of mismatch between prescribed antimicrobial and associated indication (p=0.031) and long IV/oral courses (p=0.041) in comparison to medical microbiologists (Table 3). Respondents from hospitals with EPMA experience (in comparison to those without) assigned higher priority to: a daily report of newly-prescribed critical antimicrobials (p=0.015); and a daily report of any newly-prescribed antimicrobial (p=0.024). When responses from teaching hospitals were compared with responses from DGHs, there were no statistically significant differences in opinions of priority for any of the active prescription

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surveillance software features. The majority (>50%) of respondents considered that both patient safety (53%; 71/135) and ability to deliver antimicrobial stewardship (60%; 80/134) were extremely likely to be improved (Figure 4). Two respondents expressed the view that an improvement in outcomes was extremely unlikely: one for reduction in expenditure on drugs; and one for reduction in risk of *Clostridium difficile*.

Prescribing Trend Surveillance Software Features

Prescribing trend surveillance reports as a software feature were generally considered by respondents to be of lower priority compared with prescribing prompts and active prescription surveillance, with no trend surveillance software feature rated as essential by more than 50% of respondents (Table 5). However, the majority of respondents did consider all of the proposed trend surveillance features to be at least high priority. There were no statistically significant differences in opinions of priority for prescribing trend surveillance software features between specialist pharmacists and medical microbiologists, nor between respondents with or without EPMA experience. Respondents from DGHs assigned a higher priority to the report of trends in proportion of stat doses where administration was delayed software feature (p=0.034) (Table 3). The majority of respondents considered that the prescribing trend surveillance group of software features would be likely or extremely likely to have a positive impact on all of the listed clinical, microbiological and process outcomes (Figure 5). More than 90% of respondents anticipated a positive impact on their ability to deliver AMS.

Respondent opinions of selected technical aspects of prescribing trend surveillance reporting are summarised in Table 6. Respondents expressed equal preference for patient days or patient admissions as an activity denominator. A preference for annual and quarterly reporting intervals rather than more frequent reports was evident. Surveillance reports for the whole hospital and by

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clinical speciality or hospital department were rated more highly than reports by hospital ward or individual responsible consultant physician. Finally, surveillance reports of prescribing and administration of individual antimicrobials, by antimicrobial drug class and by locally defined drug groups such as broad-spectrum agents were rated most highly by respondents with reports grouped by route of administration considered of lesser importance.

Freetext narrative responses

Thirty-five respondents recorded narrative responses when prompted to submit suggestions for additional software features not included in the questionnaire and 69 unique statements were identified and grouped into nine common themes, presented in Table 7. Eighteen respondents suggested an interface with other electronic systems for previous and current microbiology investigations and results and for drug and clinical information to guide prescribing. There was an apparent demand for flexibility in reporting software to allow reports to be customised locally but also to generate a standard set of reports for reporting to Public Health England in accordance with antimicrobial stewardship guidance for English Hospitals: Start Smart – Then Focus.[22]

DISCUSSION

This is the first survey of UK infection specialist healthcare professionals evaluating opinions of the potential for e-prescribing software to facilitate antimicrobial stewardship. The two largest health professional groups responsible for AMS are represented and the majority of respondents were experienced in a specialist role. We estimate an approximate response rate of 24% of NHS hospital specialist infection pharmacists and at least 8% of practising UK medical microbiologists.[23, 24] Responses were included from 68 unique IP addresses representing up to 36% (68/188) of NHS hospital trusts/boards if the questionnaire was completed from the employing hospital's IP

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address.[25-28] Teaching hospitals are proportionately over-represented compared with DGHs but there was a good balance of respondents with experience of EPMA systems and those without.

The prescribing prompt software features ranked of highest priority by respondents were allergy checker, interaction checker and dose checker, which are already incorporated as standard functionality in a number of existing EPMA systems in NHS hospitals.[29] The response data suggest an unmet need for AMS-relevant features such as recording of indication and "soft stop" functionality; that are not routinely incorporated into existing EPMA systems. The responses suggest relatively little appetite among UK infection specialists for software features to support restriction of prescribing of selected antimicrobials, possibly reflecting the inter-speciality conflict inherent in such policies, resource implications and the lack of longer-term superiority over persuasive interventions.[30] Priorities for active prescription surveillance software features were divided between an emphasis on patient safety (drug-indication mismatch and missed doses) and stewardship (prescriptions for critical antimicrobials and long course lengths). Reports of new or ongoing prescriptions of any antimicrobial were considered lower priority, potentially reflecting the limited resources available to AMS teams to review these prescriptions.[31] Opinions of the expected impact of the proposed prescribing prompt and active prescription surveillance software features on patient outcomes, public health outcomes and resource use outcomes were overwhelmingly positive. It is particularly striking that more than 90% of respondents considered prescribing prompt software features and active prescription surveillance features either likely or extremely likely to improve patient safety, corroborated by an expectation of improved treatment efficacy and reduced *Clostridium difficile* infection. An improvement in ability to deliver stewardship and more efficient deployment of stewardship resources was also anticipated.

We found that pharmacists were more likely to prioritise a prescribing prompt to record indication, which may reflect the uncertainty faced by hospital pharmacists when validating new prescriptions

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for antimicrobials (for safety and effectiveness) prior to authorising dispensing; and the requirement to audit antimicrobial prescribing for adherence to local treatment guidelines.[22, 32] Pharmacists also prioritised the treatment protocol software feature, consistent with their preference for daily reports of drug-indication mismatch in contrast to medical microbiologists. We found that medical microbiologists were more likely to prioritise prescribing prompts for dose checking and interaction checking in comparison to pharmacists, perhaps indicating differences in undergraduate teaching and endorsing the value of a multi-disciplinary approach to infection management. Respondents from hospitals with experience of EPMA systems ranked the indication prompt feature as relatively more important in comparison to those without, suggesting an unmet need amongst existing software systems.

When technical aspects of surveillance reports were considered, it is of interest that reports by individual responsible consultant physician were considered of lesser importance than reports by clinical speciality or hospital department. This finding suggests a lack of willingness to employ a "name-and-shame" approach to stewardship and may represent a preference for promoting a sense of collective responsibility amongst clinician colleagues. Freetext comments identified strong user demand for an interface with the microbiology laboratory software system to support selection of effective therapy and de-escalation and to facilitate prompt intervention when patients are prescribed potentially ineffective therapy.

This cross-sectional survey was designed in accordance with recommended principles of health professional survey design as far as possible within the available resources.[33, 34] However, a shorter questionnaire may have improved the response rate.[33] The exclusion of data relating to address or employer means that we cannot rule out the possibility that multiple responses may have been

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submitted by the same individuals and it is likely that multiple respondents from the same Trust had an effect on our findings. We were also unable to collect information on non-responders so the respondent sample is likely to be biased towards more motivated individuals who are engaged with quality improvement and/or information technology. Approximately half of respondents reported experience of EPMA or e-prescribing and this suggests a potential bias towards hospitals with such systems when compared with a survey carried out by Public Health England in 2014 which reported only 17/76 (22%) of respondent hospitals with e-prescribing for at least one inpatient area.[35] The questionnaire did not specifically elicit a description of the existing software features of EPMA systems currently installed in NHS hospitals but anecdotal evidence from the research team and from professional networks in the UK suggests that software features to support AMS are extremely limited. Some of the software features proposed in this survey may not be technically possible for existing e-prescribing systems and separate data-mining software may be required, particularly for prescribing trend surveillance. Finally, the present questionnaire was primarily distributed by e-mail to members of professional organisations and therefore may not represent the views of non-members.

The target audience for this survey – consultant medical microbiologists and specialist pharmacists – was deliberate, to focus on individuals most likely to be responsible for stewardship within an NHS hospital organisation. However, other healthcare workers also play an important role in AMS at the individual patient level including junior and senior doctors, nurses, non-medical prescribers and ward pharmacists.[36-41] Inclusion of these professional groups in user-testing at the design stage of EPMA implementation is likely to be critical to the success of the proposed software features. Future surveys focussing on front-line prescribers and medication administrators are critical.

The advent of e-prescribing to NHS hospitals represents a unique new opportunity to engage with healthcare professionals to promote safe, effective and proportionate antimicrobial prescribing and

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to refresh the antimicrobial stewardship message. It must be acknowledged however that with this opportunity also comes new threats to patient safety from prescribing and administration errors as well as potential de-skilling of healthcare professionals.[42-44] The judicious use of educational prompts may facilitate a sustained change in prescribing behaviour but this must be balanced against the recognised risk of "alert fatigue" and competing priorities for e-prescribing system functionality from other medical and surgical specialities.[45] Successful implementation of the proposed antimicrobial stewardship software features into e-prescribing systems will likely be contingent upon a variety of sociotechnical considerations including seamless integration into the prescribing workflow with minimal time penalties for end-users and full compatibility with existing NHS information technology hardware and software.[43, 46]

This survey represents the first attempt to canvas opinion of infection specialists in the UK on the potential for e-prescribing software to support antimicrobial stewardship. The findings illustrate fundamental principles that are equally relevant to health systems in other countries. The survey results reveal considerable demand for additional software features expressed by the healthcare professionals charged with promoting rational use of antimicrobials and a consensus of anticipated positive impact on patient safety and efficiency outcomes. The survey demonstrates key differences in health professionals' opinions of different healthcare benefits of EPMA and underscores the need for a multi-disciplinary approach to the development of EPMA system specifications. We trust this information will prove valuable to software manufacturers currently developing e-prescribing systems when prioritising software functionality and systems interface development and potentially to healthcare commissioners when drafting e-prescribing system specifications. Finally, we commend this topic to research funders with a view to funding research into the potential benefits and unintended consequences of e-prescribing system functionality designed to support antimicrobial stewardship.

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TRANSPARENCY DECLARATIONS

None to declare.

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506 **Table 1. Glossary of key terms used in the survey of opinions of infection specialists on electronic**
507 **prescribing and antimicrobial stewardship**

Term	Explanation
Prescribing alert / prompt	The prescriber will be alerted via a "pop-up" message – an "alert or prompt" – e.g. if attempting to prescribe an antimicrobial which is contra-indicated because of an allergy or a drug interaction
Active prescription surveillance	Active prescription surveillance refers to the application of surveillance data in real-time for identification of patients currently prescribed antimicrobial therapy. Software features allow prioritisation of patients for intervention by the antimicrobial stewardship team (AST).
	Active prescription surveillance reports would typically include: patient name, date of birth, hospital number, inpatient location in the hospital, drug name, drug dose, start date, stop date (if specified), prescriber and responsible senior physician.
Prescribing trend surveillance	Prescribing trend surveillance refers to the review of retrospective data relating to antimicrobial prescribing and administration – typically as trends over time. Prescribing trend surveillance allows continuous monitoring of performance for the purposes of controls assurance and for evaluating the impact of stewardship interventions.
Order Sets	This software feature allows the prescriber to select an infection (e.g. pneumonia, community-acquired, severe) and the system will automatically populate the prescription with the locally pre-defined treatment regimen (single drug or combination of drugs) at standard doses.
Critical antimicrobial	An antimicrobial may be designated "critical" by a hospital AST according to local priorities – for example, broad-spectrum antimicrobials such as carbapenems or antimicrobials with a narrow therapeutic range such as colistin. A prescriber may be alerted when prescribing a critical antimicrobial with an appropriate locally-defined message containing details of actions required when prescribing.
Restricted antimicrobial	An antimicrobial may be designated "restricted" by a hospital AST on grounds of financial cost, propensity to predispose to *Clostridium difficile* infection or local decision to reserve for multidrug-resistant infections. Prescribing of restricted antimicrobials requires pre-authorisation by a medical microbiologist or infectious diseases physician ("restricted antimicrobial authorisation") or prescribing is limited by the prescribing software to senior clinicians ("restricted antimicrobial block").

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Soft Stops	This software feature allows the prescriber to nominate a date when the antimicrobial prescription should be reviewed with a view to stopping, changing treatment or switching route of administration to oral. After the review date has passed, the drug will remain visible and available to nursing staff to administer but will be prominently highlighted as being past the review (soft stop) date
Blood level monitoring order set	When a relevant drug is prescribed, the EPMA system will automatically pair the drug prescription with an order for a blood specimen to be taken at an appropriate time post-dose.
Drug-indication mismatch	A mismatch occurs when a prescribed antimicrobial is not appropriate or unauthorised for the recorded indication/provisional diagnosis.
Days of Therapy (DOTs)	One DOT represents the administration of a single systemic antimicrobial on a given day regardless of the number of doses administered or dosage strength. For example, administration of ceftriaxone as 4g once-daily or as 2g twice-daily for one day would both represent 1 DOT. A single patient receiving both vancomycin and ceftazidime during the same day would be recorded as receiving 2 DOTs (1 of vancomycin and 1 of ceftazidime).[47]
Length of Therapy (LOT)	LOT refers to antimicrobial course length and is the number of sequential days that a patient receives any systemic antimicrobial drug(s), irrespective of the number of different drugs.[47] A prescription of intravenous piperacillin-tazobactam and vancomycin for 2 days followed by oral co-amoxiclav for 5 days corresponds to a LOT of 7 days.
Point Prevalence	Point prevalence is the proportion of hospital patients active on the EPMA system that are prescribed any antimicrobial at a specific point in time (for example at noon on the first day of each month).

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Figure 1. Demographic profile of respondents: professional group and years of experience in specialist infection role

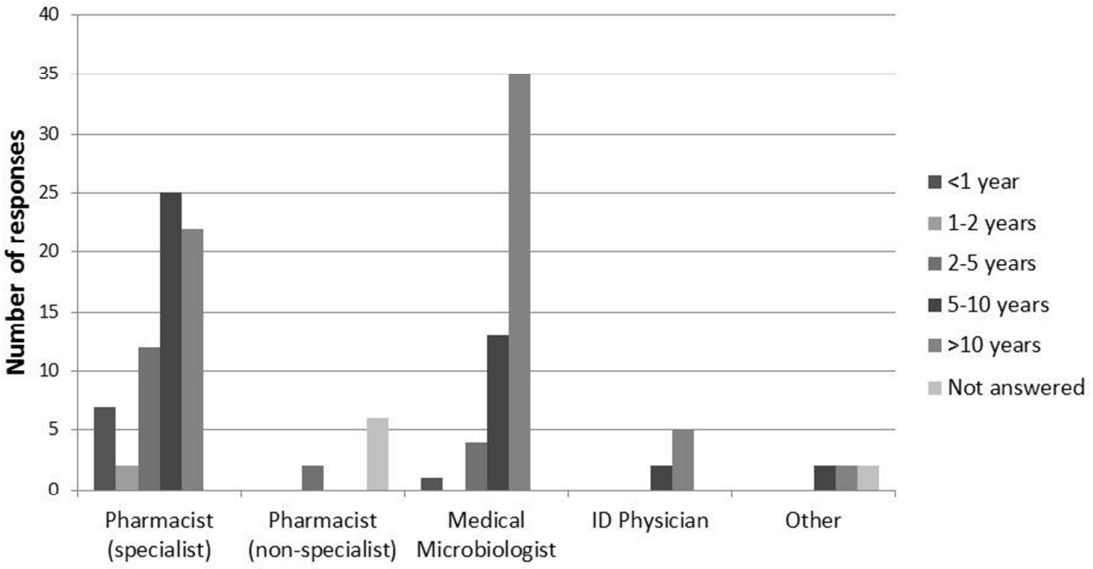

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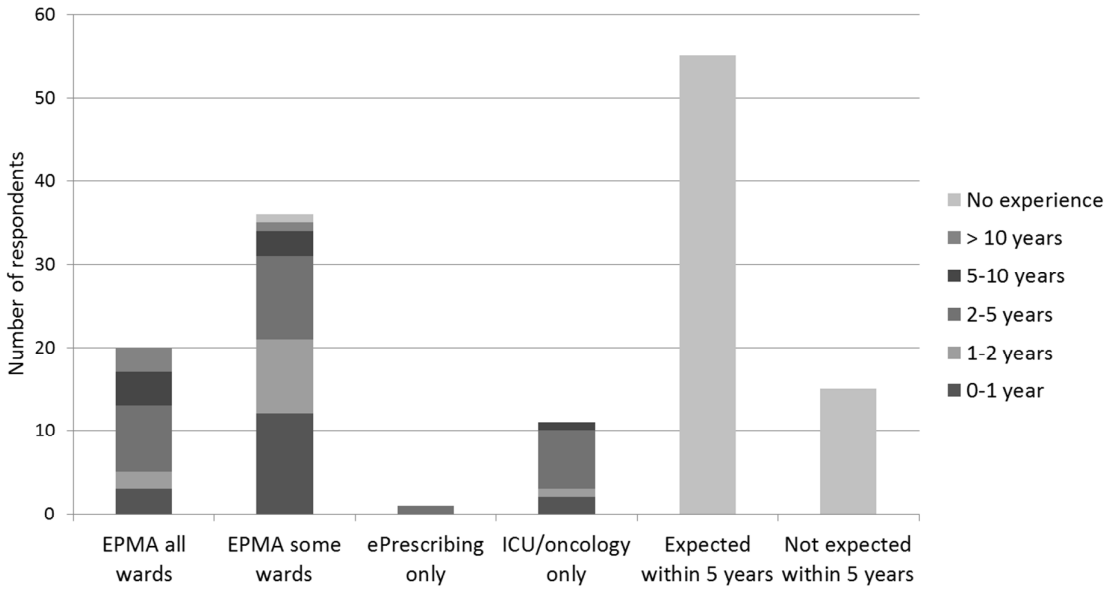
Figure 2. Respondent experience of EPMA and ePrescribing systems (n=139)



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516 **Table 2. Prescribing Prompt software features ranked in order of respondent-assigned priority**

Software feature	Number of responses	Essential	High priority	Medium priority	Low priority	Not a priority
Allergy checker	142	80.3%	14.8%	3.5%	1.4%	0.0%
Indication prompt	139	56.8%	30.9%	10.8%	1.4%	0.0%
Interaction checker	143	45.5%	35.7%	14.7%	4.2%	0.0%
Soft stop	141	38.3%	51.1%	7.1%	2.8%	0.7%
Blood level prompt	140	35.0%	46.4%	15.7%	2.9%	0.0%
Dose checker (children)	142	33.8%	44.4%	19.0%	2.1%	0.7%
Dose checker (adults)	141	25.5%	48.2%	22.0%	3.5%	0.7%
Critical antimicrobial prompt	141	24.1%	48.2%	21.3%	4.3%	2.1%
Indication order set	143	21.7%	45.5%	25.2%	4.9%	2.8%
Blood level order set	140	21.4%	39.3%	29.3%	9.3%	0.7%
Restricted antimicrobial require authorisation	142	18.3%	25.4%	30.3%	17.6%	8.5%
Restricted antimicrobial block by prescriber	140	15.7%	31.4%	26.4%	16.4%	10.0%

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519 **Table 3. Differences in software feature priority assignment between respondent groups found to**
520 **be statistically significant**

Domain / Respondent group	Software feature	Respondent group (% of responses rated essential)		Mann-Whitney U test p-value
Professional group		**Pharmacists**	**Medical microbiologists**	
Prescribing prompts	Allergy checker	90%	69%	p=0.003 (n=68, 52)
	Indication prompt	73%	39%	p<0.001 (n=67, 51)
	Treatment protocols	28%	15%	p=0.003 (n=68, 53)
	Dose checker (adults)	16%	34%	p=0.023 (n=68, 53)
	Interaction checker	34%	51%	p=0.047 (n=68, 53)
Active prescription surveillance	Drug-indication mismatch	35%	25%	p=0.031 (n=65, 49)
	Long IV/oral course	31%	24%	p=0.041 (n=65, 50)
EPMA experience		**EPMA-experienced**	**Non EPMA-experienced**	
Prescribing prompts	Indication prompt	66%	47%	p=0.049 (n=68, 68)
	Restricted antimicrobial block	12%	17%	p=0.011 (n=67, 70)
	Dose checker (children)	26%	39%	p=0.024 (n=68, 70)
	Blood level monitoring alert	24%	44%	p=0.033 (n=67, 70)
Active prescription	Daily report of newly-prescribed critical antimicrobials	64%	40%	p=0.015 (n=64, 68)

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surveillance	Daily report of any newly-prescribed antimicrobial	23%	16%	p=0.024 (n=64, 68)
Hospital type		**Teaching**	**District General**	
Prescribing trend surveillance	Report of trends in proportion of stat doses where administration was delayed	28%	18%	p=0.034 (n=55, 65)

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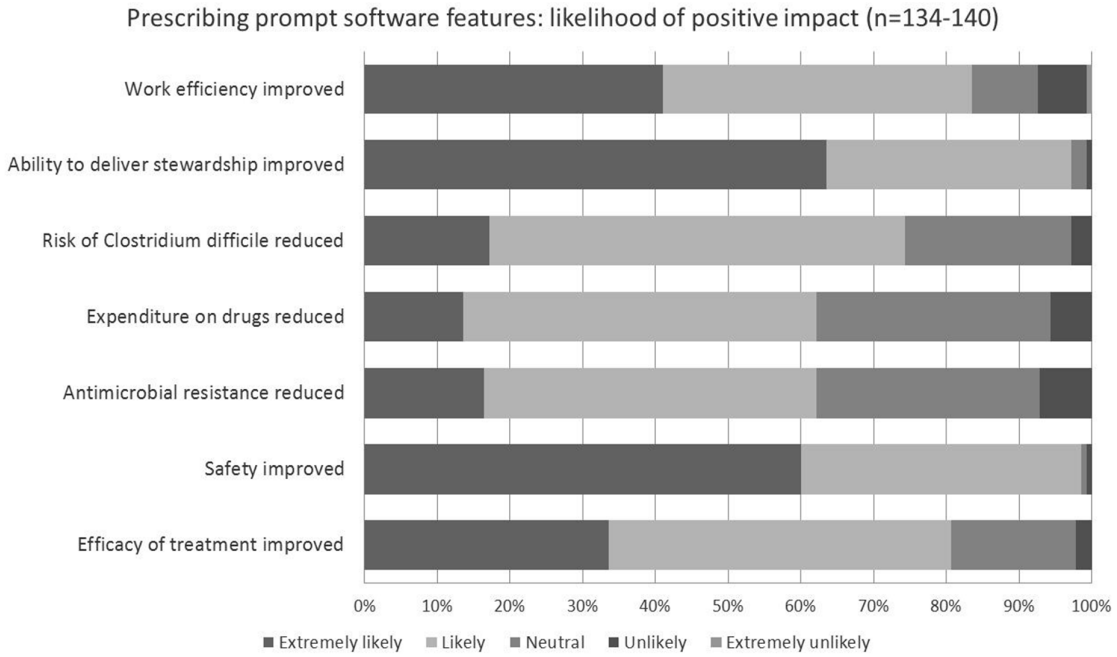
523 **Figure 3. Respondent opinions of the likely impact of Prescribing Prompt software features**
524 **on clinical, microbiological and process outcomes**



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528 **Table 4. Active Prescription Surveillance software features ranked in order of respondent-**
529 **assigned priority**

Software feature	Number of responses	Essential	High priority	Medium priority	Low priority	Not a priority
New Rx of critical drug	135	51.9%	41.5%	6.7%	0.0%	0.0%
Ongoing Rx of critical drug	135	42.2%	42.2%	15.6%	0.0%	0.0%
Drug-indication mismatch	134	31.3%	47.8%	17.9%	3.0%	0.0%
Long IV/oral course	135	28.9%	54.8%	14.8%	0.7%	0.7%
Missed Abx doses	132	26.5%	43.9%	22.7%	6.1%	0.8%
Long IV course	132	25.0%	59.8%	14.4%	0.8%	0.0%
High-dose aminoglycoside	133	23.3%	40.6%	25.6%	9.0%	1.5%
New Rx for sepsis of unknown origin	134	20.1%	57.5%	19.4%	1.5%	1.5%
New Rx of any antibiotic	136	19.1%	27.9%	33.1%	17.6%	2.2%
Ongoing Rx of any antibiotic	133	13.5%	30.8%	36.1%	15.0%	4.5%
New Rx for diagnosis of interest	135	13.3%	51.9%	30.4%	3.0%	1.5%

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533 **Figure 4. Respondent opinions of the likely impact of Active Prescription Surveillance software**

534 **features on clinical, microbiological and process outcomes**

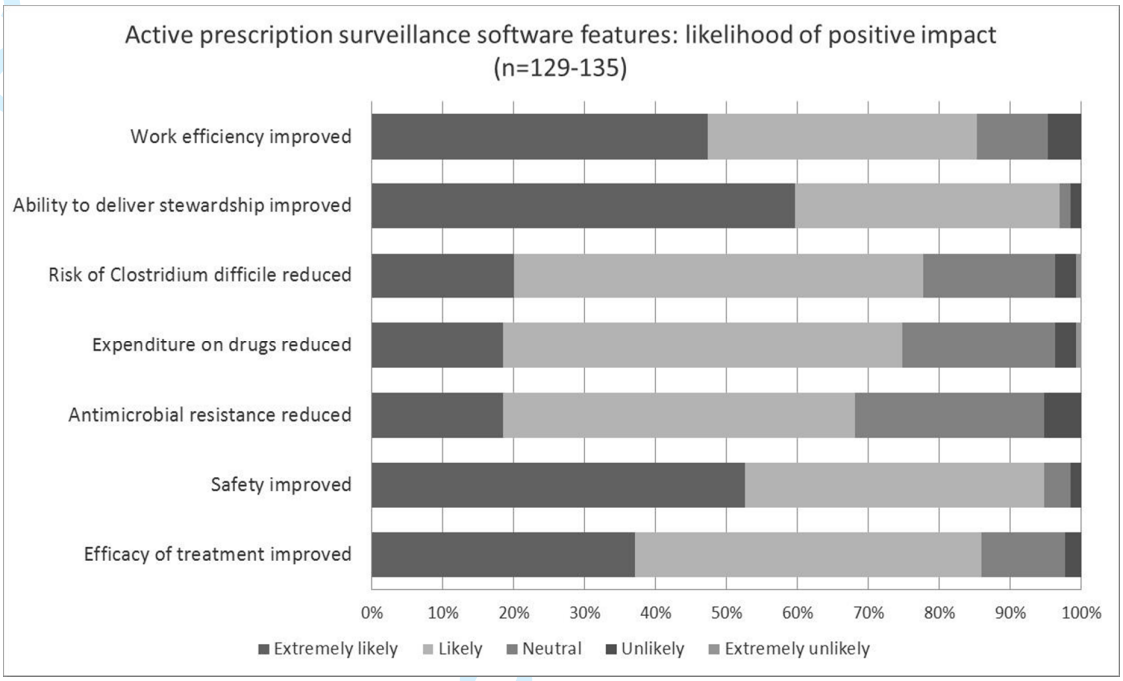

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Table 5. Prescribing Trend Surveillance software features ranked in order of respondent-assigned priority

Software feature	Number of responses	Essential	High priority	Medium priority	Low priority	Not a priority
Trends in point prevalence	130	29.2%	44.6%	23.1%	2.3%	0.8%
Trends in missed doses	130	26.9%	45.4%	24.6%	2.3%	0.8%
Trends in delayed stat doses	130	23.1%	53.8%	19.2%	3.8%	0.0%
Trends in total days of therapy (DOTs)	130	13.1%	39.2%	37.7%	7.7%	2.3%
Trends in average length of therapy (LOT)	131	13.0%	53.4%	29.0%	3.8%	0.8%

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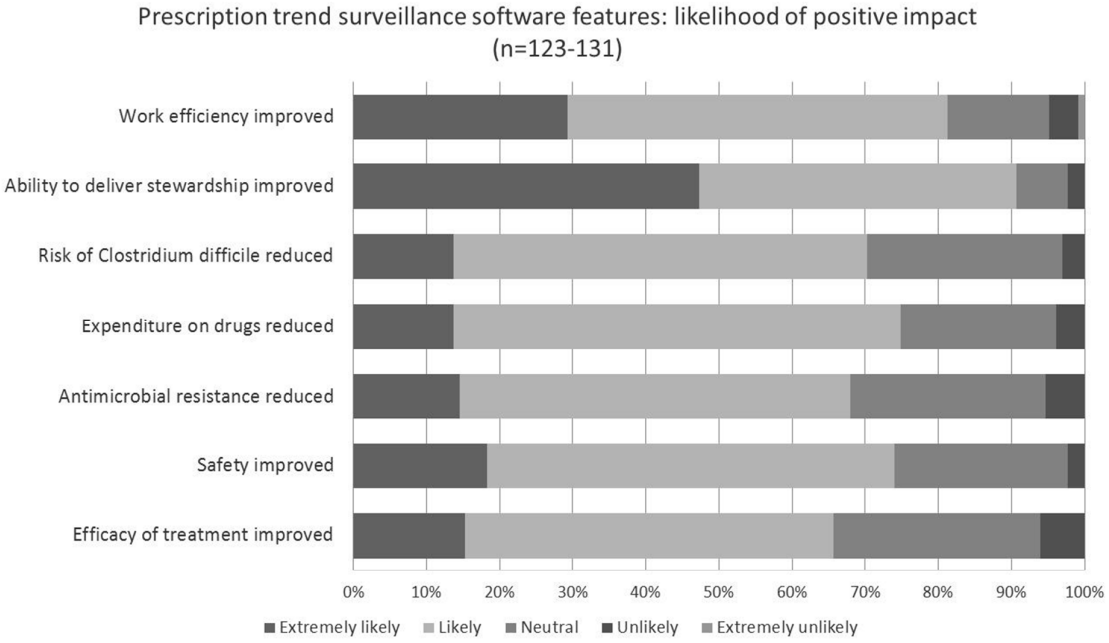
542 **Figure 5: Respondent opinions of the likely impact of Prescribing Trend Surveillance software**

543 **features on clinical, microbiological and process outcomes**



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546 **Table 6: Respondent opinions of technical aspects of prescribing trend surveillance reporting**
547 **software features ranked in order of respondent-assigned priority**

	Response Count	Importance attributed by respondents				
		Very high	High	Moderate	Some	None
ACTIVITY DENOMINATOR						
EPMA patient days (total number of patients multiplied by number of days)	130	16.2%	40.0%	31.5%	10.8%	1.5%
EPMA admissions (new patients)	130	13.8%	38.5%	36.2%	10.8%	0.8%
REPORT TIME INTERVALS						
Annually	130	48.5%	31.5%	13.1%	3.8%	3.1%
Quarterly	130	40.0%	42.3%	13.8%	2.3%	1.5%
Monthly	130	24.6%	36.9%	29.2%	6.9%	2.3%
Weekly	129	7.8%	20.9%	27.9%	28.7%	14.7%
Daily	130	4.6%	15.4%	22.3%	26.2%	31.5%
HOSPITAL SUBDIVISIONS						
Whole hospital	129	49.6%	38.8%	6.2%	4.7%	0.8%
Clinical speciality	128	42.2%	41.4%	11.7%	3.9%	0.8%
Hospital departments	128	40.6%	36.7%	16.4%	4.7%	1.6%
Wards	128	32.8%	39.1%	21.1%	5.5%	1.6%
Responsible consultant physician	129	32.6%	37.2%	20.2%	9.3%	0.8%

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DRUG GROUPINGS						
Individual drugs	129	48.8%	36.4%	10.9%	2.3%	1.6%
Drug class (e.g. macrolides)	128	41.4%	41.4%	13.3%	3.9%	0.0%
Locally-defined drug group (e.g. broad-spectrum, narrow-spectrum)	130	40.0%	38.5%	16.9%	4.6%	0.0%
Antibacterials, antifungals, antivirals, antiparasitics	127	33.9%	37.0%	15.7%	13.4%	0.0%
All antimicrobials	130	30.0%	36.9%	19.2%	11.5%	2.3%
By route of administration	129	24.0%	40.3%	24.8%	8.5%	2.3%

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551 **Table 7. Thematic analysis of freetext narrative responses to the question: "Do you have any**
552 **other suggestions for potential functionality for electronic prescribing and medicines**
553 **administration systems?"**

Theme	Frequency	Details of additional user requirements
Microbiology laboratory system interface	13	• Susceptibility testing – prescription conflict ("drug-bug mismatch")
		• Previous microbiology including healthcare-associated infections
Reporting functions	9	• Flexibility of reporting – capacity to customise reports locally
		• Reporting to national standard (Start Smart – Then Focus)
		• Defined daily doses in addition to DOTs
Clinical information system interface	5	• Link to guidelines
		• Drug information: adverse effects, drug administration, drug monitoring
		• Disease severity scoring systems
Restriction systems	5	• Authorisation codes
		• Authorisation by named specialist
		• System access restricted to trained prescribers
		• Compulsory recording of indication
Additional narrative fields	5	• Infection specialist advice
		• Justification for off-guideline prescribing
		• Precise nature of drug allergy
		• Reasons for missed doses
Soft stops / review dates	4	• Block administration until review
		• Patient safety of automatic prescription stop
Dosing support	3	• Dosing by age, weight and renal function
Drug history	3	• Primary care and previous hospital admissions
Stat doses	3	• Automatic associated stat dose and appropriately spaced maintenance dose
		• Stat dose remains visible if delayed
Miscellaneous	19	

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Electronic Prescribing & Antibiotic Stewardship

Survey of opinions of infection specialists on electronic prescribing and antibiotic stewardship.

The aim of this research is to IMPROVE THE DESIGN OF ELECTRONIC PRESCRIBING SYSTEMS TO PROMOTE ANTIBIOTIC STEWARDSHIP.

We would be very grateful if infection specialists could take a few moments to respond to this brief but important survey. There are 4 pages with a total of 42 questions and completion takes 10-12 minutes.

Please respond EVEN IF YOU DO NOT CURRRENTLY HAVE AN E-PRESCRIBING SYSTEM.

The results will be fed back to the software manufacturers, NHS England, Dept of Health, and published in a pharmacy / infection / health informatics journal.

This research does not need NHS Research Ethics Committee approval for sites in England, Scotland, Wales or Northern Ireland http://www.hra-decisiontools.org.uk/ethics/

Sincere thanks.
Debbie Cumming (Isle of Wight) & Kieran Hand (Southampton)

1. Professional Group

- [ ] Pharmacist (infection specialist)
- [ ] Pharmacist (not infection specialist)
- [ ] Pharmacy technician
- [ ] Medical Microbiologist
- [ ] Infectious Diseases Physician

Other (please specify)

2. Experience in specialist infection role

- [ ] 0-1 year
- [ ] 1-2 years
- [ ] 2-5 years
- [ ] 5-10 years
- [ ] >10 years
- [ ] N/A (non-specialist)

3. Acute hospital setting

- [ ] Teaching (trusts with an attached undergraduate medical school)
- [ ] District General Hospital
- [ ] Specialised (trusts with very restricted specialties, such as orthopaedic and children's trusts)
- [ ] Independent (non NHS)

4. Hospital size

- [ ] Very large (>1500 beds)
- [ ] Large (1001-1500 beds)
- [ ] Medium (501-1000 beds)
- [ ] Small (<501 beds)

5. Does your hospital currently use an electronic prescribing and/or medicines administration (EPMA) system for SOME or ALL wards?

- [ ] Yes, EPMA on all wards
- [ ] Yes, EPMA on some wards
- [ ] Yes, but electronic prescribing only (no medicines administration function)
- [ ] Yes, but ICU/Oncology system(s) only.
- [ ] No, but expected within 5 years
- [ ] No, NOT expected within 5 years

6. How long has your EPMA or electronic prescribing system been in use?

- [ ] 0-1 year
- [ ] 1-2 years
- [ ] 2-5 years
- [ ] 5-10 years
- [ ] >10 years
- [ ] N/A

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Electronic Prescribing & Antibiotic Stewardship

Section 1: PRESCRIBING PROMPTS

Please indicate the priority you would place upon each of the following options.

7. TREATMENT PROTOCOLS / ORDER SETS -
The prescriber has an opportunity to select an infection (e.g. pneumonia, community-acquired, severe) and the system will automatically populate the prescription with the locally pre-defined treatment regimen (single drug or combination of drugs) and standard doses.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

8. ALLERGY CHECKER -
The prescriber will be alerted via a pop-up message if attempting to prescribe an antimicrobial from the same class of drugs as a previously recorded allergy.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

9. INTERACTION CHECKER -
The prescriber will be alerted via a pop-up message if attempting to prescribe an antimicrobial that interacts in a clinically-significant manner with any of the currently-prescribed drugs.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

10. DOSE CHECKER (ADULTS) -
The prescriber will be alerted via a pop-up message if attempting to prescribe a dose of antimicrobial that is above or below a pre-specified dose range for adult inpatients.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

11. DOSE CHECKER (CHILDREN) -
The prescriber will be alerted via a pop-up message if attempting to prescribe a dose of antimicrobial that is above or below a pre-specified dose range for inpatient age or weight.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

12. CRITICAL ANTIMICROBIAL ALERT -
The prescriber will be alerted via a pop-up message if attempting to prescribe certain locally-defined critical antimicrobials (e.g. carbapenems), with brief details of actions required. The prescriber will NOT be blocked from prescribing the critical antimicrobial.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

13. RESTRICTED ANTIMICROBIAL BLOCK -
Prescribing of restricted antimicrobials will be limited to certain groups of prescriber (e.g. consultant) and blocked for unauthorised prescribers.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

14. RESTRICTED ANTIMICROBIAL AUTHORISATION -
Prescribing of restricted antimicrobials will require authorisation by an infection specialist or senior doctor (e.g. by entering a release code).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

15. SOFT STOPS -
The system will allow the prescriber to nominate a date when the antimicrobial prescription should be reviewed with a view to stopping, changing treatment or switch to oral. After the review date has passed, the drug will remain visible and available to nursing staff to administer but will be prominently highlighted as being past the review (soft stop) date.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

16. INDICATION PROMPT -
When selecting an antimicrobial, the prescriber will be required to complete a mandatory field for indication/provisional diagnosis from a drop-down list of body systems or indications. This data field may be edited later when the indication is confirmed. ‘Sepsis of undetermined origin’ should be an option.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

17. BLOOD LEVEL MONITORING ALERT -
The prescriber will be alerted via a pop-up message that they have selected a drug which requires blood level monitoring and brief details of actions required.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

18. BLOOD LEVEL MONITORING PROTOCOL / ORDER SET -
When a relevant drug is prescribed, the system will automatically pair the drug prescription with a "prescription" for a blood specimen to be taken at an appropriate time post-dose.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

19. If some or all of these PRESCRIBING PROMPT functionalities are available in an electronic prescribing system, please indicate the likelihood of a positive impact upon the following outcomes:

	Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely
Efficacy of treatment improved	○	○	○	○	○
Safety improved	○	○	○	○	○
Antimicrobial resistance reduced	○	○	○	○	○
Expenditure on drugs reduced	○	○	○	○	○
Risk of Clostridium difficile reduced	○	○	○	○	○
Ability to deliver stewardship improved	○	○	○	○	○
Work efficiency improved	○	○	○	○	○

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Electronic Prescribing & Antibiotic Stewardship

Section 2: ACTIVE SURVEILLANCE

Active surveillance reports should be available to specialist pharmacists and infection doctors and may be used to plan stewardship ward rounds or telephone consults.

Reports would typically include: patient name, date of birth, hospital number, inpatient location in the hospital, drug name, drug dose, start date, stop date (if specified), prescriber and responsible consultant.

Please indicate the priority you would place upon each of the following options.

20. Daily report of NEW prescriptions of CRITICAL antimicrobials -
Generate a list of inpatients newly-prescribed, locally-defined, CRITICAL antimicrobials (e.g. carbapenems) within the last 24 hours (excluding stat doses).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

21. Daily report of NEW prescriptions of ALL antimicrobials -
Generate a list of inpatients newly-prescribed ANY antimicrobial within the last 24 hours (excluding stat doses).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

22. Daily report of ONGOING prescriptions of CRITICAL antimicrobials -
Generate a list of all inpatients currently prescribed CRITICAL antimicrobials (e.g. carbapenems).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

23. Daily report of ONGOING prescriptions of ALL antimicrobials -
Generate a list of all inpatients currently prescribed ANY antimicrobial.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

24. Daily report of DRUG-INDICATION MISMATCH -
Generate a list of all inpatients newly-prescribed an antimicrobial within the last 24 hours that is not authorised for the recorded indication/provisional diagnosis.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

25. Daily report of prescriptions for SEPSIS OF UNDETERMINED ORIGIN -
Generate a list of all inpatients newly-prescribed an antimicrobial within the last 24 hours with a recorded indication/provisional diagnosis of ‘sepsis of undetermined origin’.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

26. Daily report of prescriptions for DIAGNOSIS OF INTEREST -
Generate a list of all inpatients newly-prescribed an antimicrobial within the last 24 hours with a recorded indication/provisional diagnosis of interest locally (e.g. septic shock).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

27. Daily report of MISSED DOSES -
Generate a list of all inpatients currently prescribed ANY antimicrobial with a missed dose recorded in the previous 24 hours, including REASON FOR MISSED DOSE (if recorded).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

28. Daily report of LONG INTRAVENOUS COURSE LENGTH -
Generate a list of all inpatients currently prescribed an INTRAVENOUS antimicrobial started >72 hours ago. 72-hour cut-off may be modified locally.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

29. Daily report of LONG TOTAL COURSE LENGTH -
Generate a list of all inpatients currently on day 8 or longer of sequential therapy with any drug from BNF Chapter 5 (antimicrobials) by any route of administration. Day 8 cut-off may be modified locally.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

30. Daily report of HIGH-DOSE AMINOGLYCOSIDE prescriptions -
Generate a list of inpatients prescribed doses of gentamicin/tobramycin/amikacin above a locally-defined total daily dose threshold (e.g. 300mg/300mg/1000mg).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

31. If some or all of these ACTIVE SURVEILLANCE functionalities are available in an electronic prescribing system, please indicate the impact you anticipate on the following outcomes:

	Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely
Efficacy of treatment improved	○	○	○	○	○
Safety improved	○	○	○	○	○
Antimicrobial resistance reduced	○	○	○	○	○
Expenditure on drugs reduced	○	○	○	○	○
Risk of Clostridium difficile reduced	○	○	○	○	○
Ability to deliver stewardship improved	○	○	○	○	○
Work efficiency improved	○	○	○	○	○

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Electronic Prescribing & Antibiotic Stewardship

Section 3: PASSIVE SURVEILLANCE

Reports should be available to named pharmacists and infection doctors and may be used to monitor performance over monthly, quarterly or annual time trends for a date range specified by the user.

Please indicate the priority you would place upon each of the following functionality options for electronic prescribing and medicines administration systems.

32. Antimicrobial days of therapy (DOTs) -
Generate a report (line trend over time) of the number days of therapy (DOTs) for all antimicrobials prescribed during the selected time interval (e.g. total DOTs per month).

One DOT represents the administration of a single agent on a given day regardless of the number of doses administered or dosage strength. For example, administration of ceftriaxone as 4g od or as 2g bd would both represent 1 DOT. A single patient receiving both vancomycin and ceftazidime would be recorded as receiving 2 DOTs (1 of vancomycin and 1 of ceftazidime) [Polk RE et al, CID 2011].

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

33. Antimicrobial length of therapy (LOTs) -
Generate a report (line trend over time) with the AVERAGE length of therapy (LOT) for all antimicrobial courses during the selected time interval (e.g. average LOT per month).

The LOT is the number of sequential days that a patient receives ANY systemic antimicrobial drug(s) from BNF Chapter 5, irrespective of the number of different drugs [Polk RE et al, CID 2011].

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

34. Percentage of inpatients prescribed antimicrobials (POINT PREVALENCE) -
Generate a report (line trend over time) with the percentage of all patients on the EPMA system during the selected time interval who were prescribed at least one dose of a drug from BNF Chapter 5 (antimicrobials).

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

35. DELAYED STAT DOSES -
Generate a report (line trend over time) with the number of incidents where a patient is prescribed a stat dose of a drug from BNF Chapter 5 (antimicrobials) and administration is delayed by >1hour from the prescribed time for the selected reporting time interval.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

36. MISSED DOSES of antimicrobials -
Generate a report (line trend over time) of the number of missed doses of a drug from BNF Chapter 5 (antimicrobials) for the selected reporting time interval.

Not a priority	Low priority	Medium priority	High priority	Essential
○	○	○	○	○

37. For passive surveillance reports described above (DOTs and LOTs), how important is it to be able to adjust reports for the following activity denominators?

	No importance	Some importance	Moderate importance	High importance	Very high importance
EPMA patient days (total number of patients multiplied by number of days)	○	○	○	○	○
EPMA admissions (new patients)	○	○	○	○	○

38. For passive surveillance reports described above (DOTs, LOTs and Point Prevalence), how important is it to be able to generate reports at the following time intervals?

	No importance	Some importance	Moderate importance	High importance	Very high importance
Annually	○	○	○	○	○
Quarterly	○	○	○	○	○
Monthly	○	○	○	○	○
Weekly	○	○	○	○	○
Daily	○	○	○	○	○

39. For passive surveillance reports described above (DOTs, LOTs and Point Prevalence), how important is it to be able to generate reports for the following subdivisions?

	No importance	Some importance	Moderate importance	High importance	Very high importance
Whole hospital	○	○	○	○	○
Hospital departments	○	○	○	○	○
Wards	○	○	○	○	○
Clinical speciality	○	○	○	○	○
Responsible consultant doctor	○	○	○	○	○

40. For passive surveillance reports described above (DOTs, LOTs and Point Prevalence), how important is it to be able to generate reports for the following drug groups?

	No importance	Some importance	Moderate importance	High importance	Very high importance
All antimicrobials (BNF Chapter 5)	○	○	○	○	○
Antibacterials, antifungals, antivirals, antiparasitics (BNF Chapter 5.1 etc)	○	○	○	○	○
Drug class (e.g. macrolides)	○	○	○	○	○
Drug group (e.g. broad-spectrum, narrow-spectrum - locally defined)	○	○	○	○	○
Individual drugs	○	○	○	○	○
By route of administration	○	○	○	○	○

41. If some or all of these PASSIVE SURVEILLANCE functionalities are available in an electronic prescribing system, please indicate the impact you anticipate on the following outcomes:

	Extremely unlikely	Unlikely	Neutral	Likely	Extremely likely
Efficacy of treatment improved	○	○	○	○	○
Safety improved	○	○	○	○	○
Antimicrobial resistance reduced	○	○	○	○	○
Expenditure on drugs reduced	○	○	○	○	○
Risk of Clostridium difficile reduced	○	○	○	○	○
Ability to deliver stewardship improved	○	○	○	○	○
Work efficiency improved	○	○	○	○	○

42. We are extremely grateful to you for taking the time to participate in this survey.

We hope the results will influence the design of electronic prescribing systems and improve the care of patients with infection.

DO YOU HAVE ANY OTHER SUGGESTIONS FOR POTENTIAL FUNCTIONALITY FOR ELECTRONIC PRESCRIBING AND MEDICINES ADMINISTRATION SYSTEMS? Please describe your ideas below.

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