Feasibility, usability, and uptake of a decision support tool for common infections in ambulatory care: A qualitative study with semi-structured interviews

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Master of Family Medicine
Masterproef Huisartsgeneeskunde
Academiejaar: [2025 – 2026]

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Abstract

Introduction: The rise of antimicrobial resistance (AMR) presents a significant global public health threat. A major driver of AMR is the inappropriate use of antibiotics, including overprescription, unnecessary treatments, and non-adherence to clinical guidelines. The primary objective of this study is to evaluate a web application that provides real-time access to up-to-date antibiotic prescribing guidelines for general practitioners (GPs) in Belgium. The tool seeks to improve the accessibility and usability of guidelines, reduce inappropriate antibiotic use, and contribute to national and international efforts to combat AMR.

Materials and Methods: This study employed a qualitative design with semi-structured interviews. The population consists of 25 participants, including GPs and GP trainees. There were two visits with the participants, one before and one after a three month period in which the participants could use the application. In the first visit quantitative data including demographic variables and defensive attitude scores were collected. In the second visit a retrospective think-aloud interview based on two patient cases and a semi-structured interview were conducted to explore usability, acceptability, and the perceived influence of the application on clinical reasoning and prescribing behaviour.

Results: The statements and visions of the interviewed physicians can be divided into four themes. The use of the application was mostly triggered by specific clinical contexts (theme 1). The tool was not used when perceived as redundant. Clinical uncertainty and patient-specific risk factors can trigger tool use. Situational context also plays a role in the usage. The application was perceived as user-friendly and intuitive, while further refinement is needed to capture a broader clinical spectrum (theme 2). The application should integrate with existing clinical practice, while adding value beyond traditional guidelines (theme 3). An important aspect of this theme was the integration of the application into the Electronic Health Record (EHR) software, which was viewed as an added value for almost all of the physicians. Most physicians stated the tool could have an educational impact and could be used as a communication tool towards patients (theme 4). For most physicians, the use of the application did not lead to major changes in their prescribing behavior

Discussion: Overall, the tool has been evaluated as an intuitive application which can help in the clinical decision-making process. The integration of the application into the EHR systems will likely increase the efficiency and use of the tool even more. These findings could inform the development of similar digital health interventions, both in Belgium and globally, supporting efforts to combat antimicrobial resistance on a wider scale.

Nederlandstalige Samenvatting

Inleiding: De toename van antimicrobiële resistentie (AMR) vormt een aanzienlijke bedreiging voor de volksgezondheid wereldwijd. Een belangrijke oorzaak van AMR is het onjuiste gebruik van antibiotica, waaronder overmatig voorschrijven, onnodige behandelingen en het niet naleven van klinische richtlijnen. Het primaire doel van deze studie is het evalueren van een webapplicatie die huisartsen in België in ware tijd toegang biedt tot actuele richtlijnen voor het voorschrijven van antibiotica. De tool heeft tot doel de toegankelijkheid en bruikbaarheid van richtlijnen te verbeteren, oneigenlijk antibioticagebruik te verminderen en bij te dragen aan nationale en internationale inspanningen om AMR te bestrijden.

Materialen en methoden: Deze studie maakte gebruik van een kwalitatief onderzoeksopzet met semigestructureerde interviews. De populatie bestond uit 25 deelnemers, huisartsen en huisartsen in opleiding. Er vonden twee bezoeken plaats met de deelnemers, één voor en één na een periode van drie maanden waarin de deelnemers de applicatie konden gebruiken. Tijdens het eerste bezoek werden kwantitatieve gegevens verzameld, waaronder demografische variabelen en scores voor defensieve houding. Tijdens het tweede bezoek werd een retrospectief think-aloud-interview op basis van twee fictieve casussen en een semi-gestructureerd interview afgenomen om de bruikbaarheid, acceptatie en de waargenomen invloed van de applicatie op klinische redeneringen en voorschrijfgedrag te onderzoeken. In deze studie werden alleen de kwalitatieve gegevens weergegeven.

Resultaten: De uitspraken en visies van de geïnterviewde artsen kunnen worden onderverdeeld in vier thema's. Het gebruik van de applicatie werd meestal getriggerd door een specifieke klinische context. (thema 1) De tool werd niet gebruikt wanneer deze als overbodig werd beschouwd. Klinische onzekerheid en patiëntspecifieke risicofactoren kunnen aanleiding geven tot het gebruik van de tool. Ook de situationele context speelt een rol bij het gebruik. De applicatie werd als gebruiksvriendelijk en intuïtief ervaren, maar er is verdere verfijning nodig om een breder klinisch spectrum te kunnen omvatten. (thema 2) De applicatie moet worden geïntegreerd in de bestaande klinische praktijk en tegelijkertijd een toegevoegde waarde bieden die verder gaat dan de standaard richtlijnen. (thema 3) Een belangrijk aspect van dit thema was de integratie van de applicatie in de software van het Elektronisch Medisch Dossier (EMD), wat door bijna alle artsen als een toegevoegde waarde werd gezien. De meeste artsen gaven aan dat de tool een educatieve impact kan hebben en kan worden gebruikt als communicatiemiddel naar patiënten toe. (thema 4) Voor de meeste artsen leidde het gebruik van de applicatie niet tot grote veranderingen in hun voorschrijfgedrag.

Discussie: Over het algemeen wordt de tool beoordeeld als een intuïtieve applicatie die kan helpen bij het klinische besluitvormingsproces. De integratie van de applicatie in de EMD-systemen zal de efficiëntie en het gebruik van de tool waarschijnlijk nog verder vergroten. Een tool als deze kan de klinische besluitvorming stroomlijnen en oneigenlijk antibioticagebruik terugdringen. Deze bevindingen kunnen als basis dienen voor de ontwikkeling van soortgelijke digitale gezondheidsinterventies, zowel in België als wereldwijd, en zo de inspanningen om antimicrobiële resistentie op grotere schaal te bestrijden, ondersteunen.

Introduction

The rise of antimicrobial resistance (AMR) presents a significant global public health threat. Infections that were once easily treated with standard antibiotics are becoming increasingly difficult to manage, leading to prolonged illness, higher healthcare costs, and increased mortality. The World Health Organization (WHO) has identified AMR as one of the top global health threats, with projections suggesting it could cause up to 10 million deaths annually by 2050 if current trends continue (1, 2). A major driver of AMR is the inappropriate use of antibiotics, including overprescription, unnecessary treatments, and non-adherence to clinical guidelines.

While AMR is a global issue, it is also a growing concern in Belgium (1, 2, 3). Despite the efforts of the Belgian government and healthcare institutions, including the Belgian Antibiotic Policy Coordination Committee (BAPCOC), significant gaps in adherence to antibiotic prescribing guidelines persist (3). These gaps contribute to the ongoing development of resistance and undermine the effectiveness of national and international efforts to preserve the efficacy of existing antibiotics.

In Belgium, the BAPCOC has developed comprehensive guidelines (4) to support general practitioners (GPs) in making appropriate antibiotic prescribing decisions. However, adherence to these guidelines remains suboptimal. Factors such as diagnostic uncertainty, patient expectations, and time constraints contribute to the continued misuse of antibiotics. Studies show that inappropriate antibiotic use is a pervasive issue worldwide (5), underlining the need to address these barriers to guideline adherence. Moreover, the accessibility and usability of clinical guidelines during routine consultations pose additional challenges. GPs often find it cumbersome or time-consuming to search for the relevant information while managing patients. This highlights the urgent need for innovative digital tools that can streamline access to guidelines and promote appropriate antibiotic use in primary care settings. Digital transformation in healthcare, particularly through the integration of evidence-based guidelines in clinical workflows, offers a promising avenue to address these challenges. A growing body of evidence suggests that mobile applications and computerized decision support systems (CDSS) can significantly reduce cognitive burden, improve clinical decision-making, and support evidence-based antibiotic prescribing (6, 7). Therefore, a web application, that integrates current guidelines and provides real-time support for GPs during consultations, could help overcome several barriers to appropriate prescribing. By making guidelines more accessible and user-friendly, such a web application is a possible antimicrobial stewardship strategy as it has the potential to improve prescribing accuracy, reduce unnecessary antibiotic use, and ultimately contribute to the broader fight against AMR.

Furthermore, studies highlight the role of technology in improving adherence to prescribing guidelines (8). Digital tools that integrate evidence-based guidelines into clinical workflows have shown promise in improving decision-making efficiency and guideline adherence by providing real-time, easy-to-use support during consultations (8).

This research aligns with the growing interest in digital transformation within healthcare. The primary objective of this study is to evaluate the user experience and perceived clinical value of a web application that provides real-time access to up-to-date antibiotic prescribing guidelines for GPs in Belgium. By seamlessly integrating the BAPCOC guidelines into routine clinical practice, the application aims to support GPs in making evidence-based prescribing decisions during patient consultations. Ultimately, the web application seeks to improve the accessibility and usability of guidelines, reduce inappropriate antibiotic use, and contribute to national and international efforts to combat AMR.

Materials and Methods

1. Study Design

This study employed a mixed-methods design, consisting of a prospective observational cohort study combined with a nested qualitative component. The study design was guided by the Medical Research Council (MRC) framework for process evaluations of complex interventions (9). Both quantitative and qualitative data were collected to assess user experiences and interactions with the educational web application for antimicrobial stewardship in ambulatory care.

2. Participants

2.1 Inclusion and Exclusion Criteria

Participants eligible for inclusion in this study met all of the following criteria:

1. GP/GP trainee during the whole study period
2. Working in Belgium (i.e., Flanders, Brussels, or Wallonia)
3. Owning a device which can use the application (i.e., computer, mobile phone, or tablet) and which can make screen recordings
4. Volunteered to participate and
5. Provided the signed informed consent form

Participants eligible for study must not meet any of the following criteria:

1. GP who completed practice
2. Medical specialties other than GPs
3. More than 2 participants working in the same practice

2.2 Recruitment and Sampling

Participants were recruited via professional contacts, previous research collaborators, and targeted advertisements on relevant academic (KU Leuven, University of Antwerp, University of Ghent, University of Brussels, UCLouvain, ULiège, UMONS, UNamur and Université libre de Brucxelles) and medical platforms (Domus Medica, Centre de Coordination Francophone pour la Formation en Médecine Générale (CCFFMG), ICHO actua and primary care zones). Recruitment materials, for example posters (see supplementary materials A.) were distributed through university networks, newsletters and websites (10).

Purposive sampling was applied to ensure variation in gender, years of clinical experience, institution of medical graduation, type of practice (solo, duo, or group), and practice location (urban or rural).

3. Application

The application is available at https://www.prescriptionsearchsupport.be/ and requires a login-procedure through a regulated identification (eID, ItsMe..) or through a university student account for which you can sign up.

Once logged-in, you get three levels of drop-down menu as shown in the associated images. We use a hypothetical clinical case to give an insight into the application (see addendum case 1).

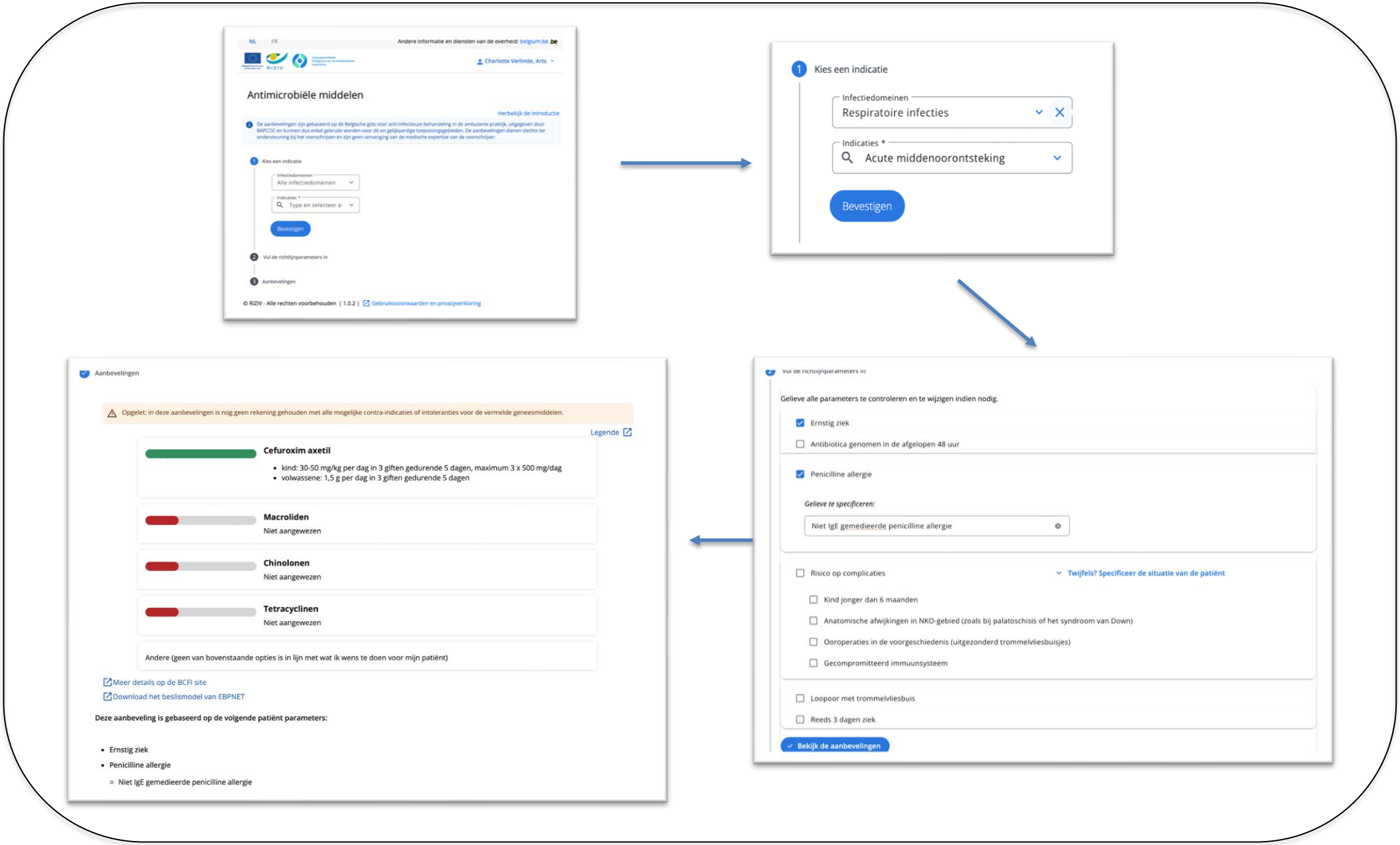


Figure 1: Graphical representation of the application during the execution of case 1 ((Screenshots taken 28-10-2025 12h01)

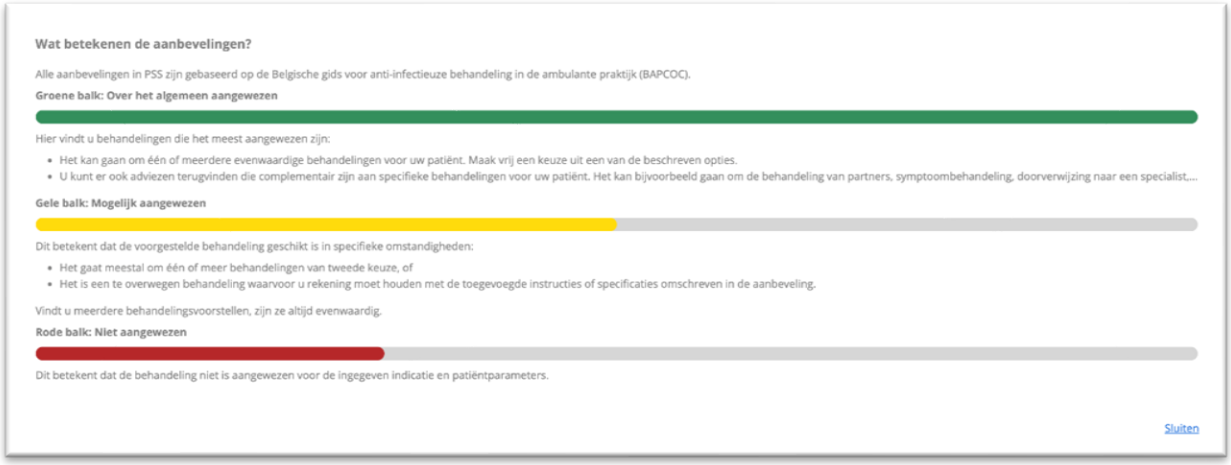


Figure 2: Explanation of the color-coded recommendations in Dutch

The recommendations were color-coded: green for the preferred treatment option, yellow for options to consider in specific situations, and red for non-recommended options.

4. Procedure

4.1 Baseline Visit (Visit 1)

At baseline, a researcher (AV, EV, DVD, CV or HD) met each participant in person or online. No other persons were present. Informed consent was obtained, and a demonstration of the tool was provided using screenshots and a live example on the researcher's device. Demographic data were collected, including gender, year of medical graduation, training status, practice type, and whether colleagues had access to the application.

Participants completed a validated "defensive attitude score" questionnaire to assess risk-avoidant clinical behaviour (11). This score served as a proxy for the participant's tendency to prescribe antibiotics.

4.2 Use of the application

Participants used the application for a duration of three consecutive months. To assess user interaction, log file data were collected. The following metrics were registered:

- Number of times the final list of recommendations was generated,
- Time elapsed between indication selection and recommendation choice,
- Content of selected recommendations,
- Whether a hyperlink to the full guideline was accessed,
- Justifications for deviations from recommended choices.

These data informed analyses of intervention fidelity (whether the application was used as intended), dose (extent of use), and reach (engagement of the target population).

4.3 Follow-up Visit (Visit 2)

At the end of this period (after 99 days on average), a second in-person visit was conducted. For 2 participants, this was an online meeting because of practical issues. Participants completed a brief survey assessing usability and user satisfaction, based on a modified version of the System Usability Scale (SUS) (12,13).

A retrospective think-aloud interview was then conducted. Participants were instructed to verbalize their thought processes while using the application with fictional cases (see supplementary materials B.) with screen recordings capturing their navigation behaviour. This method enabled in-depth exploration of user cognition and interaction patterns (14, 15).

Subsequently, semi-structured interviews (see supplementary materials C.) were conducted to explore usability, acceptability, and the perceived influence of the application on clinical reasoning and prescribing behaviour. Interviewers also recorded field notes on non-verbal cues and contextual observations.

5. Data Collection and Analysis

5.1 Quantitative Data

Quantitative data included demographic variables, defensive attitude scores, usability survey responses, and application log data.

5.2 Qualitative Data

All interviews and think-aloud sessions were screen- and audio-recorded, transcribed verbatim using an AI application (TurboScribe and clipto.ai) with manual checking afterwards, and pseudonymized. If necessary, the text was translated (from French to Dutch) using the AI tool or Deepl.com, with corrections based on the audio file if needed for understandability. Transcripts were analysed using reflexive thematic analysis (16). This process involved repeated reading of transcripts, coding, generation of themes based on the collected date (done by AV, EV, DVD, CV or HD), and iterative refinement in collaboration with the full research team. (see supplementary materials D.) NVivo software was used to support qualitative data analysis.

Data from the think-aloud interviews were further used to construct a cognitive task model describing the mental processes involved in application use.

6. Ethical Considerations and Data Management

Ethical approval was obtained on 27 September 2024 from the ethics committee UZ/KU Leuven prior to study initiation (MP031770). Informed consent was obtained from all subjects before data collection.

All data were stored securely using OneDrive for Business (KU Leuven). Participant data were pseudonymized to protect confidentiality. Audio and screen recording files were saved securely after transcription, and only the pseudonymized transcripts were retained.

Data handling complied with GDPR regulations and KU Leuven policies on confidentiality and data protection. Access to raw data was restricted to members of the study team, and participants were informed of their rights through the informed consent process.

7.Reflexivity statement

AV (MD), EV (MD), and CV (MD) are white female GP trainees. AV previously completed an internship at the GP practice where two of the participants were working. EV is part of the same educational group for GP trainees as one of the participants. DVD (MD) is a white male GP trainee. AV, EV, CV and DVD are conducting the study as their master's thesis for becoming a GP. JV (prof., MD) is a white male GP with 17 years of clinical experience. HD (MSc.) and TDB (PhD) are white female biomedical scientists not involved in treating infections or prescribing, so their understanding is research-oriented and may differ from the clinical perspective. HD, EV, TDB, and JV had prior experience in qualitative research, and HD conducted the study as part of her PhD. All researchers are born in Belgium.

Results

A total of 57 physicians were recruited, of which 14 were unable to be reached for further inclusion, two dropped out after inclusion (one responded to the first follow-up e-mail but was unable to be contacted after; another let know not to participate anymore due to unsuitable timing), three let know not to be interested in participating anymore (no reason provided) and 13 were contacted by us saying the target sample had already been reached. A total of 25 physicians participated, with an equal distribution of GPs and GPs in training (see table 1). We achieved a good distribution of participants across Belgium (see figure 3).

Table 1. Characteristics of the participants (n = 25).

Characteristic	***N (%)***
Gender	
Male	8 (32%)
Female	17 (68%)
Years of clinical experience	
GP trainee (first year)	3 (12%)
GP trainee (second year)	3 (12%)
GP trainee (third year)	6 (24%)
GP (4-10 years)	9 (36%)
GP (11-20 years)	2 (8%)
GP (> 20 years)	2 (8%)
Practice setting	
Group practice	19 (76%)
Duo practice	3 (12%)
Solo practice	3 (12%)
Someone else in the practice has used the tool	
Yes	13 (52%)
No	12 (48%)
Rurality	
Town or suburb	16 (64%)
City	5 (20%)
Rural area	4 (16%)
Institution of basic medical degree	
KU Leuven	10 (40%)
Ghent University	6 (24%)
University of Liège	3 (12%)
UCLouvain	2 (8%)
ULB	2 (8%)
University of Antwerp	2 (8%)

GP: general practitioner



Figure 3: Demographic distribution of participating physicians across Belgium

In this paper, we only report the analysis of the qualitative data. For the analysis of quantitative data and the mixed-methods approach, we refer to another paper (17).

Theme 1: The use of the application is triggered by specific clinical contexts

The majority of the interviewed physicians do not use the application for every infection they encounter in their office. The use of the application is in most cases triggered by blind spots in their knowledge like less frequent diagnoses or certain aspects of a case that makes them doubt the different treatment options.

Subtheme 1.1: The tool is not used when perceived as redundant

There are two frequently reported reasons to not use the application. The first is when the physicians feel like they know the guidelines well enough, so they do not need extra information on how to treat the infection. This is the case for infections they encounter frequently (on daily or weekly basis). For example, some physicians stated they do not use the application for otitis media, others stated they do not use it for pneumonia and some other physicians also stated they do not use the application for urinary tract infections. On the other hand, a few physicians mentioned they did use the application for urinary tract infections.

P24, GP: "There are still many cases where I no longer consult the recommendations because I know them or think I know them, and they are usually still up to date."

P26, GP trainee: “I feel that in most situations I encountered, I was already well aware of the recommendations, for example about cystitis and such things. I use those recommendations often, so I think I know them well, so I don't need to look them up every time. So I think that's why I didn't use them very often.”

Secondly, the application is also not used when the diagnosis is a viral infection like a common cold, flu or bronchitis, because in this case the physicians immediately decide there is no need for antimicrobial treatment. This was stated by the majority of the interviewed physicians.

P26, GP trainee: “But it's true that we've had a lot of viral infections, for example, so I didn't feel the need to go and see because I know that antibiotic treatment isn't necessary.”

Subtheme 1.2: Patient-specific risk factors trigger more utilisation of the application

Not only diagnoses triggers tool use, but also the patient-specific risk factors are an import aspect for the physician to use the application. Most of the interviewed physicians thought the tool would be useful for complex cases with more fragile patients. Age (elderly and young children), decreased kidney function, compromised immune system and pregnancy were the most reported risk factors. The physicians frequently used the application in those cases to check which type of antibiotics were indicated and if there is need for an adjustment of the dose.

P14, GP trainee: “Yes, if I already know that, oh dear, he's a high-risk patient, or she's pregnant, or that's a child, or he has poor kidney function, then I do double-check what I'm allowed to give. And at what dosage.”

The most reported reason triggering tool use was allergy to antibiotics, most physicians stated they used the tool in case of allergy to antibiotics.

P16, GP trainee: “I think I mainly used this application when there were real allergies. I usually don't know about second choice options and such. The first choice is easier. But if there are allergies, I would always use something like this, the app.”

Subtheme 1.3: Clinical uncertainty triggers tool use

The application is mostly used in case of doubt. On the one hand, doubt is caused by the previously mentioned patient-specific characteristics (subtheme 1.2). Another reported cause of doubt is less frequently encountered diagnoses. Pyelonephritis, orchitis, prostatitis, diverticulitis, vulvovaginitis and sexual transmitted diseases were all reported as infections the physicians encounter less frequently and trigger the use of the application because of uncertainties about the treatment of those infections.

P22, GP: “For those exceptional infections, such as diverticulitis and orchitis, which happen to be the examples I'm thinking of right now, but pneumonia, otitis, and cystitis are pretty much your basic routine, actually.”

One physician also reported to use the tool in case of doubt about the diagnosis (i.e., diagnostic uncertainty) to compare the differences in treatment options between two diagnoses. (see theme 2 step 1). One GP trainee found it useful in case of doubt because they feel more uncertain due to a lack of experience.

Subtheme 1.4: The tool was mostly used in retrospect and was not frequently used outside the doctor's office.

The application was mostly used in retrospect, after their clinical decision-making process. This could be during or after the consultation, as a way for the physician to check their chosen treatment option. Some of them did not use it during the consultation due to a lack of time. One physician said to use the BABCOC guidelines instead because it was more accessible, compared to the login procedure of the application. Some physicians reported to use the application during the consultation. One of them said they found the application faster to search for the appropriate treatment option than searching in the other guidelines.

P19, GP trainee: "I found it very useful to check myself afterwards: did I prescribe the right antibiotic? Yes, and usually it was confirmed."

One physician mentioned to use it prior to a phone consultation to a patient that they had seen earlier.

Some physicians used the application in the GP out-of-hours centre. One physician reported the GP out-of-hours centre setting as a cause of doubt. Since they do not know the patients there as well as their own patients and have limited information about them, there are more antibiotics prescribed than if they would see the same patient in their own office. This physician also stated, by using the tool in the GP out-of-hours centre setting, it reduced the doubt about the treatment options and gives confirmation about the chosen treatment option. One physician mentioned specifically not to use it in the GP out-of-hours centre due to a lack of time and the high patient turnover.

P23, GP: "Interviewer: And would you also use it in the GP out-of-hours centre? Would it be useful there? P23: I think so. Because in the GP out-of-hours centre, we see that antibiotics are prescribed a lot, because they don't know the patients. And that just means there is a lot more uncertainty."

P19, GP trainee: "In the GP out-of-hours centre, I think the reason I didn't use it there is simply time. It's super busy and there's a new patient every ten minutes. So I just didn't find the time or the routine to use it."

The application was not frequently used during house calls because it is a web application. Some physicians stated it was difficult to use on location because they do not always take their computer on house calls and found the web application difficult to use on their phones. A few physicians asked if there could be an application designed to download on their mobile phones.

P26, GP trainee: "So, I actually do a lot of house calls. And so I tried to use it with my phone. Ultimately, when I'm doing house calls, I don't always have my computer with me because I'm mainly in a nursing home. So, I don't necessarily take my computer with me. And so I found it really cumbersome to use on the phone. So I admit that I hardly ever used it when I was visiting, when I was making decisions at that moment."

Theme 2: The application's content is positively evaluated, though adaptions are suggested to improve the user-friendliness and address a wider clinical spectrum

Overall, the application was perceived as user-friendly and intuitive. This section provides an overview of the different steps of the application, accompanied by the feedback obtained.

Step 1: Broadening diagnostic applicability while improving selection efficiency

Firstly, it was noted that the accessibility of the diagnosis selection could be improved by incorporating synonyms into the system. For example, participants suggested adding "urinary tract infection" as a synonym for "cystitis," and "acute otitis media" for "middle ear infection." Additionally, it was mentioned that the search function could be enhanced by making it less sensitive to strict spelling. This feedback was particularly relevant for participants using the French-language version of the application where the frequent use of accents affected search results. Some participants made the suggestion to organize diagnoses by body system. This would allow the application to be used even in cases of diagnostic uncertainty. An important point to consider is that most of these barriers would likely be resolved if the application was integrated into the Electronic Health Record (EHR) system.

P18, GP trainee: "I have occasionally used it like... . The diagnosis was uncertain, because you're not sure whether it's pneumonia or bronchitis or not, so I first look at one and then the other, and compare the treatment of the two different conditions in that way, to see if there was a clinical difference, or a difference in therapy. If there wasn't, it doesn't matter if you investigate further. So I've used it a few times, because I was a bit unsure about the diagnosis at the time. And I think it's definitely useful in those situations. And I would use it like that."

Several missing diagnoses were identified. Multiple participants indicated the absence of skin infections (e.g., cellulitis, erysipelas), oral and dental infections, and diverticulitis. Others noted the relevance of including otorrhea (with or without tympanostomy tubes), diarrhoea (e.g., Salmonella), bite wounds, Mycoplasma pneumonia and chronic sinusitis.

On the other hand, some diagnoses currently included in the application do not require antibiotic treatment, such as influenza and the common cold. However, participants emphasized that retaining these diagnoses may still be useful. In particular, the application could serve as an educational tool to discourage unnecessary antibiotic prescribing (see subtheme 4.2 and 4.3), and to support clinicians in explaining to patients why antibiotics are not indicated (see subtheme 4.4).

Step 2: Encouraging interactive engagement in selecting patient characteristics

The second step of the application, in which patient characteristics are entered, was generally described as useful. Some physicians stated that it makes them notice certain patient characteristics that they did not know were important in the decision of prescribing antibiotics. Participants appreciated the ability to navigate back and forth between different input fields, which was seen as a clear advantage. Several noted that this functionality helped them better understand the range of available options and prompted more reflective consideration of each case.

P19, GP trainee: "Yes, you are a little more aware of the special cases. Because you often see the pattern. But if you immediately, for example, see the contraindications for furadantine or recent antibiotic use, those are sometimes things you don't always think about. And I think that's a good reminder to learn from. To see that again or something."

P14, GP trainee: “I find it very useful. Certainly, that you can adjust things like... Okay, seriously ill, not seriously ill or something like that. Little things like that you can adjust, or whether you're going to change your policy or not.”

Most participants found the list of patient characteristics to be sufficiently comprehensive. Objective parameters—such as renal function, age, and comorbidities—were considered the most relevant. In contrast, subjective parameters (e.g., "severely ill child" or "risk of complication") were perceived as more difficult to interpret. Another physician recommended that the distinction between children and adults—for example, in the case of acute bronchitis—should be incorporated in step 2, rather than already being split across different diagnoses in step 1. A few participants also noted missing parameters, such as CRP (point-of-care testing) and the duration of symptoms.

An important consideration mentioned was the need to maintain the application’s clarity and usability. Participants emphasized that any potential addition to the list of parameters should be carefully evaluated to avoid clutter and cognitive overload.

A commonly appreciated feature was the collapsible nature of the patient characteristics section. This allowed users to skip it if they deemed it unnecessary. However, many GPs in training reported that they nearly always expanded the list, using it as a checklist to ensure that all relevant factors were considered.

The “allergy” parameter generated specific feedback. Some participants expressed a preference for placing this information in a separate step, rather than as part of the patient characteristics section. It was also noted that, if the application were to be integrated into the EHR, it would be essential that allergy information (IgE mediated or not) is known and correctly coded in the patient file (see subtheme 3.2).

In addition, few physicians reported that inclusion of previously used antibiotics would be useful. Some diagnoses in the tool have the option to indicate previously used antibiotics, but not all diagnoses have this. This was missed by a few physicians with use of the application.

P11, GP trainee: “They had already taken some medication. And I just couldn't choose it ***previous medication use*** with that diagnosis. Now, I think that's still useful, because sometimes they've already taken two days of amoxicillin that they had at home. And then you think, yes, what should I do with this now? Those are the cases where you'd like to take a look, and it doesn't come up at every diagnosis, for example.”

Several participants considered this second step as an added value compared to the traditional BAPCOC guideline. They felt the application contained more relevant clinical information and was more time-efficient in its use. Nonetheless, one physician found BAPCOC to be more structured and easier to navigate.
One specific addition mentioned was the guideline for cystitis in nursing homes, as well as protocols for endocarditis prophylaxis.

Step 3: Ensuring clarity and simplicity in the visualisation of recommendations

User Perceptions of the Recommendations Display

All participants found the presentation of the recommendations visually appealing, describing it as a clear and well-structured overview of the various treatment options. Few physicians admitted they did not read all the recommendations. Most participants appreciated that even the non-recommended therapies were included. This feedback was particularly well-received by younger physicians or GPs in training, as it was seen as a learning opportunity.

P20, GP trainee: "Well, if I had used it, I would have used moxifloxacin instead of azithromycin. Moreover, I was surprised to see that azithromycin was completely in the red, when I know that many people use it for sinusitis with penicillin allergy."

One physician suggested that the reasoning behind a non-recommended treatment should be made more explicit. One physician proposed the implementation of a clickable pop-up feature for additional information (see paragraph 'Suggestions for Additional Content'). This would allow users to access more detailed content when desired, without overwhelming those who have limited time or do not require further explanation.

P10, GP: "Only, I do miss the educational aspect there (e.a. the last step). But that's up to the people who are interested. Why you don't provide it. That's always nicer (... to know). "

P10, GP: "And if a switch has been made, then it's like, why is this or that, why is it different? So that you can add a group of extra information if necessary. That way, if you're interested, you can still go a little further. Or, if necessary, you can be linked to an online programme, explaining why macrolides, tetracyclines and quinolones are not suitable."

Most respondents indicated that step 3 contained sufficient information and did not feel the need to consult the guidelines separately. However, one participant felt that the information provided lacked detail and reported frequently referring to the BAPCOC guidelines for additional information (e.g., pricing, reimbursement and medication leaflet).

Some participants found the diversity of recommendations thought-provoking, as it challenged habitual prescribing patterns. The application was described as promoting reflection, which contributed to its educational value.

P3, GP: "I think it can be useful and certainly also a bit of confirmation or something. You know most things somewhere, but not 100%. So you get some confirmation or new ideas, like, ah, maybe we can solve it that way too. Of course, you still have the clinical and prior knowledge or other knowledge that makes you think, maybe that or that, but actually you have to follow the guidelines. ..., so you try to follow it, but then there's also that bladder infection (case 2). I don't know if I would follow that completely, but it does give you food for thought: is it really necessary to do that?"

Color-Coded Display and Clinical Usefulness

The color-coded design was unanimously praised as intuitive and highly user-friendly, especially in contrast to continuous text formats provided by the BAPCOC guideline. Some physicians also used the colour codes during patient consultations as a tool for patient education (subtheme 4.4). The physicians appreciated that there were several options instead of one, in this way they were free to follow their own decision-making process.

P12, GP trainee: "Yes, I think it's definitely useful, also with those colours, so you remember that green is good, yellow is less good and red is not good ... because if it's not indicated in the text, or only indicated if, well, it doesn't stick in your mind so well."

P7, GP: “And sometimes explaining it to patients too. Like, look, you see... I turned my screen towards them and said, look, you see, actually it's still in the green, the wait-and-see policy. But, as you can see, in the orange, if they have a fever for three days, then amoxicillin is recommended. But now we really still have some leeway for the doubting patients. ”

The distinction between green and yellow options was also considered useful in certain settings, such as nursing homes, where having second- and third-line treatment alternatives was seen as beneficial

Suggestions for Additional Content

Participants suggested expanding the content of step 3 to include topics such as the management of pertussis outbreaks, reimbursement criteria for medications like ciprofloxacin, and magistral formulations (e.g., nitrofurantoin for paediatric use). However, some questioned whether these additions would still fall within the intended scope of the application.

Some physicians recommended the integration of a dosage calculator, especially for paediatric dosing based on weight. One participant further suggested indicating the most appropriate packaging form for prescriptions.

P9, GP trainee: “What occurred to me now was that with those thirty milligrams, you could add a calculator. You could add the kilogram of body weight. Because that's where we always lose the most time, I think.”

Several physicians suggested adding a list of alarm symptoms that could be shared with patients when a watchful waiting strategy was chosen, guiding them on when to seek follow-up care.

Drug interaction alerts were not considered a useful addition; one participant argued that recognizing relevant interactions is based on clinical expertise and cannot be fully captured in an application.

<u>Theme 3: The application should integrate with existing clinical practice, while adding value beyond traditional guidelines</u>

Subtheme 3.1: Complementary with the complex nature of clinical decision-making

Many of the physicians explicitly stated that the clinical assessment of a patient largely determines the clinical decision-making process, which may make them deviate from the guidelines provided in the application. One of the physicians also added that the contra-indications in the application might be relative, and that the clinical assessment and knowledge of a patient's history (both medical and in terms of what they already received as treatment in the past and its effect), might overrule the recommendations.

P10, GP: “Gosh. I find "feeling sick" somewhere , I really find that very... That's such a gut feeling, I think. I'd rather see that in a less rigid system. That's what I think, yes... It's just a very subjective thing sometimes. Because sometimes you really sense that something isn't right. And then, yes, you can use your gut feeling, so to speak, your "uneasy" feeling, let's say.”

As already mentioned in theme 2, the clinical assessment in the tool is presented as parameters, for example: “seriously ill”. Some of the physicians stated that a flowchart determining the answer to the parameter (“seriously ill”: “yes or no”) could be a useful addition in supporting the physician’s decision, especially for young physicians or trainees, whereas others say it is difficult to integrate such flowcharts since it is merely based on a subjective clinical feeling.

P11, GP trainee: “This is partly a clinical assessment anyway, but I think it could be useful for young doctors and junior GPs. Without having to answer all those questions, but if you want, to be able to use the decision tree.”

Most of the physicians declared that they take more factors into account when deciding on the appropriate treatment than the tool offered. For example, the severity, duration, course and timing (e.g. shortly before the weekend) of the symptoms affect their management of the disease. These factors were not always possible to indicate in the tool. Other reasons impacting the management were for example the presence of fever and the effect of antipyretics on it, and the fact that the patients or parents’ story is not always reliable.
Other factors weighing in on the decision included the age of the patients, the available packaging size, the context (e.g. residential setting) and the health literacy (e.g. delayed prescriptions are not suitable for all patients).

P10, GP: “The duration of the symptoms. Just as I said earlier. People have a very poor understanding of when their symptoms started.”

P23, GP: “I don't always think fever is a good parameter. Parents are... ‘Oh dear, it's 39°C’ and then they immediately become concerned. Whereas 39 is fine. Some children run a high fever, others run a low fever. It's more the general condition of a child that says much more than those 39 degrees.”

P17, GP: “Not every patient is always able to assess when the situation is worsening. So that delayed prescription is not suitable for everyone.”

Subtheme 3.2: Demand for integration into electronic health record (EHR)

During the study, the login-procedure was often seen as a burden by many of the physicians, since it required opening a new tab in the internet browser and connecting through an email address and a password. Some of them admitted they could have reduced this burden by saving the login information into a keychain with automatic login. The general opinion was that the login-procedure was time-consuming, and this increased the threshold for using the application by some of the physicians during consultations.

P2, GP trainee: “That meant that I often only did it afterwards. So not during my consultation, but afterwards to check whether what I had done was correct. And during use, I use BCFI, because that was a bit more accessible. But yes, indeed, if it didn't require login details, then it could also be done during...”

The integration of the application into the EHR software is therefore viewed as an added value for almost all of the physicians. However, there is still debate about what form this integration should take.

The opinions differ between an automatic pop-up and an extra button in the EHR much like the in Belgium well-known Cebam evidence linker. This is a summarizing tool containing many different evidence-based links based on the entered diagnosis in the EHR. The extra button next to the diagnosis in the EHR was the preferred method of integration for most of the physicians, since it would mean they are in control of when they would like to open the tool and it is perceived as less invasive.

P12, GP trainee: “But yes, perhaps like the evidence linker is useful, that it stands out enough. Because I often look at the evidence linker now. But the fact that it's there and that you see it and think, ah yes, okay, and then it automatically appears in that selection menu.”

P18, GP trainee: “I think that like the Evidence Linker offers significant added value, because then you don't have to type it in. And many doctors do indeed have a problem with clicks, or with repetitive work in general. So if you, like Evidence Linker, seem to offer added value, because then you're going to make it even more accessible. “
P27, GP trainee: “ On the one hand, I think that if it is placed as Evidence Linker, I doubt that many people will bother to click on it. So perhaps it would be better if it were displayed automatically.”

One of the suggestions was a small pop-up coming up after entering the diagnosis with complementary information like “often no antibiotics needed in this situation” (similar to the alert given in the software used in Mediris, which is a wide-spread used software in the GP out-of-hours centre in Belgium). Other suggestions were a pop-up after prescribing antimicrobial agents with the notification that the one prescribed is not the first choice or a pop-up with the drop-down menu of the tool. Aspects to consider in this situation were the necessity of a small pop-up (not taking up too much space in the already crowded screen of the EHR) and the possibility of alert-fatigue with too many pop-ups and the adverse effect of not consulting the recommendation within the pop-up anymore. On the other hand, few of the participants stated that with mandatory pop-ups, you can more easily nudge physicians into using the tool and thus directing them into prescribing antimicrobial agents following the guidelines.

P5, GP: “If you really want to achieve results in the long term, then I think you should do that. With a separate button, you will reach us, the young, conscientious doctors who want to check. And often perhaps also the less confident doctors who want to check whether they are doing the right thing with their treatment or their antibiotics. And not those who say: ah yes, I've been doing it this way for years, it's fine. You won't reach them with that. Then you need a pop-up, I think.”

P10, GP: “If a pop-up appears during a diagnosis, I would check each time to see if what I am doing is still correct.”

P18, GP trainee: “But I think a pop-up will cause a lot of frustration, that it pops up too quickly, that you just keep clicking it away, so that eventually you stop using it.”

Regarding the automatization and possible integration of information from the EHR, some of the physicians indicated that they do not agree with adding too many automatizations during the decision-making process in the tool. In this way, physicians would feel like losing the clinical touch with prescribing or being overtaken by a computer or artificial intelligence (AI). Many of the physicians declared it would be helpful if some information from the EHR would be integrated directly into step two of the tool, sparing them some time and effort. An inevitable prerequisite for this to work, would be a well-completed coded EHR on both history and up-to-date patient information (e.g. recent weight and allergy). Only one of the physicians stated they would feel comfortable with AI taking over their clinical decision making, as it would help with the efficiency in their practice.

P9, GP trainee: “When you are filling in CareConnect (EHR), and you write, for example, “acute otitis media” in the diagnosis, and you have also stated in your objective — in your observation — that there is a fever, or this or that...
That, based on that, you already get a kind of pop-up saying: this is not necessary, or: this is necessary.
You don't have to click anything extra, but a small pop-up or something like that just appears?”

Interviewer: “Either the fact that you have to click on it to get the recommendation, or that the recommendation appears immediately when prescribing?” P4: “I would prefer it to be added immediately ... as a pop-up"

P9, GP trainee: “Whether that, I don't know, a certain AI application or whatever, can also extract certain things from your medical history. That's part of it. For example: that drooling, that dysphagia, not being able to eat properly — that is a symptom, so we may need to address that as well. So that once you've entered everything, you don't have to enter it all again somewhere else.”

Subtheme 3.3: Added value beyond traditional guidelines

Most of the physicians preferred using the application over the regular BAPCOC guidelines. They expressed that one of the key conditions to use the application, was the additional value by its user-friendly design and the quick access to critical information. Given examples were that the tool provided faster access to contraindications, which were presented as parameters in step two, making them easier to identify. This feature helped prevent prescribing errors. The application also included additional advice, such as the importance of partner treatment for sexually transmitted infections (STIs), which served as a helpful reminder. A few physicians also found that the application prompted them to consider important aspects they might have otherwise overlooked. Most participants also appreciated the tool's simplicity, finding that it provided just enough information while offering the option to click for more details. The intuitive interface is a significant improvement over the BAPCOC guidelines, which were sometimes perceived as less user-friendly.

P1, GP: “But since it's so similar to what the BCFI offers, and the BCFI sometimes...well, sometimes it's more comprehensive, which is also its purpose, it suggests the type of treatment, the reimbursement, the...the price, the shape of the boxes, and the number of tablets. It's more comprehensive, more exhaustive. So, out of habit, I often use BCFI, but this is also a possibility.”

P10, GP: “It (ea. the tool) was easier because everything was bundled together, rather than having to search for it in BAPCOC in BCFI. So that was simpler. But in general, it was very efficient, yes.”

P12, GP trainee: “I do like using it. Because you... Compared to BAPCOC, for example, where you often have to click on lots of different things to finally get where you want to be. Then you first have to find the antibiotics section. Then you have to click on lots of different things to find your policy. You may already know a lot of those things from practice, but then you go straight to which antibiotics you need and in what dose. But then you sometimes skip between those steps... When exactly are antibiotics indicated or no longer indicated?”

However, some of the physicians found that the application is still a work in progress. Not all diagnoses had been incorporated yet, and there was no direct access to patient information leaflets. Another potential area for improvement was the inclusion of parameters for specific patient conditions, such as renal function adjustments, which were not yet fully integrated in every indication.

Interviewer: “And do you often click through to the full guideline? Or do you stick to that?” P14, GP trainee: “Yes. Yes, if I'm not entirely sure... Or to double-check the dosages. Well, because with cystitis, I know that it's just very... Like... Indeed, with pregnant women or other things, it's always a bit different. So sometimes I do click through.”

The traditional BAPCOC guidelines were considered more comprehensive by some of the physicians. Additionally, a few participants also stated that the BAPCOC guidelines offer the ability to view related recommendations for different clinical situations, which helps users refresh their knowledge. The familiarity and user habit contribute to an efficiency that were valued by some physicians.

P24, GP: “But it is true that it is a bit more user-friendly than BAPCOC. I find it somewhat comparable to using BAPCOC, but at least it is a fairly straightforward application. So it's a bit more practical, more useful; it's not a huge difference, but it does help. But it's true that there's a bit more choice; for example, if you want to say that someone is at risk, you can choose from

more options. It's a bit more comprehensive than BAPCOC for infections, but it's true that I sometimes had to look something up in BAPCOC or elsewhere because it wasn't included."

Other guidelines that were used by some of the participants, were the NHG-guidelines (from the Netherlands), which offer a broad background about the clinical presentations mentioned in the tool. However, it was noted that the antimicrobial agent's recommendations mentioned in the NHG-guidelines are not always usable in the Belgian ambulatory setting .

P18, GP trainee: "Yes, there are indeed, because the NHG is often more comprehensive on certain matters, but then again, that's the Netherlands, and here with antibiotics it's a bit different."

Theme 4: Experienced impact of the application on physicians' knowledge and clinical decision-making

Subtheme 4.1: Facilitating user adoption

Participating physicians stated that awareness of the application is likely to be established through peer recommendations, regional meetings, practice-level communication, and newsletters. This will be further supported by the fact that the tool is easily accessible online. Some basic computer literacy is required, as colleagues with prior e-health experience integrated the tool more quickly. Physicians indicated that the application could also be useful for more experienced GPs, although they noted that this group is often the most difficult to reach. They pointed out that a major pitfall is that the application will mainly reach those physicians who are already conscientious about responsible antibiotic use, and less so the group that pays less attention to this issue. At the same time, participants felt that the application could still offer added value to the experienced physicians. Several participants mentioned that it would be useful to provide short tutorial videos to quickly explain the app's functionality and added value.

P10, GP: "That's also the difficulty of this study. What kind of people are participating in this study? These are people that are already very involved in antibiotic policy. People who are not involved in antibiotic policy will not cooperate with this."

P6, GP: "I do think it will need to be promoted. It needs to be advertised in local circles during training courses where it can be demonstrated. I think that will be more effective than sending a letter or email about it."

P7, GP: "You can always try with the app, and I hope it's a bit more evidence based. Now, it's really being drummed into young people. And older people are less likely to pay attention to it, I think. Those who were really used to being paternalistic and whose will was law are simply not going to bother with it, because their will is law."

P16, GP trainee: "I just showed it to a colleague who said, "Ah, that's actually quite interesting." And that's someone who's fifty or forty years old. He said it was interesting. So I think a lot of people would be open to it."

In this study, the physicians did not receive a practice incentive, as the application was still in a testing phase. Nevertheless, most of them were asked about their views regarding the potential role of a financial incentive. Physicians indicated that such an incentive could provide motivation to use the application. Several of them suggested that setting a clearly defined condition, such as a minimum number of consultations using the tool per year, might encourage physicians to integrate it more structurally into their practice.
At the same time, physicians raised concerns about possible unintended consequences. Some expressed that a financial incentive could carry the risk of colleagues using the tool merely as a quota-driven instrument, without considering the underlying quality of decision-making. According to some

physicians, incentives should therefore be linked to measurable and clinically relevant criteria, while monitoring should ideally be automated through EHR integration in order to avoid additional administrative workload.

P12, GP trainee: “You could work with it, like the evidence linker, in such a way that you have to click on it at least a certain number of times per year. That way, you will maybe realize that it might actually be useful and start using it more often.”

P23, GP: “You will encourage physicians. If there is a financial incentive, they will do it.”

P7, GP: “I think we are already monitored so much in everything we do that I don't need that. I find it a very interesting tool that I will mainly use for myself.”

Subtheme 4.2: Perceived educational impact

Physicians indicated that the application served as a useful continuing education tool because it was directly based on the BAPCOC guidelines. Several participants stated that the clear and case-based design made it easier to stay up to date with existing guidelines, compared to going through the full BAPCOC guideline documents. Participants noted that the structured format of the tool provided quick access to relevant details.

P10, GP: “It would be very useful if, when the guidelines are updated, the applicationalso automatically updates so that you are always up to date.”

P10, GP: “Why am I not allowed to give something? I would add that as additional information.”

Participants indicated that the application could also serve as a learning tool for GPs in training and interns. They reported that the case-based and step-by-step structure of the application provided a clear framework that helped to teach the correct reasoning process around antibiotic prescribing. Physicians emphasized that working through successive steps supported young doctors in developing an evidence-based way of clinical reasoning.
Several participants noted that the application’s explicit attention to comorbidities, allergies, and risk factors contributed to more critical prescribing behavior among physicians in training.
In addition, physicians pointed out that the immediate feedback provided by the tool, in case they choose an option that is not a first-choice therapy with the BAPCOC guidelines, created a learning opportunity in which ‘mistakes’ were transformed into concrete educational moments. They can use this feedback for the next case.

P4, GP: “I also use it with interns. It's useful for teaching how to make a decision and how to arrive at it.”

P18, GP trainee: “I definitely find it an added value because I am still a bit insecure, and with the application, I can easily go through the list of risk factors and comorbidities when I am in doubt.”

P11, GP trainee: “You can also clearly see what the risk factors are. And by looking at that, you naturally learn from it too.”

P12, GP trainee: “Because you have to go through all those steps before you arrive at your recommendation, you also think about all the elements that do or do not determine whether you need antibiotics. So I do think you think more critically about your policy, because you have to follow the steps and can't just look directly at the dose of this antibiotic.”

Subtheme 4.3: Perceived impact on prescribing behaviour

For a substantial number of physicians, the use of the application did not lead to major changes in their prescribing behavior. They indicated that the recommendations provided by the tool usually aligned with the choices they had already considered themselves. Several physicians emphasized that this was likely explained by the fact that the study group mainly consisted of GPs (in training) who were already motivated and familiar with evidence-based antibiotic prescribing.

P14, GP trainee: “It's often more of a confirmation. Like, okay, that's what I had in mind, and now I know it's right. I don't know if it has often led to major changes. Usually, it's a confirmation of, okay, wait and see first, then antibiotics. Or, these antibiotics are good.”

P5, GP: “But in general, it's just nice to check: am I right? Or does something else need to be done because the patient has this or that characteristic? And very occasionally, that can steer you in a slightly different direction.”

A few physicians indicated that the use of the application in certain cases led to concrete changes in their prescribing behavior. Whereas some physicians previously tended to choose broad-spectrum antibiotics out of habit or caution, the application more often suggested a narrow-spectrum alternative or indicated that antibiotics were not necessary when clinical criteria were not met. These physicians reported that this prompted them to reconsider their choices more consciously.

P21, GP trainee: “I was considering one antibiotic, but the application recommended another one. And I followed his advice.”

P4, GP: “What I have noticed is that I am actually prescribing antibiotics slightly more often for some types of bronchitis, whereas I hardly ever did so in the past.”

In addition, several participating physicians reported that the stepwise decision-making plan of the application structured their thinking process: first assessing whether antibiotics were needed, then determining which antibiotic was preferred, followed by dosage and treatment duration. According to them, this structured approach helped reduce unnecessary prescriptions and facilitate more targeted choices.
Some physicians also noted that they appreciated the fact that the application, at the final step, always displayed different treatment options, including second-line therapies and treatments that were not recommended. Physicians explained that this gave them room to deliberately opt for an alternative approach when clinically justified (i.e., therapeutic freedom).

P12, GP trainee: “For example, for cystitis, the green recommendation is to wait and see, but I don't actually do that. And then you start thinking about it, and I think I'm going to wait and see more often when it comes to cystitis.”

P2, GP trainee: “This could help general practitioners who might still be prescribing too many antibiotics, because it gives them a clear picture. Okay, in this case it's okay to wait and see. Because in BAPCOC, you still make your own choice. It just says ‘first choice’ and all of them have indications. But still, this might push things more in the direction of the right policy.”

Subtheme 4.4: The application as a patient communication tool

The physicians indicated that the web application has the potential to support both patient engagement and patient education during consultations. Most of the physicians had not initially considered that the tool could also serve as a means of communication with patients, but when asked further, they acknowledged that the visual presentation of treatment options could be of significant

added value. According to them, the color-coded system made it easier for patients to understand why antibiotics were or were not prescribed in their particular situation. In addition, participating physicians stated that the application could also play an important educational role for patients. By reviewing the underlying rationale together with patients, they reported that patients gained insight into the broader principles of rational antibiotic use.

P4, GP: “So I would be more inclined to prescribe antibiotics in consultation with the patient or family. You can also use that to show them what the options are. With people who clearly say, “I've looked it up, it's not possible,” you try to calm them down. And that works. I turn on the screen so they can see what I'm doing. It's actually quite useful.”

P23, GP: “But when a doctor who prescribed a lot of antibiotics retires, new patients ask, “But don't I need antibiotics after all?” And then you have to start explaining everything all over again. It's very useful to be able to explain that the guidelines have changed and that we are following the latest guidelines.”

Discussion

Main findings

The application was generally perceived as an intuitive and supportive tool within the clinical decision-making process, yet its use appeared to be highly situational and primarily triggered by clinical uncertainty. GPs rarely consulted the tool for routine infections such as otitis media, cystitis or pneumonia, nor for presentations that were clearly viral in nature. Instead, they tended to rely on it when facing diagnostic or therapeutic ambiguity, when dealing with less common infections—including pyelonephritis, orchitis, diverticulitis and sexually transmitted infections—or when managing patients with specific risk factors such as allergies, reduced renal function, pregnancy, immunosuppression, or very young or advanced age.

Tool use often occurred retrospectively rather than during the consultation itself. Many GPs reported consulting the tool after the patient encounter to confirm their initial clinical reasoning. During consultations, the tool was used less frequently due to time pressure and a cumbersome login procedure, which formed a practical barrier. In contrast, usage increased during on-call shifts, where higher levels of uncertainty were common. Tool use during home visits remained limited, largely because of insufficient mobile accessibility.

The content of the tool was positively evaluated, particularly in terms of clarity, intuitive structure, and the supportive colour-coding system. However, participants expressed the need for a broader diagnostic scope, including conditions such as skin and dental infections, otorrhoea, diarrhoea, bite wounds, Mycoplasma infections and chronic sinusitis. They also emphasised the importance of synonyms and a more robust search function, especially regarding accent sensitivity. Additional contextual information—such as the rationale behind non-recommended treatment options—was considered desirable, along with practical features like a paediatric dose calculator, packaging information and guidance on red flags for patients.

Step 2 of the tool, which focuses on patient characteristics, was consistently regarded as a major strength. This component helped GPs approach clinical decisions more systematically and ensured that important risk factors were not overlooked. Objective parameters were seen as particularly valuable, whereas subjective elements, such as assessing whether a patient appeared “severely ill,” were more challenging to interpret. Several items were perceived as missing or difficult to retrieve, including C-reactive protein values, symptom duration and previous antibiotic use.

Finally, seamless integration into the electronic health record (EHR) emerged as a critical requirement for routine use in daily practice. The main barrier identified was the current login process and the need to access the tool via a separate webpage. GPs expressed a clear preference for a dedicated button integrated directly within the EHR—similar to existing tools like Evidence Linker—over automated pop-ups. Such integration would streamline navigation, improve efficiency, and allow automatic import of essential patient information, such as allergy history.

Comparison with existing literature

The introduction of this tool for antimicrobial agents has the potential to significantly enhance the quality, safety, and consistency of antibiotic prescribing in primary care (18). By providing GPs with rapid, context-specific access to up-to-date national antimicrobial guidelines, such a tool can streamline clinical decision-making and reduce inappropriate antibiotic use.

The study of Fralick et al. showed that an antibiogram and treatment algorithm could increase knowledge of prescribing antimicrobials in the context of local antibiotic resistance patterns (5).

In France, there is a similar initiative (Antibioclic), where implementation is yielding similar results (19). They had a bigger response, which gave them more quantitative data on tool use. Unlike this study, our study also examined the implementation of the tool using qualitative research methods .

Other guidelines, for example those of the NHG (the Dutch General Practitioner Association), are not always entirely usable. Differences in ambulatory care settings between Belgium and the Netherlands include the antibiotic resistance profiles and the epidemiology. For example, the treatment for pneumonia following the BAPCOC in a healthy adult is amoxicillin 3x1000mg for seven days, compared to amoxicillin 3x500mg for five days following the NHG-guidelines (20).

There was no conclusive opinion on how comprehensive the parameter “severe illness” should be. Some physicians preferred objective criteria that can be checked to know if someone is severely ill, for example the presence of fever. Others preferred a more subjective interpretation based on their gut feeling. For example, in the study of Verbakel et al. (21) a decision tree is used to determine when to use point-of-care CRP tests in children, which consists of both objective and subjective criteria: clinician's gut feeling something is wrong, dyspnea, and temperature ≥40ºC. The group GPs using the decision tree significantly prescribed less antibiotics, compared to those provided with standard care (21).

Strengths and limitations

This study has provided valuable information about the user-friendliness, usefulness and practical implementation of a clinical decision support tool. It contains diverse insights from various GPs and GPs in training about which elements are important for optimizing the use of the tool in daily practice. These elements can certainly inform the implementation process of similar tools in clinical practice.

More women than men (17 (68%) versus 8 (32%)) participated despite the purposive sampling. This is a poor distribution, since in Belgium there is an almost equal gender distribution within the population of GPs and GPs in training (22). In addition, selection bias was present: GPs and GPs in training who were interested in antibiotic policy were easier to find than doctors who were less involved in this area. Furthermore, the study was conducted in the middle of the infection season, which naturally influenced the use of the app. The study took place during the infectious season (October to April), which had an an impact on the antibiotics being prescribed (i.e. more antibiotics are being prescribed for bacterial surinfections).

Implications for clinical practice and further research

The impact of the application on GPs' (in training) prescribing practices remains unclear in this study, but the availability of the application will probably help physicians to use an evidence-based hands-on approach of the antimicrobial guidelines.

As many participants stated, GPs often face time constraints and complex cases, where selecting the appropriate antimicrobial agent can be challenging. A digital tool that allows quick searching by infection type and patient factors ensures that recommendations are directly aligned with current evidence-based guidelines. This helps standardize prescribing practices and minimizes reliance on memory, habitude or outdated references (23).

It is widely known that AMR is increasing, of which inappropriate or unnecessary prescribing of antibiotics is a major driver. By nudging physicians toward evidence-based choices and optimal durations, the tool can contribute to reducing over-prescription and misuse of broad-spectrum antibiotics, an essential step toward combating resistance. Access to clear dosing guidance and contraindications, and feedback about unrecommended antibiotic choices, supports safer, more individualized prescribing. This can reduce adverse drug events, improve treatment efficacy, and enhance patient confidence in evidence-based care (24, 25, 26).

A well-designed standalone application can save valuable consultation time. The ability to instantly cross-reference patient characteristics (e.g., allergies, renal function) with antibiotic options further supports the prescribing process. As many physicians in the study noted, the perspective of having the application interface integrated into the EHR systems, will increase the efficiency and use of the tool even more. By aligning primary care prescribing behaviour with national stewardship goals, the tool has potential to become a practical, easy to use instrument for sustaining responsible antibiotic use and improving long-term public health outcomes (27). The development of a clinical decision support tool integrated in the EHR is included in the Belgian national action plan against AMR (28).

The results of this study could also serve as a foundation for the development of similar digital tools in other areas of clinical decision-making, promoting their broader adoption across healthcare systems. The study evaluates not only the usability of the application but also its potential to influence clinical decision-making and prescribing behaviour. Recommendations based on these study results for the development of future digital health interventions, are the importance of a user friendly and time efficient intervention. When an intervention is time consuming for example due to an unintuitive design or complicated login procedure, physicians will use it less frequently, especially during their consultation. This can create a threshold for implementation into clinical practice.

The findings of this study suggest that financial incentives, such as a practice bonus, may play a role in promoting the use of digital decision-support tools for antibiotic prescribing. Participants viewed such a bonus as a potential motivating factor, particularly when linked to clear and achievable conditions, such as a minimum number of uses per year. At the same time, participants emphasized important reservations regarding a reward structure based solely on quantitative criteria. They expressed concerns that a bonus might lead some physicians to use the application merely to meet formal targets, without genuine engagement with the qualitative aspects of their clinical decisions.

One physician stated he would like the integration of Artificial intelligence (AI) software in the tool to advise if antibiotics were necessary or not. He also stated it would be useful that, if the application was integrated in the EHR software, the AI software could take elements out of the anamnesis and clinical investigation and suggest diagnosis and treatment options. However, most doctors value their own clinical assessment. There are also challenges and limitations about the use of AI in medicine, in particular for the integration in clinical decision-making processes. A major problem is the poor-quality evidence supporting AI applications in the clinical setting. Machine learning, which is inherent to AI software, is limited by data availability and susceptibility to data bias, such as spectrum bias, reporting bias, and measurement bias (29). Also, data privacy and security, discrimination, lack of transparency and accountability for AI errors are some of the problems we face when using AI for clinical decision making, which creates ethical challenges (30).

Conclusion

Overall, the tool has been evaluated as an intuitive application which can help in the clinical decision-making process. The availability of the application will probably help physicians to use an evidence-based hands-on approach of the antimicrobial guidelines. The integration of the application into the EHR systems will most likely increase the efficiency and use of the tool even more. These findings could inform the development of similar digital health interventions, both in Belgium and globally, supporting efforts to combat AMR on a wider scale.

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Supplementary materials

A. Recruitment poster (Dutch)



B. Cases (visit 2)

CASE 1:
Emma is 2.5 years old (13 kg). Her mother brings her to the consultation with the following story.
Emma has been complaining of earache since yesterday. Last night she had a fever (38.2 °C). She was very restless during the night. This morning, her pillow was stained with yellowish fluid from her left ear and there was dried fluid around her ear. She is very drowsy, has not eaten anything today and is struggling to drink anything.
You perform a clinical examination: the left ear canal is indeed full of purulent fluid, but the eardrum cannot be assessed. The right eardrum is slightly red. Her temperature is now 39 °C. No other abnormalities.
Emma has previously had an allergic reaction after taking amoxicillin (not IgE-mediated); she does not have ear tubes.

CASE 2:
Claire is 45 years old. She has Crohn's disease, for which she has been taking Azathioprine daily for ten years.
For the past two days, she has been experiencing pain when urinating. She describes this as a burning sensation during and immediately after urination. She also needs to go to the toilet more often and urinates small amounts at a time. Since today, she has had a slight nagging pain in her lower abdomen. She brought a urine sample to the consultation: the urine is cloudy. The culture and antibiogram of the urine are not yet known at this time.

C. Interview guide semi-structured interview (visit 2)

1. What is your general impression of the WebApp? Would you recommend the WebApp to a colleague and why?
2. What features did you like (dislike)?
3. Can you tell me how you (might) use this tool in your everyday practice? In which situations or for which patients do (or would) you use the WebApp mostly?
4. How often do you find yourself reading the recommendations? What factors influence your decision to read or not to read the recommendations?
5. How do you perceive the impact of using the WebApp on your understanding and knowledge regarding the proper use of antimicrobial agents for common infections (in children) in ambulatory care?
6. How do you estimate the impact of using the WebApp on supporting your decision making with regard to antibiotic prescribing for your patients (or for acutely ill children)?
7. What other items help in decision-making regarding whether or not to prescribe antibiotics (in acutely ill children)? What would be useful as support, in addition to the WebApp?
8. Would you like additional information that could influence your decision-making (regarding to prescribe antibiotics [for acutely ill children] or not) that was not included in the tool?
9. How do you estimate the impact of using the WebApp on changing the way you work or prescribe (with / for acutely ill children)?
10. Which changes would you make to the WebApp to improve its usability or function?

D. Themes and accompanying codes (Dutch)

Theme 1: The use of the tool is triggered by specific clinical contexts.

Intro: Slechts enkele artsen gebruikten het voor alle infecties / situaties…

- gebruik bij alle diagnoses
- gebruik bij niet alle diagnoses
- gebruik bij alle leeftijden
- gebruik bij luchtweginfectie
- gebruik bij urineweginfecties
- gebruik bij SOA's

Subtheme 1.1: The tool is not used when perceived as redundant

- niet of minder gebruikt bij virale pathologie
- niet of minder gebruikt wanneer indruk richtlijn goed gekend

Subtheme 1.2: Patient-specific risk factors as a trigger for tool use

- gebruik bij risicofactoren
- gebruik bij allergie
- gebruik bij voorafgaand antibioticagebruik

Subtheme 1.3: Clinical uncertainty as a trigger for tool use

- gebruik bij twijfel
- gebruik bij minder frequente diagnoses

Subtheme 1.4: Situational context shapes tool use

- gebruik tijdens raadpleging
- gebruik retrograad
- gebruik tijdens belmoment
- gebruik bij huisbezoek of bezoek op verplaatsing
- gebruik bij wachtpost
- voorkeur computer boven mobiel
- voorkeur mobiel boven computer

Theme 2: The tool's content is well-received, while further refinement is needed to capture a broader clinical spectrum.

Subtheme 2.1: Expanding the tool's diagnostic scope while enhancing selection efficiency

- diagnose selecteren stap 1
  - synoniemen diagnoses (stap 1)
  - subcategorieën diagnoses (stap 1)
    - meerdere symptomen of diagnoses
- ontbrekende diagnose (stap 1)
  - pathogeen
- overbodige diagnose (stap 1)

Subtheme 2.2: Interactive engagement while selecting patient characteristics

- instellen parameters stap 2
  - patiëntspecifieke aanbevelingen
- duiding bij patiëntkarakteristieken
  - meer duiding bij ernstig ziek
    - beslisboom ernstig ziek
    - klinische inschatting (ernstig ziek) past moeilijk in PSS
  - meer duiding bij immuungecompromitteerd
- invullen allergie
  - allergie als aparte of extra stap
- invullen leeftijd
- invullen nierfunctie

- ontbrekende patiëntkarakteristieken (stap 2)
    - CRP
    - Woonzorgcentra

Subtheme 2.3: Clarity and simplicity in recommendation visualisation

- keuze aanbevelingen bij stap 3
    - kleurencode
    - advies dosering
    - niet-aanbevolen keuze stap 3
    - link naar richtlijn stap 3
- lezen aanbevelingen
- ontbrekende aanbevelingen (stap 3)
    - calculator dosis
        - voorstel beste verpakking
    - advies voor patiënt bij stap 3
        - alarmsymptomen vermelden bij afwachtend beleid stap 3
    - informatie contra-indicaties, risico's en interacties rode aanbevelingen stap 3
    - terugbetalingscriteria
    - magistrale bereidingen
    - testbeleid mycoplasma

Theme 3: The tool should integrate with existing clinical practice, while adding value beyond traditional guidelines.

Subtheme 3.1: Complementary with the complex nature of clinical decision-making

- klinische kennis of ervaring
    - overrulen
    - vervanging arts door automatisering of AI
- ernst, duur en tijdstip klacht beïnvloedt anamnese en beleid
    - koorts
    - verhaal patiënt of ouders niet altijd betrouwbaar
- leeftijd beïnvloedt beleid
- context beïnvloedt beleid
    - uitgesteld voorschrift niet voor iedereen geschikt
- verpakkingsgrootte beïnvloedt beleid

Subtheme 3.2: Request for integration into EHR

- toegankelijkheid
    - aparte webpagina PSS (niet geïntegreerd in EMD)
        - inlogprocedure
- integratie EMD
    - beperkte ruimte EMD
- activatie PSS na ingeven diagnose
- activatie PSS tijdens voorschrijven
    - melding bij voorschrijven
- knop naar PSS in EMD
    - nieuw tabblad PSS in EMD
    - Evidence Linker
- automatische activatie PSS in EMD (zonder knop)
    - pop-up venster PSS in EMD
    - alert fatigue
- parameters stap 2 uit EMD halen of in EMD invullen

    - kwaliteit codering EMD
- integratie voorschrijfsoftware
    - samenwerking apotheek

Subtheme 3.3: Value beyond traditional guidelines

- andere hulpmiddelen
    - andere bron richtlijnen geeft meer informatie of is vollediger
    - meer informatie dan andere bron
    - verschillende aanbevelingen tussen bronnen
- gebruiksvriendelijk
    - compleet of volledig
    - eenvoud
    - intuïtief of logische opbouw
    - overzichtelijk
    - schrijfwijze, lettergrootte of verwoording
- tijdsinvestering
    - scrollen
    - minder gebruik bij drukke periodes

Theme 4: Exploring the tool's potential impact on the user's knowledge and behaviour

Subtheme 4.1: Facilitating user adoption

- bekendheid bij gebruikers
    - implementatie door demonstraties
    - kennis computers of informatica
- praktijkpremie

Subtheme 4.2: Perceived educational impact

- educatief
    - beperkte nieuwe informatie
- nuttig voor HAIO's en-of stagiaires

Subtheme 4.3: Perceived impact on prescribing behaviour

- verandering voorschrijfgedrag
    - ander beleid dan verwacht
    - gedragsturend werken
- update of verandering richtlijnen
    - update of verandering richtlijnen snel bij arts krijgen
    - melding bij verandering richtlijn
- geen of weinig verandering voorschrijfgedrag
    - bevestigend
    - goede of bewuste voorschrijver
- nuttig voor ervaren artsen
    - minder goede of bewuste voorschrijver

Subtheme 4.4: The tool as a patient communication tool

- patiëntbetrokkenheid of shared decision making
- educatie patiënt

E. COREQ-checklist

COREQ (COnsolidated criteria for REporting Qualitative research) Checklist

A checklist of items that should be included in reports of qualitative research. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Topic	Item No.	Guide Questions/Description	Reported on Page No.
Domain 1: Research team and reflexivity			
Personal characteristics			
Interviewer/facilitator	1	Which author/s conducted the interview or focus group?	9
Credentials	2	What were the researcher's credentials? E.g. PhD, MD	10
Occupation	3	What was their occupation at the time of the study?	10
Gender	4	Was the researcher male or female?	10
Experience and training	5	What experience or training did the researcher have?	10
Relationship with participants			
Relationship established	6	Was a relationship established prior to study commencement?	10
Participant knowledge of the interviewer	7	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	N/A
Interviewer characteristics	8	What characteristics were reported about the inter viewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	10
Domain 2: Study design			
Theoretical framework			
Methodological orientation and Theory	9	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	7
Participant selection			
Sampling	10	How were participants selected? e.g. purposive, convenience, consecutive, snowball	7
Method of approach	11	How were participants approached? e.g. face-to-face, telephone, mail, email	7
Sample size	12	How many participants were in the study?	11
Non-participation	13	How many people refused to participate or dropped out? Reasons?	11
Setting			
Setting of data collection	14	Where was the data collected? e.g. home, clinic, workplace	9
Presence of non-participants	15	Was anyone else present besides the participants and researchers?	9
Description of sample	16	What are the important characteristics of the sample? e.g. demographic data, date	11
Data collection			
Interview guide	17	Were questions, prompts, guides provided by the authors? Was it pilot tested?	9, 36
Repeat interviews	18	Were repeat inter views carried out? If yes, how many?	N/A
Audio/visual recording	19	Did the research use audio or visual recording to collect the data?	9-10
Field notes	20	Were field notes made during and/or after the inter view or focus group?	10
Duration	21	What was the duration of the inter views or focus group?	N/A
Data saturation	22	Was data saturation discussed?	N/A
Transcripts returned	23	Were transcripts returned to participants for comment and/or	

Topic	Item No.	Guide Questions/Description	Reported on Page No.
		correction?	N/A
Domain 3: analysis and findings			
Data analysis			
Number of data coders	24	How many data coders coded the data?	10
Description of the coding tree	25	Did authors provide a description of the coding tree?	37-39
Derivation of themes	26	Were themes identified in advance or derived from the data?	10
Software	27	What software, if applicable, was used to manage the data?	10
Participant checking	28	Did participants provide feedback on the findings?	N/A
Reporting			
Quotations presented	29	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	12-25
Data and findings consistent	30	Was there consistency between the data presented and the findings?	N/A
Clarity of major themes	31	Were major themes clearly presented in the findings?	12-25
Clarity of minor themes	32	Is there a description of diverse cases or discussion of minor themes?	12-25

Developed from: Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007. Volume 19, Number 6: pp. 349 – 357

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.