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Original article

Determinants of sustainable adoption in primary care of a clinical decision support system for antimicrobial prescribing: A qualitative study

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ABSTRACT

Objective: The objective of the study was to analyse the determinants for sustainable adoption by General Practitioners (GPs) of Antibioclic, a Clinical Decision Support System (CDSS) for antimicrobial prescribing, and the results of and limitations to its use in clinical practice.
Materials and methods: Individual interviews with GPs and a focus group were carried out concerning their use of Antibioclic, a CDSS for antimicrobial prescribing in primary care. Antibioclic is a publicly funded, freely available CDSS targeting 48 common infectious diseases. Interviews were recorded, transcribed and coded using NVivo 12. Data were analysed via inductive thematic analysis.
Results: Interviews were conducted with 25 GPs, and nine additional GPs participated in the focus group. Median age was 34 years (IQR 32–43) and 20 participants (59 %) were women. All of them frequently and sustainably used Antibioclic in their practice. Adoption of the CDSS was explained by system characteristics: usability, up-to-dating and trustworthiness; it was also considered as routinized, interwoven with consultations and antimicrobial prescribing, and conducive to improved practices and communication with patients. The GPs emphasized the role of CDSSs role in bridging the gap between clinical guidelines and daily practice, while contributing to contextual learning and continuous medical education. Lastly, participants pointed out the importance of co-design of CDSSs with end-users.
Conclusion: These determinants of sustainable adoption of a CDSS may guide future implementation of electronic tools in into clinical practice.

1. Background and significance

Antimicrobial resistance (AMR) is a global threat to the health and wealth of nations [1]. Inappropriate use of antibiotics, which includes non-use, delay in use, or overuse, promotes AMR [2]. Many factors contribute to the inappropriate use of antibiotics: the a lack of guidelines for antimicrobial prescribing in some countries, non-compliance with existing guidelines by healthcare professionals, and healthcare user behavior [3]. About 80–90 % of antibiotics for humans are prescribed in primary care. In France, general practitioners (GP) account for over 75 % of these [4].

Electronic Clinical Decision Support Systems (CDSS) have been

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designed to provide prescribers with rapid access to up-to-date information essential to appropriate treatment decision-making [5]. Widely available on computers and smartphones, these systems are recognized by the WHO as one of the 13 urgent health challenges of the next decade [6] and as supports for patient management in primary care [7]. In the UK's 2019–2024 national action plan designed to tackle antimicrobial resistance, one of the goals was to report the percentage of antibiotic prescriptions guided by a diagnostic test or a CDSS [8]. In a systematic review of CDSSs in antibiotic management, the authors found 58 articles describing 38 CDSSs. However, only 11 of them were adapted to primary care, and all of them were exclusively focused on infections of a single anatomical area. None of them covered the full spectrum of infectious situations encountered by GPs or were based on French guidelines. In a review of French-speaking CDSSs, we identified 11 tools developed in France, only two of which were specifically adapted for use in primary care [10]. The authors demonstrated the heterogeneous evaluation methods and challenges in ensuring long-term use, which were to some extent due to a lack of initial assessment of user needs. As is the case with many healthcare innovations, many CDSSs have been abandoned on account of multiple factors, particularly an absence of pre-implementation [11,12]; due to low uptake and poor adherence to generated advice, they often showed low clinical impact [13,14].

It is urgently necessary to design and promote CDSSs that integrate seamlessly into clinical workflows, reduce antibiotic use, and adequately address AMR. The contextual, structural, and behavioural factors that enable CDSS use in prescribing need to be better understood.

As a CDSS used daily by over 5000 general practitioners (GPs) in France, covering 48 infectious diseases at the time of the study, Antibioclic seemed well-suited to critical evaluation.

The objective of the study was to analyse (a) the determinants for sustainable adoption of Antibioclic, (b) the results of its adoption, and (c) limitations to its use in clinical practice.

2. Materials and methods

2.1. Antibioclic – A CDSS for antibiotic prescribing

Antibioclic (https://antibioclic.com) is a French CDSS for antibiotic prescribing in primary care, targeting 48 common infectious diseases, freely available on the web and as a smartphone application on iOs and Android. It was co-developed in 2011 by general practitioners, infectious disease specialists and engineers. Clinicians can enter the diagnosis of a patient on the website or application, and are then asked targeted questions (age group, comorbidities, renal function, breastfeeding and/or pregnancy) after which they receive a tailored recommendation of antibiotic regimen, dose and duration in accordance with French national guidelines (Supplementary material 1). Antibioclic provides therapeutic recommendations, and not diagnostic advice. It was developed as a means of transforming French national clinical practice guidelines into computer-interpretable guidelines based on decision-trees. It is regularly updated and modified as soon as a new guideline is published. The number of Antibioclic users in France has steadily increased over recent years from a median [IQR] of 414 [245–494] a day in 2012 to 5365 [2891–5769] a day in 2018, without showing saturation [15]. By December 2023, around 50,000 French GPs among the 89,000 registered Antibioclic users across all healthcare occupations were registered in the system, [16].

2.2. Interviews

An interview schedule was developed with multidisciplinary expertise: infectious disease doctors; GPs; and experts in implementation science, qualitative research, and Antibioclic use. This interview guide was piloted by two GPs and subsequently revised, based on feedback. The reasons for using Antibioclic, methods of utilization, results, limitations and drawbacks, and potential avenues for improvement were addressed (Supplementary material 2). All interviews were done by a male doctor specialized in infectious diseases and trained in qualitative research. They were conducted until data saturation occurred, which was was when no new themes emerged during analysis of the final interviews.

2.3. Focus group

After analysing the interviews and developing a thematic analysis framework, the data were triangulated with the help of a focus group chaired by the doctor having conducted the interviews. The combination of individual interviews and focus group was chosen as a triangulation strategy, allowing both in-depth exploration of personal experiences and interactive discussions that highlighted common perspectives. The discussion revolved around four questions: in your opinion, what accounts for the success of Antibioclic? What are the results of Antibioclic use in your clinical practice? What are the limitations and possible negative consequences of Antibioclic use? What can be added or changed to make Antibioclic more useful in your clinical practice? The focus group lasted 90 min and contemporaneous notes were taken by two investigators, coded and integrated into the thematic analysis framework.

2.4. Participants

Participants were recruited for the interviews through the Antibioclic mailing list and at a course on antimicrobial prescribing in primary care organized by the Antibioclic team at Université Paris Cité. Participants were provided with an information sheet (including information on the interviewer) and gave written consent. The GPs participating in the interviews were provided with a 50-75€ incentive according to interview duration. The focus group was conducted as part of a university diploma program on antimicrobial prescribing in primary care.

2.5. Data analysis

The interviews were recorded, anonymised and transcribed *verbatim* by a professional company and checked against the interviews by a researcher, who applied inductive thematic analysis [17]. Another author independently and inductively analysed three transcripts. The two researchers collectively reviewed and, through independent coding and discussion, reached a consensus about the application of themes, which were then reviewed and agreed upon by the research team. The interviews were then coded according to themes using the NVivo 12 software. Data were presented as absolute numbers, proportion or median ± interquartile range (IQR). The Consolidated criteria for Reporting Qualitative research (COREQ) checklist is available as Supplementary material 3.

2.6. Ethics

An information sheet was given to every participant and a written consent was taken for every participant. No distinguishable personal information was recorded and all the data were analysed anonymously. In accordance with French law, the study complied with the Commission Nationale de l'Informatique et des Libertés (CNIL, reference number 2213247). The IRB CER-MIT (IRB00011642) approved the study (reference number 2019–0701).

3. RESULTS

3.1. Participants

Interviews were conducted with 25 GPs, mostly face-to-face (15, 60 %), but also by phone (10, 40 %), with a median duration of 40 min (IQR

33–44). Six GPs initially expressed interest in participating but did not follow through with the interview. Nine additional GPs participated in the focus group for the triangulation of results. Overall, 20 participants were women (59 %), median age was 34 years (IQR [32–43]) and most of the GPs worked in an urban environment (n = 24, 71 %) (Table 1, individual details in Supplementary material 4). All the GPs used a medical software for the management of patient files. They used Antibioclic at a median frequency of seven times a week (IQR 2–8), most often on the website and at times on the smartphone application, especially during home visits. All participants reported sustained use of Antibioclic, for over a year. Antibioclic was the most widely used CDSS across all medical decisions. The doctors mentioned that they frequently encountered problems of bacterial resistance in their clinical practice, particularly for urinary tract infections (UTI).

3.2. Determinants of success

Eight key themes that explained the sustainable adoption of the CDSS were identified: usability, trustworthiness, routinization, convenience, antimicrobial prescribing, improved practices, contextual learning and a perceived lack of negative consequences (Table 2, Fig. 1). These themes were split into three groups: those related to the CDSS itself (usability, trustworthiness), those related to its use (routinization, convenience, antimicrobial prescribing); and, lastly, those related to results (improved practices, contextual learning, lack of negative consequences).

3.3. CDSS characteristics

The participants evoked the confidence they had in the CDSS as a key determinant of success; it was based on several points. First of all, Antibioclic was often presented during their training; many doctors discovered the tool during their residency or medical studies. Some GPs discovered the CDSS through peers or residents working in the surgery.

D9: “Obviously, it inspires your confidence when your colleagues also use it and everyone seems satisfied with it.”.

Users also appreciated the fact that Antibioclic is supported by academic structures and relies exclusively on guidelines validated by health authorities, rather than expert opinions. Indeed, Antibioclic was often presented by official social welfare inspectors during their visits to surgeries. The fact that the CDSS is completely independent from pharmaceutical companies and has been financed, since its creation, by public funding alone helped to build confidence, which was also based on regular updating. Participants also declared that the treatment recommendations were reliable and up-to-date; they praised CDSS as an easy-to-use and highly reliable ergonomic tool. Moreover, the CDSS was considered as an exhaustive means of management of common bacterial infections. Its simplicity seemed essential, and it was easy to successfully integrate the CDSS into consultations. Lastly, the GPs declared that a mobile application made it possible to remotely use the CDSS anytime, including during home consultations.

D8: “Having a tool like this helps those who do not have the time or the courage to do training and update themselves to catch up. And it is a tool that we have in our pocket all the time and it is very precise, it is not time-consuming. On the contrary, it saves time.“.

The GPs also pointed out the importance of co-design between GPs and infectious diseases specialists in the development of a CDSS.

D1: “So yes, I think it is fundamental to associate both, I think, infectious diseases specialists in their fields, and down-to-earth generalists/GPs, on what patients want.”.

Table 1
Patient characteristics.

	Number (%) [IQR] (n = 34)
Median age (years) [IQR]	34 [32–43]
Women	20 (59)
Years since qualification	7 [3–14]
Modality	
Face-to-face interview	15 (44)
Phone interview	10 (29)
Focus group	9 (26)
Duration of the interview (minutes)*	40 [33–44]
Working environment	
Urban	24 (71)
Rural	10 (29)
Region	
Île-de-France	26 (76)
Grand Est	3 (9)
Hauts-de-France	2 (6)
Normandy	1 (3)
Auvergne-Rhône-Alpes	1 (3)
Provence-Alpes-Côte d’Azur	1 (3)
Use of patient management software	34 (100)
Use of Antibioclic	34 (100)
Website	34 (100)
Smartphone application	7 (21)
Number of uses per week	7 [2–8]

*Only for interview participants.

3.4. CDSS use

The participants described the CDSS as a tool that readily fits into the consultation and the decision-making process in their daily practice. Antibioclic guides practitioners on therapeutic decisions (selection of antibiotics, etc.), and is perfectly suited for doctors, whereas diagnosis is mainly clinical and less suited to a CDSS. According to some participants, Antibioclic has occupied a “vacant” place insofar as the medical representatives who used to occasionally provide information on the new recommendations had disappeared.

Several participants stated that they used the CDSS to communicate with patients, especially those who contested the non-prescription of antibiotics. Some said they showed a CDSS screen to demonstrate that their attitude was in accordance with current recommendations.

D21: “And on top of that, I used it to persuade the patient who comes up eager to be prescribed antibiotics. (…) I show Antibioclic: “You see, you have acute bronchitis, no recommendation for an antibiotic”.

Doctors also discussed the discrepancy between guidelines and daily clinical practice. Many deplored the difficulty of accessing most recommendations and said they used Antibioclic as a quick visualization tool adapted to their practice.

D15: “The new medicine is a bit like that, we have access to a lot of information so we remember the place where we must go to get it, and perhaps less the information itself “.

Routinized use of Antibioclic was described; according to all the participants it saved time, replacing the consultation of recommendations in books or on the Internet, and providing the right information at the right time.

D6: “I use it [Antibioclic] because the recommendations of expert groups take a long time to read in consultation; it takes time to find the right chapter and the right recommendation on what interests us during the consultation”.

Frequency of use was an important point for the doctors, who observed that when used infrequently, a CDSS ends up being forgotten and abandoned. Since antibiotic prescribing is a daily decision, the CDSS effectively became part and parcel of their practice. The participants pointed out that as a highly standardized decision, framed by numerous, regularly updated guidelines, antibiotic prescribing was conducive to routine use of CDSS. At the same time, it is a complex decision, often discussed with patients and having a significant individual and global impact through its repercussions on AMR.

Different types of use were observed: many GPs described systematic

Table 2
Determinants of the sustainable adoption of a CDSS.

1. Trustworthy
1.1 Based on national guidelines
1.2 Supported by health authorities
1.3 Frequently updated
1.4 Presented and encouraged by peers
1.5 Academic
1.6 Co-designed with General Practitioners
1.7 Sustainable
1.8 Reliable content and technique
1.9 Independent of pharmaceutical companies
2. Ease of use
2.1 Simple and ergonomic
2.2 Free
2.3 Quick
2.4 Comprehensive for primary care
2.5 Tackles every component of a prescription
2.5 Adapted platforms: website and application
3. Integration into the consultation
3.1 Fills a vacant place
3.2 Replaces guidelines that are long and difficult to use
3.3 Clear position in medical decision making
3.4 Helps to communicate with patients
4. Antibiotic prescribing: a special decision
4.1 Structured decision
4.2 Frequent decision
4.3 Constant updating
4.4 Complex decision
5. Routinization
5.1 Gain of time
5.2 Frequent use
5.3 Sustainable use
6. Practice improvement
6.1 Adherence to guidelines
6.2 Promotes antimicrobial stewardship
6.3 Management of complex situations
6.4 Improves antibiotic prescribing
7. Few risks identified
7.1 Does not replace Infectious Disease specialists
7.2 Does not increase screen time
7.3 No deskilling
7.4 Good reception by patients
7.5 Does not prevent critical appraisal
8. Facilitates learning
8.1 Situated learning
8.2 Learning through repetition
8.3 Updating knowledge
8.4 Simple decision trees that promote learning
8.5 Modulation of use over time

and rapid use to validate antibiotic prescriptions, even in simple clinical situations. Some practitioners used it for frequent infections in a specific population (pregnant women, breastfeeding women, renal failure, etc.), in which the accuracy and completeness of the CDSS appreciably facilitated selection of the right antibiotic, duration and dosing. Lastly, numerous practitioners said that they used it in a regular manner to make sure that there was no new update of the guidelines.

Sometimes I go back there and ask myself,'Hasn't there been an update since last time?'.".

3.5. Contextual learning

The interviews with GPs highlighted the major contribution of Antibioclic to continuous medical education. More specifically, the CDSSs actively contributed to the dissemination of the guidelines issued by scientific societies and health authorities. Participants repeatedly emphasized the role of a CDSS in updating knowledge on common bacterial infections. According to some, the information provided by the CDSS was registered and retained insofar as it was associated with an actually encountered clinical situation.

D7: "It updates my knowledge when something has changed. I take erysipelas as an example; I realized that the duration of the antibiotic therapy had changed. It was on Antibioclic that I learned that it had been updated".

As previously reported, Antibioclic was used frequently by GPs, allowing current treatment recommendations and strategies to be repeated over and over again. Repetition was a powerful educational tool and surefire means of consolidating knowledge.

D17: "Maybe the first time, I followed the CDSS a little stupidly, but then I saw several patients, and now I remember it.".

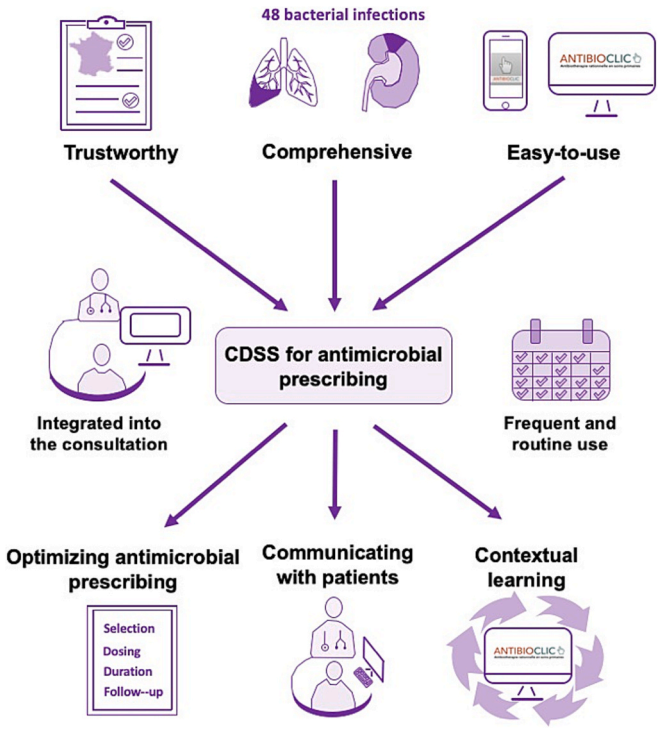

Fig. 1. Use and results of a CDSS in antimicrobial prescribing.

According to participants, the use of Antibioclic evolved over time and according to updates: the CDSS was initially used to learn new guidelines after a recommendation change, and then used progressively less as practitioners became able to prescribe without it. Overall, doctors felt that Antibioclic enabled "intelligent" prescribing by facilitating learning while prescribing. Contrary to common assumptions in CDSS literature, it could contribute more to reskilling than to deskilling.

D6: "It brings me up to date. It has "reskilled" me, so to speak.".

3.6. The results of DSS use

Another objective of the interviews was to identify unexpected consequences. Participants reported no risks or negative effects of CDSS use. Antibioclic did not reduce patient confidence; on the contrary, patients were reassured by their doctor consulting up-to-date recommendations. Doctors also felt that it did not impair critical thinking. The CDSS neither increased screen time nor diminished the quality of doctor–patient interactions. Importantly, it did not replace consultations with infectious disease specialists, which were still sought out in complex cases.

3.7. Avenues for CDSS improvement

The interviews highlighted room for CDSS improvement. While participants emphasized its value as an educational tool, some suggested better explanation of the rationale behind recommendations. As of now, Antibioclic provides advice on antibiotic choice, duration, and dosage, but without specifying the reasons for preferring one option to another. Participants also proposed incorporation of vaccine recommendations as a means of reminding them of those indicated for at-risk populations.

Lastly, many participants emphasized the potential of CDSSs in public education. They suggested providing patients with printable information sheets, including guidance on antibiotic treatment, infection prevention (especially UTIs), and the impact of antibiotics on resistance.

4. Discussion

This study explored the determinants of sustainable adoption of an electronic CDSS in general practice in France. According to participants, the success of Antibioclic was based on eight key themes: usability, confidence, routinization, convenience, improved practices, antibiotic prescribing, contextualized learning, and a perceived lack of negative consequences. Participants highlighted its educational value, emphasizing its role in GPs' continuous training. Our findings offer insight on successful integration of CDSS in routine clinical care.

A *meta*-synthesis of qualitative research on CDSS identified challenges in integrating these tools but found no studies explaining successful adoption of CDSS [18]. A general lack of research on CDSS–prescriber interactions and unintended consequences was observed. Regarding the consequences of CDSS use, a recent study with 29 physicians found that it could be viewed as time-consuming or tending to limit critical thinking [19]. On the contrary, the 34 GPs in our study found that CDSS saved time and supported informed decision-making. Usability and accessibility of recommendations emerged as shared facilitators. As noted in a recent review, the impact of electronic systems and AI on human health depends largely on their use [20].

The theoretical NASSS framework (non-adoption, abandonment, scale-up, spread and sustainability) highlights the potential pitfalls of CDSS implementation [11]. Better understanding of routine CDSS use can guide future system development, including machine learning [21]. Among the 73 strategies proposed in the Expert Recommendations for Implementing Change, four stood out: forming academic partnerships, holding educational meetings, facilitating clinical data relay, and informing local opinion leaders [22]. These findings should help to design future CDSSs or user interfaces fully adapted to actual clinical workflows.

As it allows easy access to information, Antibioclic has been seen as contributing to medical training and education. Similarly, in an article proposing a ranking of the most "reliable, relevant and readable" tools at the point of care, the CDSS has been placed at the top of the ranking followed by textbooks [23]. More specifically, it has been shown that by citing the evidence favoring specific decisions, CDSS has great educational promise for trainees and practitioners alike, and offers the opportunity to move practice from newly published research to standard of care much more quickly than the 17 years it usually takes [24]. To our knowledge, however, the specific role of CDSSs in continuous medical education has not been analyzed, and only a few studies have addressed their use in undergraduate training [25].

Our qualitative work complements a recent quantitative study on Antibioclic use among French GPs [15] and should contribute to discussions about implementing CDSS for antimicrobial prescribing in primary care in low- and middle-income settings [26,27]. However, we did not assess the impact of Antibioclic on prescribing volume, appropriateness, or patient outcomes. Although the themes were straightforward and consistently interpreted with high inter-coder agreement, limited double-coding represents a methodological limitation. The study sample consisted exclusively of long-term regular users of Antibioclic, who were financially compensated, possibly biasing their answers and limiting exploration of barriers affecting non-users or occasional users. Most participants were practicing in the Île-de-France region, a factor limiting the generalizability of our findings. Moreover, this study focused on individual prescribers, and further work si needed to apply our results to the healthcare system taken as a whole, and encompassing secondary and tertiary care.

5. Conclusion

According to the present study, adoption of a CDSS for antimicrobial prescribing is based on eight key themes: usability, confidence, routinization, convenience, improved practices, antibiotic prescribing, contextual learning and the perceived lack of negative consequences.

Our study provided valuable information on (a) the determinants of the long-term adoption of a CDSS and (b) a framework to inform the development and implementation of future CDSSs.

Ethical statement

An information sheet was given to every participant and a written consent was taken forom every participant. No distinguishable personal information was recorded and all the data were analysed anonymously. In accordance with French law, the study complied with the Commission Nationale de l'Informatique et des Libertés (CNIL, reference number 2213247). The IRB CER-MIT (IRB00011642) approved the study (reference number 2019–0701).

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.idnow.2025.105157.

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