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## Impact of a computerized decision support system on compliance with guidelines on antibiotics prescribed for urinary tract infections in emergency departments: a multicentre prospective before-and-after controlled interventional study

Elisa Demonchy<sup>1,2</sup>, Jean-Charles Dufour<sup>3,4</sup>, Jean Gaudart<sup>3,4</sup>, Emmanuel Cervetti<sup>5</sup>, Pierre Michelet<sup>6</sup>, Nicolas Poussard<sup>7</sup>, Jacques Levrault<sup>1,8</sup> and Céline Pulcini<sup>1,2,4\*</sup>

<sup>1</sup>Faculté de Médecine, Université Nice-Sophia Antipolis, Nice, France; <sup>2</sup>Service d'Infectiologie, CHU de Nice, Nice, France; <sup>3</sup>BIOSTIC, Pôle de Santé Publique, Assistance Publique-Hôpitaux de Marseille, Marseille, France; <sup>4</sup>UMR912 SESSTIM (AMU-INSERM-IRD-AMSE), Aix-Marseille University, Marseille, France; <sup>5</sup>ORU PACA, Observatoire Régional des Urgences en région Provence-Alpes-Côte d'Azur, Hyères, France; <sup>6</sup>Service d'Accueil des Urgences, Hôpital de la Conception, Assistance Publique-Hôpitaux de Marseille, Marseille, France; <sup>7</sup>Service d'Accueil des Urgences, Hôpital Nord, Assistance Publique-Hôpitaux de Marseille, Marseille, France; <sup>8</sup>Service d'Accueil des Urgences, CHU de Nice, Nice, France

\*Corresponding author. Centre Hospitalier Universitaire de Nice, Service d'Infectiologie, Hôpital l'Archet 1, Route Saint Antoine de Ginestière, CS 23079, 06202 Nice cedex 3, France. Tel: +33-(0)4-92-03-55-15; Fax: +33-(0)4-93-96-54-54; E-mail: pulcini.c@chu-nice.fr

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**Objectives:** Urinary tract infections (UTIs) are one of the leading reasons for antibiotic prescriptions in emergency departments (EDs), with half of these antibiotics being inappropriately prescribed. Our objective was to assess the impact of a computerized decision support system (CDSS) on compliance with guidelines on empirical antibiotic prescriptions (antibiotic and duration) for UTIs in EDs.

**Methods:** A multicentre prospective before-and-after controlled interventional study was conducted from 19 March to 28 October 2012. All adults diagnosed with community-acquired UTIs (cystitis, pyelonephritis or prostatitis) at three French EDs were included. The antibiotic therapy was considered compliant with guidelines if the antibiotic and the duration prescribed were in accordance with the national guidelines. Data were collected using electronic medical records. Paired tests were used when comparing periods within each ED and global analyses used multivariate logistic mixed models.

**Results:** Nine hundred and twelve patients were included during the 30 week study period. The CDSS was used in 59% of cases (182/307). The CDSS intervention improved the compliance of antibiotic prescriptions in only one ED in a bivariate analysis (absolute increase +20%,  $P=0.007$ ). The choice of the antibiotic was improved in multivariate analyses but only when the CDSS was used [OR=1.94 (95% CI 1.13–3.32)]. The CDSS also changed the initial diagnosis in 23% of cases, in all three EDs.

**Conclusions:** The CDSS only partially improved compliance with guidelines on antibiotic prescriptions in UTIs.

**Keywords:** antibiotic stewardship, emergency medicine, hospital, quality

### Introduction

Urinary tract infections (UTIs) are one of the leading reasons for antibiotic prescriptions in emergency departments (EDs), with inappropriate prescriptions in around half of all cases.<sup>1–3</sup>

The ideal method to encourage the uptake of clinical guidelines in hospitals is not known.<sup>4–6</sup> Computerized decision support systems (CDSSs) are one of the recommended antimicrobial stewardship strategies<sup>5,6</sup> since they have been

shown to improve antibiotic prescribing practices,<sup>7–16</sup> even though not all CDSSs were successful.<sup>15,17,18</sup> To the best of our knowledge, studies assessing the impact of CDSSs on antibiotic prescribing have rarely been conducted in EDs,<sup>8</sup> which are a very busy hospital setting, with a high number of prescribers and a significant staff turnover.

Our objective was thus to assess the impact of a CDSS on compliance with guidelines on empirical antibiotic prescriptions for UTIs in EDs.

## Methods

### Study design

We conducted a multicentre prospective before-and-after controlled interventional study from 19 March to 28 October 2012 in three French EDs. We assessed a single component intervention, using predefined protocol and endpoints, in accordance with ORION guidelines.<sup>19</sup>

### Setting

This study was performed at three academic hospitals. All three EDs had had the same specific electronic medical record (EMR) in place for more than 2 years. Over 22/25/29 different doctors (12/16/20 senior and 10/9/9 junior) were working in the three EDs on a permanent basis over the study period, with >100 additional junior doctors from other departments on duty at nights and during the weekends; the allocation of doctors to patients was not structured. Junior doctors were always under the supervision of a senior doctor.

### Participants

This study focused on the initiation of antibiotic prescriptions for all adult patients (≥15 years old) who were diagnosed with community-acquired UTI (cystitis, pyelonephritis or acute prostatitis) by the treating clinician in the ED. Patients with chronic prostatitis, a urinary catheter and/or healthcare-acquired infections were not included. Patients were excluded from the study if data were missing regarding the diagnosis and/or the antibiotic prescription.

### Intervention

The study extended over three distinct 10 week time periods (Figure 1). Period 1 corresponded to the pre-intervention (baseline) period. In Period 2, national UTI guidelines were automatically made available to clinicians in ED-A (as a pop-up window showing the PDF document) each time a UTI diagnosis was validated; such a validation (using ICD-10 codes) was compulsory. In Period 2 for ED-B and ED-C and in Period 3 for ED-A, a CDSS was automatically triggered by the diagnosis of a UTI. In Period 3 for ED-B and ED-C, the CDSS was discontinued and no intervention took place.

During the whole study period, paper copies of antibiotic prescribing guidelines based on national recommendations were available to all clinicians in the EDs but no particular efforts were made to encourage uptake of the guidelines. Clinicians were aware that the study was being conducted. The lead researchers had no clinical role in the EDs over the

study period, except for one who was present in one of the three centres until mid-April 2012. There were no planned changes in the number or composition of senior staff in the EDs or their responsibilities over the study period. Junior staff rotated every 6 months (at the beginning of May and November). No other interventions regarding antibiotic prescribing in UTIs (e.g. educational sessions) were conducted during the study period.

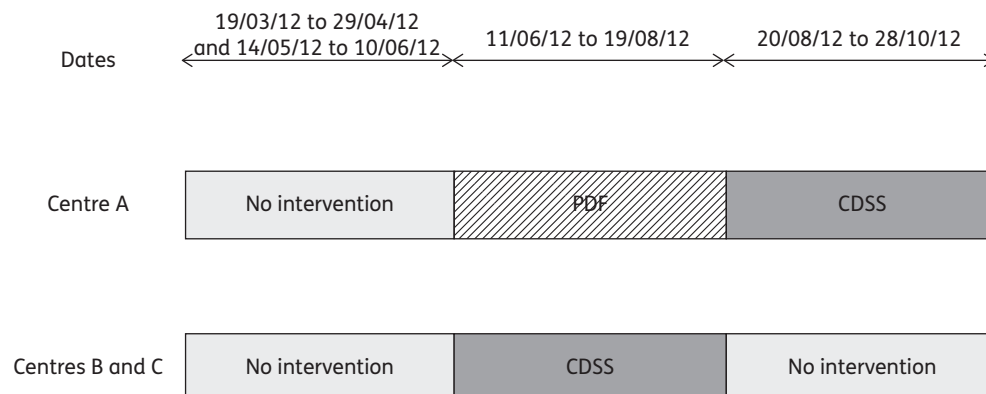
### Data collection

Anonymized data were automatically extracted from the EMR. Some data were routinely available: the age and gender of the patient, the date and hour of admission and the ICD-10 diagnosis code. Other data were entered by the clinicians in the EMR during the study period, using a specific query form with checkboxes and drop-down menus: non-inclusion criteria, ending the query (chronic prostatitis, urinary catheter and/or healthcare-acquired infections), junior/senior doctor, urine dipstick results (leucocytes and nitrites), severe sepsis or septic shock, fluoroquinolone treatment in the previous 6 months, pregnancy, antibiotic prescription (antibiotic and duration of treatment) and detailed diagnosis (asymptomatic bacteriuria, uncomplicated cystitis, complicated cystitis, uncomplicated pyelonephritis, complicated pyelonephritis or acute prostatitis). Finally, the diagnosis was entered again by the clinicians in the CDSS, after consulting the diagnostic tools embedded in the CDSS. The complete data-entering process took <20 s.

### CDSS

The CDSS was integrated into the workflow of the usual EMR and was used at the point of care on desktop computers. The CDSS was automatically triggered by the ED computer system when a UTI diagnosis was validated, i.e. at the supposed time that antibiotic prescription was considered. The CDSS software included a decision support application and a tool to collect limited additional data from popup screens. Relevant information was also extracted from the EMR to autopopulate the required data fields in the CDSS. The time spent by the clinician entering the data into the CDSS was automatically recorded; the recorded duration of use was the time needed to read and fill in the required data input forms to get the CDSS recommendations (the time needed to read the CDSS recommendations was not recorded). The clinician could decline to use the CDSS and this information was collected.

The clinical algorithm-based decision support was designed by a specialist in public health and health informatics and two infectious diseases specialists. It was based on the 2008 national UTI guidelines.<sup>20</sup> It offered diagnostic and therapeutic tools, and displayed recommendations regarding the investigations, the indications for hospitalization, the



**Figure 1.** Design of the study.

antibiotic treatment and the follow-up, tailored to the individual patient data. All functions were supportive in terms of the messages and information to help the clinician follow the guidelines. Clinicians were free to follow the guidelines advocated by the CDSS. The program used the xGA platform, as described in the literature.<sup>21,22</sup> A standalone demo version of the CDSS is available at <http://lertim2.timone.univ-mrs.fr/IUGuides-v4/>.

Before implementation the CDSS was pilot-tested by one project leader in each ED. Potential barriers to use were addressed during a meeting with this working group of emergency medicine specialists and experts in the area of health informatics and infectious diseases, based on the literature (behaviour change models).<sup>4,15,23,24</sup>

The CDSS was available only in the three participating EDs and its use was entirely voluntary. No specific incentives were provided to encourage its use. An introductory demonstration was provided to the ED staff at a hospital grand round. Thereafter, leaders in each ED informally provided demonstrations.

### Outcome measures

The primary outcome assessed was the prescription of empirical antibiotic therapy that was concordant with national guidelines, using an intent-to-intervene analysis. The antibiotic therapy was considered compliant with guidelines if both the antibiotic and the duration prescribed were in accordance with the 2008 national guidelines (Table S1, available as Supplementary data at JAC Online).<sup>20</sup> All the prescriptions were independently analysed by two infectious diseases specialists at the end of the study, with the assessors blinded to the study period and the ED. All disagreements were discussed to reach a consensus.

Compliance with guidelines for the antibiotic and the duration of treatment were also treated separately as secondary outcomes. We also assessed the impact of the CDSS on the diagnosis, i.e. the proportion of initial diagnoses that were modified after consulting the CDSS.

### Ethical statement

This study was approved by the Ethics Committee of Nice University Hospital. Individual consent from the clinicians or the patients involved was not required. The National Data Protection Authority (Commission

Nationale Informatique et Libertés), responsible for ethical issues and the protection of individual data in France, approved the EMR used in all three EDs.

### Sample size

The CDSS period aimed to include 97 patients in each ED for each period to detect an improvement in mean compliance from 40% (the prevalence based on the literature and previous audits we conducted locally<sup>1,3,25,26</sup>) to 60% (an absolute increase based on the literature<sup>8</sup>), for a power=0.8 and  $P=0.05$ .

### Statistical analysis

Bivariate analyses used a  $\chi^2$  test (or Fisher's exact test) for categorical variables and analysis of variance (or the non-parametric Wilcoxon test) for continuous variables. Paired tests were used when comparing periods within each ED, as defined *a priori* in our protocol. Global analyses were later performed using multivariate logistic mixed models, taking into account the centre as a random effect. To correct alpha risk inflation when multiple testing was performed, we considered a  $P$  value  $<0.017$  significant. All analyses were carried out using SPSS (version 18) and R (package lme4) software.

## Results

### Patients' characteristics

UTIs were diagnosed 1265 times during the study period (1.2% of all visits to EDs), with 353 ineligible episodes (chronic prostatitis, urinary catheter and/or healthcare-acquired infections). A total of 1097 UTI episodes were eligible, with 912 patients finally included in the study (as 185 had missing data). The demographic details of the patients in each time period were fairly comparable, both overall (Table 1) and for each ED (Tables S2, S3 and S4, all available as Supplementary data at JAC Online). Junior doctors (supervised by a senior clinician) took care of 629/912 (69%) UTI episodes.

**Table 1.** Patients' characteristics in the three EDs during the study period

	Period 1, N=317, n (%)	Period 2, N=348, n (%)	Period 3, N=247, n (%)	Total, N=912, n (%)
Age (years), mean (SD)	47 (23)	43 (23)	41 (22)	44 (23)*
Female	263 (83)	285 (82)	212 (86)	760 (83)
Pregnancy	7/263 (3)	6/285 (2)	2/212 (1)	15/760 (2)
Fluoroquinolone in the past 6 months	32 (10)	27 (8)	36 (15)	95 (10)*
Diagnosis <sup>a</sup>				
asymptomatic bacteriuria	0	1 (0.3)	0	1 (0.1)
uncomplicated cystitis	112 (35)	123 (35)	93 (38)	328 (36)
complicated cystitis	18 (6)	16 (5)	12 (5)	46 (5)
uncomplicated pyelonephritis	132 (42)	153 (44)	107 (43)	392 (43)
complicated pyelonephritis	14 (4)	18 (5)	10 (4)	42 (5)
acute prostatitis	41 (13)	37 (11)	25 (10)	103 (11)
Severe sepsis/septic shock	5 (2)	4 (1)	5 (2)	14 (2)
Hospitalized	59 (19)	40 (12)	30 (12)	129 (14)*

\* $P<0.05$ ;  $P$  values were calculated using a  $\chi^2$  test for categorical variables and analysis of variance for continuous variables.

<sup>a</sup>Diagnosis initially validated in the EMR.

**Table 2.** Prevalence of appropriate antibiotic prescriptions in the three participating EDs during the study period (N=912)

Centre	Period 1, no intervention, N, n (%)	Period 2, PDF, N=157, n (%)	Period 3, CDSS, N=116, n (%)	P (period 1 versus period 2)	P (period 2 versus period 3)
Centre A	Period 1, no intervention, N=143, n (%)	Period 2, PDF, N=157, n (%)	Period 3, CDSS, N=116, n (%)	P (period 1 versus period 2)	P (period 2 versus period 3)
Appropriate antibiotic and duration	38 (27)	50 (32)	28 (24)	0.32	0.16
Appropriate antibiotic	77 (54)	102 (65)	65 (56)	0.05	0.13
Appropriate duration	77 (54)	71 (45)	38 (33)	0.14	0.04
Centre B	Period 1, no intervention, N=86, n (%)	Period 2, CDSS, N=94, n (%)	Period 3, no intervention, N=75, n (%)	P (period 1 versus period 2)	P (period 2 versus period 3)
Appropriate antibiotic and duration	30 (35)	32 (34)	21 (28)	0.91	0.40
Appropriate antibiotic	55 (64)	52 (55)	41 (55)	0.24	0.93
Appropriate duration	38 (44)	48 (51)	36 (48)	0.36	0.69
Centre C	Period 1, no intervention, N=88, n (%)	Period 2, CDSS, N=97, n (%)	Period 3, no intervention, N=56, n (%)	P (period 1 versus period 2)	P (period 2 versus period 3)
Appropriate antibiotic and duration	29 (33)	51 (53)	21 (38)	<b>0.007</b>	0.07
Appropriate antibiotic	59 (67)	71 (73)	37 (66)	0.36	0.35
Appropriate duration	34 (39)	66 (68)	27 (48)	<b>&lt;0.001</b>	<b>0.016</b>

Numbers highlighted in bold represent statistically significant results in bivariate analysis ( $P < 0.017$ ).

### Compliance with guidelines of empirical antibiotic prescriptions

Table 2 details the comparisons in prescribing behaviour over the three time periods within each ED in bivariate analyses and Table 3 presents overall differences for all three periods in all three centres, using a multivariate logistic mixed model.

Overall, empirical antibiotic prescriptions were compliant with guidelines regarding both the antibiotic and the duration in 33% (300/912) of cases; the antibiotic was compliant with guidelines in 61% (559/912) and the duration of treatment in 48% (435/912), with a total excess of 1183 days of treatment. Combination therapies were prescribed in 3% of cases (31/912). Fluoroquinolones (62%), fosfomycin (13%) and ceftriaxone/cefotaxime (13%) were the most commonly prescribed antibiotics.

The PDF intervention slightly increased the appropriateness of antibiotic prescriptions in bivariate and multivariate analyses (Tables 2 and 3) but this did not reach statistical significance. The CDSS intervention improved the appropriateness of antibiotic prescriptions in ED-C in bivariate analysis (Table 2) but it did not have any impact in multivariate analyses [Table 3 and Tables S5 and S6 (both available as Supplementary data at JAC Online)]. Junior doctors were independently associated with more appropriate prescriptions, as was prostatitis (Table 3).

### Use of the CDSS

The CDSS was used in 59% (182/307) of cases, for a median duration of 29 s (IQR 18–42 s); factors associated with use of

the CDSS are presented in Table 4. Use of the CDSS was overall associated with more appropriate antibiotics in multivariate analysis (Table 3); discontinuation of the CDSS had a significant impact (Table S5), whereas implementation of the CDSS did not reach statistical significance (Table S6).

After our study had been completed we informally surveyed the clinicians of the three EDs regarding their perceived reasons for not using the CDSS. Usability was rated as good by all clinicians, with the tool considered to be user-friendly and not time-consuming. Most clinicians found the CDSS to be useful in their daily practice. Specific barriers were identified in ED-A and ED-B: a lack of agreement with the guidelines in general, a lack of awareness of the existence of the study among some junior doctors, the high turnover and understaffing rates during the study period.

### Impact of the CDSS on the diagnosis

The CDSS led to a modification of the initial diagnosis in 23% (42/182) of the cases. Two main changes were made: UTIs finally diagnosed as asymptomatic bacteriuria (20/42, 48%), and complicated UTIs finally classified as uncomplicated (17/42, 40%).

### Discussion

This study shows that implementation of a CDSS in EDs partially improved antibiotic prescribing practices for UTIs. The CDSS was widely used (59% of cases) and had an impact on the diagnostic process in nearly one-quarter of the cases.

**Table 3.** Factors associated with appropriate antibiotic prescriptions in the three participating EDs

Factor	Appropriate antibiotic and duration		Appropriate antibiotic		Appropriate duration	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
No intervention	1	—	1	—	1	—
CDSS intervention	1.07 (0.69–1.66)	0.77	0.91 (0.58–1.41)	0.67	1.36 (0.90–2.06)	0.14
PDF intervention	1.58 (0.98–2.54)	0.06	1.30 (0.81–2.08)	0.27	1.57 (0.99–2.47)	0.05
No CDSS use	1	—	1	—	1	—
CDSS used by clinicians	1.50 (0.90–2.49)	0.12	1.94 (1.13–3.32)	0.016*	1.01 (0.62–1.64)	0.98
Junior doctor	1	—	1	—	1	—
Senior doctor	0.65 (0.47–0.89)	0.009*	0.77 (0.55–1.07)	0.11	0.61 (0.45–0.83)	0.002*
Weekdays	1	—	1	—	1	—
Nights and weekends	0.98 (0.71–1.34)	0.89	0.84 (0.61–1.18)	0.32	1.08 (0.79–1.46)	0.63
Diagnosis						
cystitis	1	—	1	—	1	—
pyelonephritis	1.04 (0.76–1.42)	0.82	5.68 (4.13–7.82)	<0.001*	0.47 (0.35–0.63)	<0.001*
prostatitis	3.56 (2.25–5.63)	<0.001*	7.11 (4.11–12.29)	<0.001*	1.85 (1.16–2.94)	0.012*

All periods and all departments were included.

Overall differences between the interventions are presented (multivariate logistic mixed model).

\*Statistically significant results ( $P < 0.017$ ).

**Table 4.** Factors associated with the utilization of the CDSS in bivariate analysis ( $N = 182$ )

Factor	Prevalence of use of CDSS, n/N (%)	Bivariate analysis	
		OR	95% CI
Centre			
A	78/116 (67)	1	—
B	45/94 (48)	<b>0.4</b>	<b>0.3–0.8*</b>
C	59/97 (61)	0.8	0.8–1.4
Junior doctor	132/223 (59)	1	—
Senior doctor	50/84 (60)	1.0	0.6–1.7
Weekdays	50/84 (60)	1	—
Nights and weekends	132/223 (59)	1.0	0.6–1.6
Diagnosis			
cystitis	78/136 (57)	1	—
pyelonephritis	82/140 (59)	1.1	0.6–1.7
prostatitis	22/31 (71)	1.8	0.8–4.2

\* $P < 0.05$ .

At baseline, empirical antibiotic prescriptions did not comply with national guidelines in 67% of cases; this prevalence was slightly higher than those reported in previous studies.<sup>1,3</sup> The two main causes of inappropriate antibiotic prescriptions were an excessive use of fluoroquinolones and an inadequate duration of treatments (usually too long a duration in cystitis/pyelonephritis and too short a duration in prostatitis), in line with the literature.<sup>27</sup>

Making UTI national guidelines available as a PDF document in one ED did slightly improve the prevalence of compliant antibiotic

prescriptions, but this did not reach statistical significance. This has already been described with passive means of information transfer.<sup>4–6</sup>

The CDSS intervention had a significant impact only in bivariate analyses and in ED-C. Global multivariate analyses showed a positive impact only when the CDSS was used. Discontinuation of the tool led to less appropriate antibiotics, suggesting an absence of a sustained educative effect due to the CDSS.

In ED-A and ED-B the CDSS did not show any positive impact on antibiotic prescribing despite a comparable frequency of use of the CDSS by clinicians; it even led to a trend towards lower rates of appropriate antibiotic durations in ED-A. CDSS interventions are highly complex and their effectiveness is dependent largely on how well they are designed and implemented.<sup>7,15</sup> The successful implementation of a CDSS also depends heavily on the personnel and the setting.<sup>8,13,15</sup> The ‘culture’ within an institution has important effects on guideline implementation strategies, as demonstrated in our study. We tried to address the barriers to CDSS use in all three EDs: development by a multi-disciplinary working group, respect for professional autonomy, availability at the point of care and at the time of the decision-making, integration into the usual workflow, automatic initiation of the CDSS and advice tailored to the patient’s data.<sup>7,15,23</sup> We also targeted a duration of use of <1 min, since EDs are very busy settings. The acceptability of the guidelines seemed to be the main barrier accounting for the differences among the participating EDs.<sup>4,23</sup> Implementing the same CDSS in different hospitals might therefore have an impact in only some centres. Additional measures may be useful,<sup>15</sup> even though a recent review found that CDSSs implemented with other strategies such as education were no more successful in improving prescribing than stand-alone interventions.<sup>7</sup> A comprehensive evaluation strategy should be planned to identify and rectify barriers surrounding the implementation of an antimicrobial

CDSS, with specific resources allocated to this objective beforehand.<sup>24</sup>

Studies assessing the impact of CDSSs on antibiotic prescribing have rarely included EDs. Busing *et al.*<sup>8</sup> evaluated the impact of a CDSS on antibiotic prescribing for community-acquired pneumonia in one ED in Australia. Deployment of their CDSS was associated with an improvement in antibiotic prescribing practices that was greater than the changes seen with academic detailing.<sup>8</sup>

To date, most evaluations of CDSS in hospitals have described very complex clinical computer systems, often in academic centres with a specific interest in computerization.<sup>9,11,15</sup> This study, in contrast, describes a transferable CDSS that can be integrated with many existing clinical databases in different hospitals. Moreover, previous reviews have noted the paucity of reports of CDSSs in Europe,<sup>7,15</sup> and reported studies assessing the impact of a CDSS on antibiotic prescribing in hospitals have been mainly single-centre studies;<sup>15</sup> this paper therefore provides an important contribution. Finally, our results are strengthened by an ORION-compliant methodological design and sufficient statistical power. Our work presents, however, some limitations. First, some collected data were entered by the clinicians themselves. Second, we excluded UTI episodes with missing data from the analysis, and these episodes might correspond to the antibiotic prescriptions that were the least compliant with guidelines.

In conclusion, our CDSS only partially succeeded in improving compliance with the guidelines, but this study has demonstrated the potential for an improvement in antibiotic stewardship with a CDSS. A large cluster randomized controlled trial including many different departments is needed.

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This study was carried out as part of our routine work.

## Transparency declarations

None to declare.

## Author contributions

C. P. developed the idea for the study (in collaboration with E. D. and J.-C. D.). E. D., J. G., J.-C. D. and C. P. designed the study. J.-C. D. worked on the CDSS software development and worked with E. C. on the interoperability between electronic medical records and CDSS. J. G., C. P. and J.-C. D. were responsible for data analysis. E. C., J. L., P. M. and N. P. revised the study protocol and actively participated in the implementation of the intervention. E. D. and C. P. drafted the manuscript. All authors read and approved the final manuscript.

## Supplementary data

Tables S1 to S6 are available as Supplementary data at JAC Online (<http://jac.oxfordjournals.org/>).

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