J Antimicrob Chemother
https://doi.org/10.1093/jac/dkad235

Journal of Antimicrobial Chemotherapy

Assessing the conversion of electronic medical record data into antibiotic stewardship indicators

L. Renggli[1]*, C. Plüss-Suard[1], M. Gasser[1], B. Sonderegger[2] and A. Kronenberg [1]

[1]*Swiss Centre for Antibiotic Resistance (ANRESIS), Institute for Infectious Diseases, University of Bern, Bern, Switzerland;* [2]*Department of Infectious Diseases and Hospital Epidemiology, Cantonal Hospital Lucerne, Lucerne, Switzerland*

*Corresponding author. E-mail: luzia.renggli@unibe.ch
@anresis

Received 19 December 2022; accepted 13 July 2023

Background: Measuring the appropriateness of antibiotic use is crucial for antibiotic stewardship (ABS) programmes to identify targets for interventions.

Objectives: To assess the technical feasibility of converting electronic medical record (EMR) data into ABS indicators.

Methods: In this observational feasibility study covering a period of 2 years, the EMRs of patients hospitalized at a large non-university hospital network and receiving at least one dose of a systemic antibiotic were included. ABS indicators measuring steps in the process of antibiotic prescription proposed by the literature were collected and rephrased or defined more specifically to be calculable if needed. Algorithms were programmed in R to convert EMR data into ABS indicators. The indicators were visualized in an interactive dashboard and the plausibility of each output value was assessed.

Results: In total, data from 25 337 hospitalizations from 20 723 individual patients were analysed and visualized in an interactive dashboard. Algorithms could be programmed to compute 89% (25/28) of all pre-selected indicators assessing treatment decisions automatically out of EMR data, with good data quality for 46% (13/28) of these indicators. According to the data quality observed, the most important issues were (i) missing or meaningless information on indication (e.g. 'mild infection') and (ii) data processing issues such as insufficiently categorized metadata.

Conclusions: The calculation of indicators assessing treatment decisions from EMRs was feasible. However, better data structure and processing within EMR systems are crucial for improving the validity of the results.

Introduction

Improving the adequate use of antibiotics is crucial to slow the spread of antimicrobial resistance and is therefore addressed by antibiotic stewardship (ABS) programmes.[1] Further valuable effects of ABS programmes that have been demonstrated are reduced mortality, length of hospitalization and readmission rates, resulting in reduced healthcare costs and enhanced patient safety.[2–5] Among others, Aldeyab *et al.*[6] showed the effect of restricting the prescription of fluoroquinolones in reducing their use followed by an increase in ciprofloxacin susceptibility rates in ESBL-producing bacteria from 16% to 28%. In Switzerland, it was pointed out that consumption of anti-MRSA antibiotics was lower in hospitals that restricted the prescription of anti-MRSA antibiotics and had an established ABS group.[7]

To date, surveillance of antibiotic use has been mainly based on quantitative measures, converting pharmacy sales data into defined daily doses (DDDs), a technical unit of measurement defined by the WHO,[8] or on prescription data from point prevalence studies.[9]

However, to optimize therapy, metrics evaluating the quality of antibiotic use are needed. For this purpose, a consensus of quality indicators for antibiotic use in the inpatient setting was elaborated by van den Bosch *et al.*[10] and Monnier *et al.*[11] The more comprehensive set of quality indicators by Monnier *et al.* encompassed: (i) structural indicators reflecting organizational aspects of healthcare; (ii) process indicators describing the care delivered to patients;

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and (iii) outcome indicators such as death or antimicrobial resistance. To measure process indicators, data on antibiotic prescriptions are needed. The continuous monitoring of patient-level antibiotic prescription data is not yet done in the majority of countries worldwide as it is too resource-intensive.[12] The implementation of electronic medical record (EMR) and clinical decision support systems in an increasing number of Swiss hospitals provides prescription support for physicians and leads to increasing availability of patient-level antibiotic prescription data, which could improve the quality of antibiotic consumption monitoring.[13]

The aim of this project was to assess the technical feasibility of converting EMR data into ABS indicators, which have been proposed in the literature. A second aim was to calculate a first estimate of these ABS indicators.

Methods

Design and study population

A retrospective observational study was conducted at a large non-university hospital network over a period of 2 years. It is an 850-bed acute care hospital network with three locations. EMR data of adult and paediatric patients admitted to the hospital network between 1 October 2019 and 30 September 2021 and receiving at least one antibacterial for systemic use (ATC codes J01 and P01AB01) were included. Patients who were discharged after 30 September 2021 or patients refusing general consent were excluded. Patient data were anonymized before analysis. The study was approved by the Swiss Ethics Commission of Northwest and Central Switzerland (EKNZ) reference number 2021-00059.

Selection and categorization of (ABS) indicators

ABS indicators were selected in four steps. First, a literature search was performed, summarizing commonly used ABS process indicators. Second, we excluded ABS indicators that do not measure the steps of the process of antibiotic therapy [e.g. ABS indicators measuring the information technology (IT) process], analyse the administration of antibiotics or describe unspecific targets. Third, the ABS indicators definitions were rephrased or specified to be calculable by using EMR data, if needed (Table S1, available as Supplementary data at *JAC* Online). In the process of specifying, some ABS indicators of the literature were split into several new ABS indicators. In the fourth step, the ABS indicators were categorized into treatment decision indicators and documentation quality indicators.

Metrics for analysing antibiotic consumption patterns were added (see Table S2).[9,14,15]

Data collection and processing (Figure 1)

Antibiotic prescription data were obtained from the EMR Epic software® (see Table S3) and linked with microbiological data from the Swiss Centre for Antibiotic Resistance (ANRESIS) database (see Table S4). The microbiological data were stored in the EMR as a pdf file from the laboratory and not structurally available. We linked the data by using the identifier of the microbiological sample with microbiological data from the ANRESIS database (see Table S4). ANRESIS is a representative surveillance system that continuously collects national data on antibiotic consumption and antibiotic resistance.[16] Data were generated during the daily clinical routine, independent of the study. The algorithms for converting the EMR data into ABS indicators were written in RStudio® version 2022.2.0.443 (R version 4.2.2, RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA, USA).

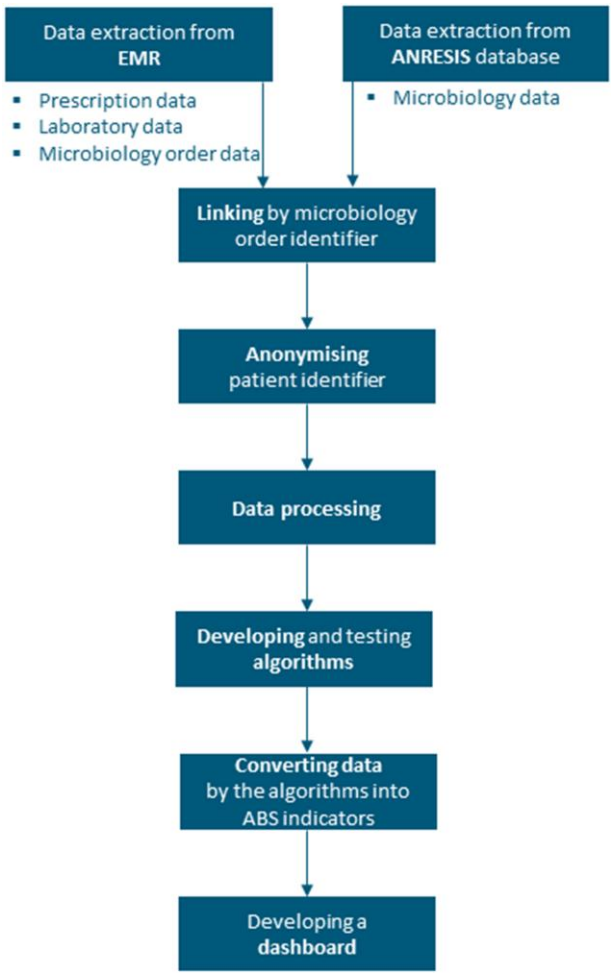

Figure 1. The steps of data collection and processing. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

Calculation and plausibility assessment of indicators

ABS indicators assessing treatment decisions were computed using the start time when the antibiotics were prescribed, but if an antibiotic was administered before it was prescribed, the time of the first administration was used as the prescription start time, assuming late documentation. Prescriptions for surgical prophylaxis (according to the field 'indication') were excluded from the analysis of ABS indicators measuring treatment decisions, except for the ABS indicators assessing surgical prophylaxis itself.

The output values of the indicators were quantified as the number of patients receiving an antibiotic and meeting the criterion of the indicator divided by all patients receiving antibiotics, or as proportion of total for subgroups of indicators. Plausibility of the output values was assessed by the study team, including the local infectious diseases specialist, and categorized as 'good data quality' or 'incomplete data', where missing information was possible due to incomplete documentation or data processing issues, i.e. some information was not stored in a structure allowing (systematic) extraction. A third category was 'indicator not computable' due to data processing issues or not being considered in the application for ethical approval. RStudio® was used to quantify the selected ABS indicators and to visualize the ABS indicators in an interactive dashboard. The dashboard presented the indicators at different levels of

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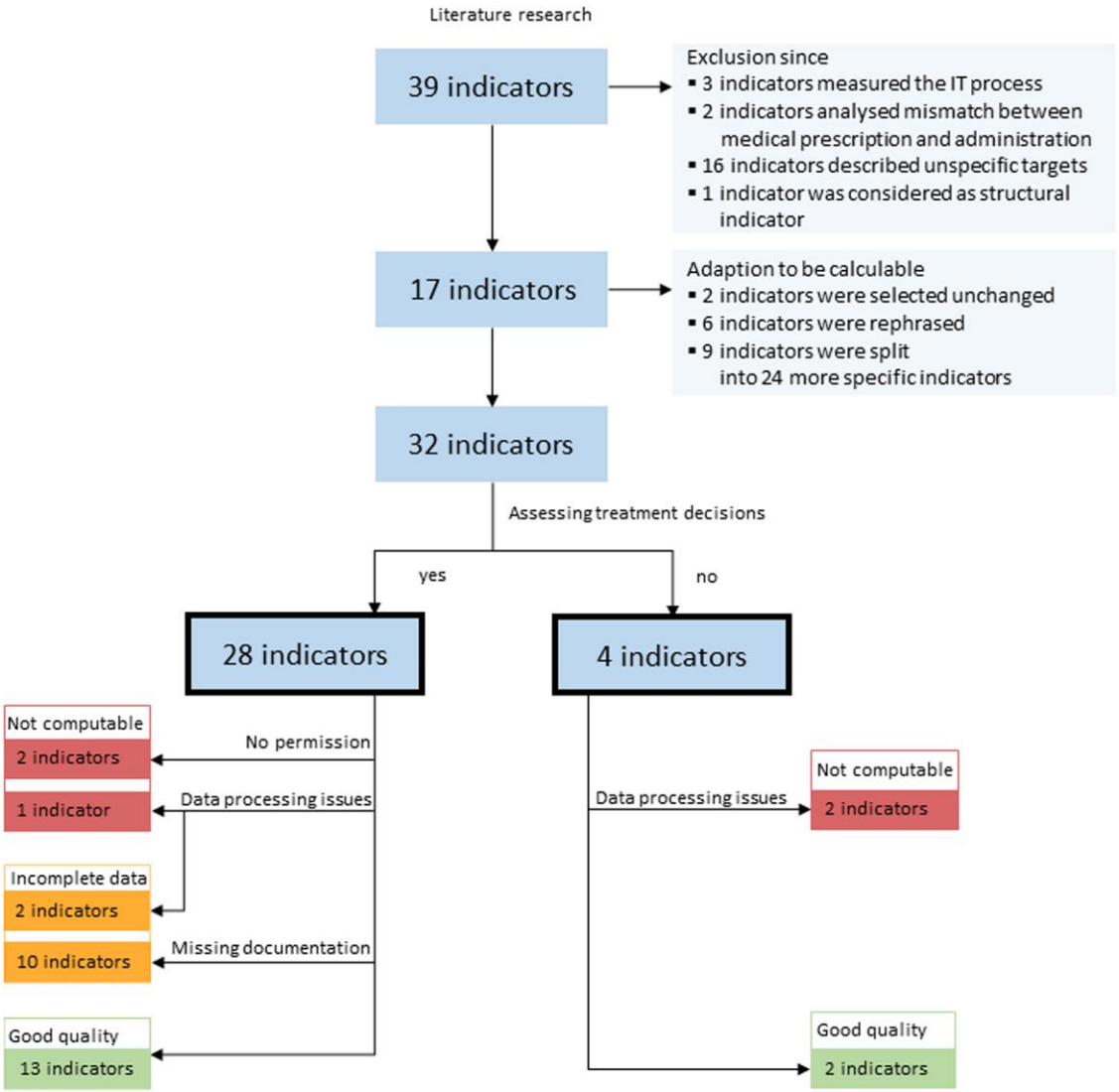

Figure 2. Selection process of selecting, coding and analysing ABS indicators. Data were categorized as good quality, incomplete data due to missing documentation or data processing issues, and not computable due to data processing issues or not being considered in the application for ethical approval. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

interest such as department, year, month and age category (<15 years versus 15–65 years versus >65 years).

As there was no indication documented for numerous prescriptions and the plausibility of results were doubted, a *post hoc* subanalysis was performed excluding patients with a duration of total antibiotic therapy less than 24 h assuming prophylaxis, regardless of staying in the surgery or another ward. In another subanalysis, cefuroxime and cefazolin were excluded, as these substances were mainly used for surgical prophylaxis according to a local infectious disease specialist.

Results

Definition of ABS indicators (Figure 2)

The first selection of ABS indicators consisted of 39 ABS indicators, comprising 36 ABS indicators described by Monnier *et al.* in their latest review on quality indicators for antibiotic use in the inpatient setting, and 3 additional quality indicators used in the Swiss point prevalence study.[9,11] As the review of Monnier *et al.* summarized almost completely all process indicators found in the literature, it was used as a basic list and supplemented when the wording in other studies was more specific (see Table S1).

In the second step, 22 ABS indicators were excluded, as 3 measured IT procedures, 2 analysed the mismatch between medical prescription and administration, and the terminology of 16 lacked the specificity to be rephrased as computable ABS indicators. Of the remaining 17 ABS indicators, 2 indicators were selected unchanged, 6 indicators were rephrased, and the remaining 9 indicators were split into 24 more specific and computable ABS indicators. This resulted in a dataset of 32 process indicators, which were categorized into 28 indicators assessing treatment decisions and 4 indicators assessing documentation quality. Details for each indicator are given in Table S1.

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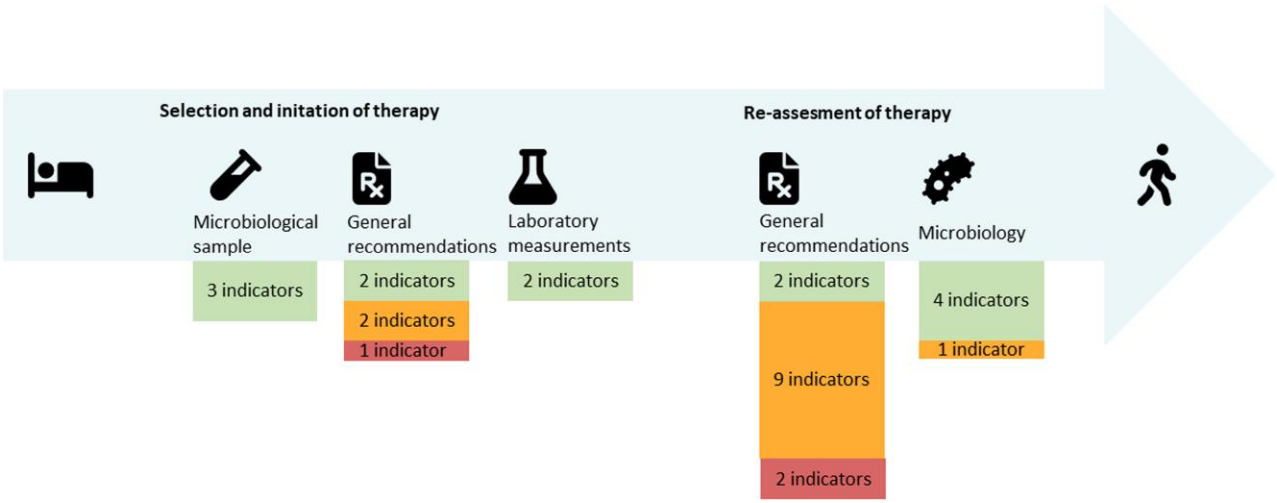

Figure 3. ABS indicators assessing treatment decisions classified based on data categorized as good quality (green), incomplete (orange) and not computable (red). This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

Analysing ABS indicators

Data extraction allowed us to program algorithms for 89% (25/28) of the pre-selected ABS indicators assessing treatment decisions (Figure 2, Figure 3, Table 1) and for 50% (2/4) of the ABS indicators assessing documentation quality (Figure 2, Table 2). The two ABS indicators that evaluated therapeutic drug monitoring could not be measured, as these data had not been considered in the application for ethical approval. The proportion of patients with a documented severe allergic reaction against penicillin and nonetheless treated with a β-lactam could not be measured since documentation of the allergy could not be evaluated due to data processing issues. More specifically, allergies to antibiotics could not systematically be distinguished from other recorded allergens.

Data quality was good for 46% (13/28) of treatment decision indicators and 50% (2/4) of documentation quality indicators (Figure 2). Data may be incomplete for the two ABS indicators 'prescription was edited within 3 days' and 'prescription was edited within 24 h after microbiological result'. Due to the data format, we could identify changes in therapy (including stopping therapy) or active new prescribing of the same therapy (which technically led to a new prescription number); however, if the therapy was simply continued, we were unable to evaluate if this was an active decision.

A major issue was the incomplete documentation of the indication for antibiotic therapy, which affected nine ABS indicators. In fact, meaningful documentation of the indication was available only in a minority of hospitalizations. An indication was considered meaningful (5%) if a clear infectious disease was named (e.g. pneumonia, pyelonephritis, sepsis, neutropenic fever), and meaningless (37%) if only general terms were used such as 'mild to moderate infection', 'general indication' or 'fever'. In 58% of the hospitalizations, indication was completely missing. Therefore, antibiotics given for surgical prophylaxis could not be properly excluded using the field 'indication'. In Epic systems®, a field indication belongs to the prescription, such as dosage and duration. It has to be filled in by the treating physician; pre-defined indications were suggested but free text was also possible and documentation was not mandatory. To assess the impact of the incomplete exclusion of surgical prophylaxis for some ABS indicators, we performed two subanalyses, extending the definitions of surgical prophylaxis either to antibiotic therapy for less than 24 h or excluding all antibiotic prescriptions with cefazolin or cefuroxime, the antibiotics used mainly for surgical prophylaxis in the study hospital network. The numbers of excluded patients in these subanalyses were 9112 (36%) and 5826 (23%) patients, respectively. A total of 5532 patients received cefazolin, and 267 received cefuroxime. Consequently, higher proportions were measured for the following ABS indicators: 'edited prescription within 3 days', 'duration of (initial) therapy', 'antibiotic therapy despite low initial C-reactive protein (CRP')', 'microbiological sample taken during hospitalization' and all ABS indicators describing the first adjustments in antibiotic therapy (see Table S5). As CRP is generally not measured before an invasive procedure, the corresponding ABS indicator was judged as unlikely to be biased by incomplete documentation of surgical prophylaxis. In total, 32% (9/28) of treatment decision indicators were presumed to be affected by missing documentation of surgical prophylaxis. In addition, it affected the two antibiotic consumption pattern indicators 'duration of therapy' and 'proportion of patients receiving antibiotics for surgical prophylaxis' (Table 3). The other 78% (7/9) of the metrics assessing antibiotic consumption patterns were considered good-quality data.

Estimation and visualization of ABS indicators

In total, data from 25 337 hospitalizations from 20 723 individual patients were analysed (details on the study population in Table S6). The estimated numbers are given in Tables 1, 2 and 3 and are presented in an interactive dashboard. Selected ABS indicators were visualized as tacho graphics in the first tab of the interactive dashboard (Figure 4). In addition, all ABS indicators were depicted in tables, allowing comparison between location

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Table 1. ABS process indicators assessing treatment decisions (for the entire study period)

Process indicator	Proportion of patients receiving antibiotics, % (*n*)	Data quality category
Selection and initiation of therapy		
Microbiological sample		
Microbiological sample taken during hospitalization	51 (25213)	Good
Microbiological sample: % samples taken before start of therapy	85 (15199)	Good
Blood cultures taken before start of therapy: % patients with at least two blood samples taken before start of therapy	85 (7118)	Good
General recommendations		
Start of AB therapy for patients with bacteraemia at admission		Good
≤3 h	69 (661)	
>3 and ≤24 h	24 (661)	
>24 h	8 (661)	
% of patients with bacteraemia and start of IV AB therapy	98 (661)	Good
Surgical prophylaxis: % patients with AB therapy <24 h	81 (190)	Incomplete
Surgical prophylaxis: % patients with one administration	39 (190)	Incomplete
Patients with a severe allergic reaction against penicillin documented and nonetheless treated with a β-lactam	—	Not computable
Laboratory measurements		
Initial PCT < 0.25 µg/L and continuation of AB therapy >24 h	32 (3480)	Good
Initial CRP < 20 mg/L and continuation of AB therapy >24 h	19 (17155)	Good
Re-assessment of therapy		
General recommendations		
Prescription was not adapted to impaired renal function[a]	30 (997)	Good
Thereof prescriptions should have been stopped due to impaired renal function[a]	8 (301)	Good
Serum level measurements performed when the treatment duration was more than 3 days for aminoglycosides or more than 5 days for vancomycin	—	Not computable
Thereof prescription was not adapted to measured serum level concentrations	—	Not computable
Prescription was edited within 3 days	31 (25213)	Incomplete
Duration of initial therapy		Incomplete
<24 h	58 (25213)	
1–3 days	24 (25213)	
3–7 days	15 (25213)	
>7 days	3 (25213)	
Types of first adjustments in AB therapy		
Step-down to oral therapy within 3 days	10 (16252)	Incomplete
Switch of substance within 3 days	10 (25213)	Incomplete
Escalation: at least one AB added within 3 days	3 (25213)	Incomplete
Escalation: narrow to broad spectrum[b] within 3 days	1 (25213)	Incomplete
De-escalation: at least one AB less within 3 days	7 (25213)	Incomplete
De-escalation: broad[b] to narrow spectrum within 3 days	1 (25213)	Incomplete
Therapy stopped within 3 days	59 (25213)	Incomplete
Microbiology (considering AB therapy >24 h after arrival of microbiological result)		
Prescription was edited within 24 h after microbiological result	31 (15199)	Incomplete
ESCR-Enterobacterales BSI treated with piperacillin/tazobactam	34 (82)	Good
MSSA treated with anti-MRSA ABs	8 (771)	Good
Carbapenem-susceptible *Pseudomonas aeruginosa* treated with substances reserved for MDR organisms[c]	0 (293)	Good
VSE treated with daptomycin/linezolid	1 (364)	Good

AB, antibiotic; PCT, procalcitonin; CRP, C-reactive protein; ESCR-Enterobacterales BSI, bloodstream infection with extended-spectrum cephalosporin-resistant Enterobacterales; VSE, vancomycin-susceptible enterococci.

[a]Only antibiotics with dosing (measured in daily dose) independent of body weight or indication and clearly recommended dose reduction according to estimated glomerular filtration rate (eGRF) were considered.[17]

[b]Carbapenems, cefepime, ceftazidime, ceftazidime/avibactam, piperacillin/tazobactam, ticarcillin/clavulanic acid.

[c]Ceftolozane/tazobactam, ceftazidime/avibactam, cefiderocol, colistin.

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Table 2. ABS process indicator assessing documentation quality (for the entire study period)

Process indicator	Proportion of patients receiving antibiotics, % (*n*)	Data quality category
Indication documented	42 (25337)	Good
Meaningful documentation	12 (10537)	Good
Antibiotic allergy documented	—	Not computable
Severity of antibiotic allergy documented	—	Not computable

Table 3. Indicators assessing antibiotic consumption patterns (for the entire study period)

Indicator	Proportion of patients receiving antibiotics, *n* (%)	Data quality category
IV therapy	83 (25337)	Good
Broad-spectrum antibiotics[a]	10 (25337)	Good
Carbapenems	1 (25337)	Good
Fluoroquinolones	7 (25337)	Good
Per AWaRe group[b]		Good
Access	61 (25337)	
Watch	38 (25337)	Good
Reserve	0.2 (25337)	
Number of different antibiotics per patient and hospitalization		
1	67 (25337)	
2	22 (25337)	Good
>2	11 (25337)	
Surgical prophylaxis	0.7 (25337)	Incomplete
Restart of therapy (defined as interval of at least 2 days)	32 (25337)	Good
Duration of therapy (excluding prophylaxis and restarted therapies)		
<24 h	36 (25213)	
1–3 days	22 (25213)	Incomplete
3–7 days	28 (25213)	
>7 days	15 (25213)	

[a]Carbapenems, cefepime, ceftazidime, ceftazidime/avibactam, piperacillin/tazobactam, ticarcillin/clavulanic acid.
[b]According to 2021 AWaRe WHO classification.[18]

and departments. The ABS indicators could be filtered according to hospital site, department, year, month and age category.

Discussion

Algorithms could be programmed to compute 89% (25/28) of all pre-selected indicators assessing treatment decisions automatically out of EMR data, with good data for 46% (13/28) of these indicators. The feasibility of using EMR data for analysing a narrowed list of ABS metrics was also recently demonstrated in the UK.[19]

Prior to the coding, most ABS process indicators described in the literature needed to be rephrased or specified to be calculable. This resulted in the exclusion of 22 ABS indicators from the literature on the one hand and splitting of 9 ABS indicators from the literature into 24 more specific and computable ABS indicators for our study on the other hand. In particular, the ABS indicators referring to the implementation of guidelines would have to be adapted locally to be helpful for defining ABS measures, even if international comparability/benchmarking were hampered. In addition, the analysis of guideline-dependent indicators would need better documentation of the indication. In our setting, three main issues impaired data analysis. First, ABS indicators that evaluate documentation of antibiotic allergies were not calculable since the allergens recorded were not systematically classifiable as antibiotic substances. To implement this, the predefined allergen list within the EMR needs to be adapted to a uniform labelling of drugs, and the preselection of 'unknown antibiotic' and 'no allergy' should be added. Second, documentation of an active decision to prolong a given antibiotic therapy in the EMR should be improved. Actually, the two ABS indicators 'prescription was edited within 3 days' and 'prescription was edited within 24 h after microbiological result' could only be calculated if therapy was adapted, stopped or reordered. Reviews and extensions were not recorded systematically. An automated trigger after 3 days of antibiotic therapy could increase the performance in these ABS indicators. Third, meaningful documentation of the indication was available in only 5% of the hospitalizations; in 58% it was completely missing, and in 37% it was meaningless. Hence, a more complete, well-structured and mandatory recording of the indication would be helpful not only to exclude (and analyse separately) the surgical prophylaxis but also to better survey choices, dosing and duration of antibiotic therapies according to the indication. Van den Broek *et al.*[20] proposed a mandatory indication-registration tool using Epic systems®, which was not considered too burdensome by the prescribers. Implementing these three main restrictions would have increased the number of ABS indicators with good-quality data from 13 to 26. In general, the data quality issues could easily be solved by implementing these simple, tailored suggestions to improve the data recording in the specific EMR.

Previous studies allowing a comparison and plausibility check of the ABS indicators were scarce. A lower value for the step-down to oral therapy was found in our study than those reported in the UK, the Netherlands or within other Swiss hospitals (10% versus 36% versus 32% versus 82%).[13,19,21] Our ABS indicator described the step-down within 3 days, while the Dutch study analysed the switch within 48–72 h. The time frame considered was longer in the two other studies mentioned—7 days or not restricting it at all. In addition, in all three other studies, step-down was analysed only in patients for whom the clinical condition would allow step-down to oral therapy. As we did not have data on the clinical condition, we considered step-down in all patients in whom IV therapy was initiated, irrespective of the clinical condition, which explains the lower percentage. For the indicator 'microbiological sample: % sample taken before the start of

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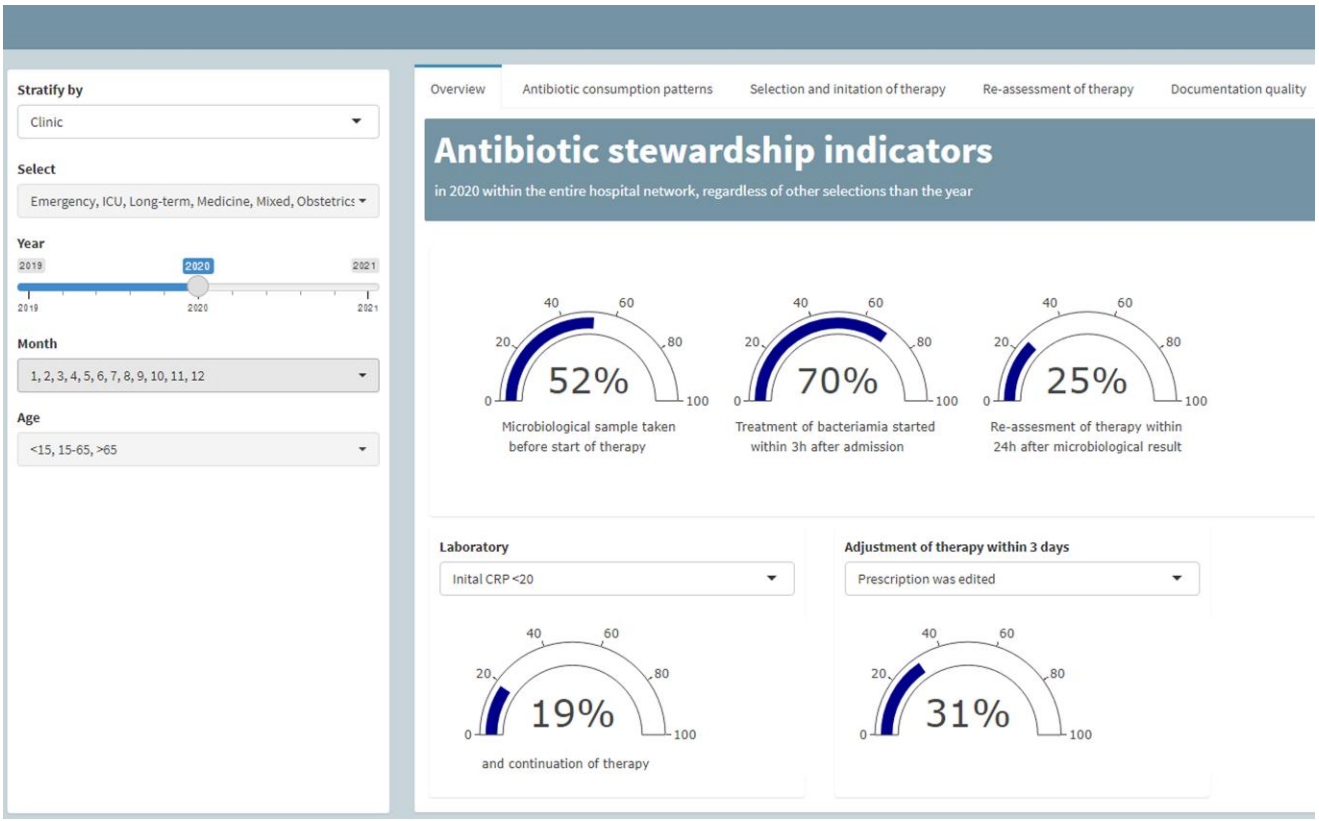

Figure 4. Screenshot of the ABS overview panel of the dashboard for 2020. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

therapy' (51%), large differences were also observed in comparison with the UK (22%) and the Netherlands (94%). Again, differences in methodology may be the reason why, in our study, samples taken on the same day as therapy was started were considered 'samples taken before the start of therapy', since the sampling date but not the time was available. However, in the Netherlands, only patients with targeted therapy were considered. The lower adaptation of the antibiotic therapy after receipt of the microbiological result in our study (31% versus 91% versus 50%), however, could be explained by technical issues as described above.[13,21]

The percentage of antibiotics prescribed for surgical prophylaxis was much lower (0.7%) than reported in the Swiss point prevalence study (34%).[9] Relying on the correct indication only, the proportion would be 0.3% (79/25337). However, in our first approach, antibiotic treatments given for the first time in the operating room were also considered surgical prophylaxis, which elevated the proportion to 0.7% (190/25337). Considering all patients with antibiotic therapy for less than 24 h or all patients treated with antibiotics, nearly exclusively for surgical prophylaxis in this setting, would have resulted in 37% and 28%, respectively. The correct classification of surgical prophylaxis not only affects the estimation of the percentage of prophylaxes but—as these prescriptions should be excluded from the analysis of antibiotic therapies—also for many other ABS indicators too. For example, excluding probable prescriptions for surgical prophylaxis in the subanalysis yielded higher values for numerous ABS indicators such as 'edited prescription within 3 days' and 'duration of therapy'. This highlights the significance in differentiating between prescriptions for surgical prophylaxis versus therapy and considering the documentation quality when comparing these ABS indicators between hospitals in the future.

Analysing the overall prescription data revealed a high correlation with hospital-level data from ANRESIS (delivered by hospital pharmacists) in proportion to antibiotic use of IV therapy, fluoroquinolones, carbapenems and per AWaRe group (see Table S7). However, the total antibiotic use of the pilot hospital network summarizing patient-level data was much lower than the consumption in comparable Swiss hospitals calculated by hospital-level data (unpublished data). A small fraction of this difference was explained by antibiotic treatment of patients not included in the study due to rejection of the general consent. As this is the case for only approximately 500 patients (2.4%), other explanations are needed, such as the disposal of opened packages or give away of limited numbers of antibiotics after discharge. These differences need clarification in the future.

The most important limitation lies in the plausibility control; internal as well as external validation, using data from other hospitals, are planned as further steps. There are no satisfactory explanations for the differences in total antibiotic use calculated by patient-level data compared with the consumption of similar hospitals computed by hospital-level pharmacy data. Conversely,

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the proportion of antibiotic use per AWaRe group was comparable. A further limitation was that feasibility was tested using data from one EMR system only. However, for the calculation of the ABS indicators we require mainly antibiotic prescription data such as substance, prescription start and prescription stop date, which should be available in every EMR system. It is planned to validate our results, including the generalization of the algorithms, by extending the analysis to other Swiss hospitals. Ethical aspects required data anonymization, which limited the real-time use of these ABS indicators and direct feedback of the prescriptions at the patient level. Another constraint was the low documentation quality on indication, which limited the selection of ABS indicators as well as the proper exclusion of surgical prophylaxis from most analyses.[20] In general, quantitative data on these ABS indicators are very sparse in the literature and highly dependent on methodological issues, which differ essentially between studies, making comparison/validation impossible. This implies that international ABS study groups should elaborate a set of unambiguously defined ABS indicators assessing treatment decisions considering computability. Compared with indicators requiring manual data evaluation or aggregated data, ABS indicators computed automatically from EMR data could be implemented in daily life, need fewer human resources and may be less prone to human errors. Consequently, computability from EMR data should be a criterion for quality indicators.

Despite these limitations, we were able to establish a continuous, automated monitoring system relying on EMR data to monitor patient-level data and conduct a systematic analysis of ABS indicators. In addition, we were able to formulate a few important steps, which essentially improve the data quality. Displaying data on an interactive dashboard enables us to give an overview, to compare the ABS indicators within departments or patient groups and to filter the data according to user-specific needs. The dashboard technology will be developed further to handle patient-level data from several hospitals, which will also allow inter-hospital benchmarking. Monitoring of continuous patient-level prescription data would be very useful for ABS teams to define and measure interventions. In addition, research projects could be initiated, e.g. by analysing which ABS indicators are associated with patient outcomes, costs and resistance. It was demonstrated by Van den Bosch *et al.*[22] that an appropriate step-down to oral therapy was associated with a shorter length of hospitalization and, thus, reduced healthcare costs.

In conclusion, the automated calculation of ABS indicators reflecting the treatment decisions from the EMR was feasible. However, a better data structure within the EMR and data from other hospitals is crucial for improving the validity of the results.

Funding

This work was financially supported by the Swiss Federal Office of Public Health and the Institute for Infectious Diseases of the University of Bern, Switzerland.

Transparency declarations

None to declare.

Supplementary data

Tables S1 to S7 are available as Supplementary data at *JAC* Online.

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