ENHANCING THE USE OF BEST EVIDENCE AT THE POINT OF CARE

ENHANCING THE DISSEMINATION, ACCESS AND USE OF CURRENT BEST EVIDENCE AT THE POINT OF CARE

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ABSTRACT

This dissertation presents a body of research consisting of 5 scientific papers with an overarching objective to develop and test interventions that can enhance the dissemination, access and use of current best evidence at the point of care. Questions constantly arise from clinicians' interactions with their patients, but more than 60% remain unanswered. The first 4 papers therefore focused on evidence dissemination to clinicians and trainees looking for answers and trying to stay alert to new evidence. We used as our "laboratory" an online tool developed at McMaster University's Health Information Research Unit, the *MacPLUS Federated Search (MacPLUS FS)*, which allows busy clinicians to search multiple top high quality resources simultaneously and display a 1-page output with the most clinically useful results at the top. Guided by effective models for the teaching of clinical skills at the point of care, we designed 3 web-based interventions addressing logistical and educational barriers to increase the quantity and quality of searching for current best evidence. These interventions were: (A) a web-based *Clinical Questions Recorder and Reminder*; (B) an *Evidence Retrieval Coach* composed of 8 short videos embedded in MacPLUS; (C) and a *Gamified Audit & Feedback* based on the allocation of "badges" and "reputation scores" for evidence searching.

We tested these interventions in 4 factorial randomized-controlled trials among 1,868 heath care professionals and students currently registered in MacPLUS FS, namely: 477 medical faculty members, 431 postgraduate medical trainees, 725 nursing students and 235 medical students. Results showed that these target populations substantially differed both in their baseline frequency of search and access to alerts, as in their responsiveness to the 3 web-based interventions on evidence utilization.

Evidence summaries have traditionally been tailored to meet the educational needs of clinicians, but are seldom provided in a format that supports shared decision-making. Our fifth paper explored a potential solution, which constitutes another route for evidence dissemination and use. In a project called *SHARE-IT*, we developed a new framework and online prototype for the generic production of decision aids, which allow physicians and patients to discuss the evidence together in the clinical encounter. We present the framework, design methods and early testing of this generic approach, which showed promising results for the translation of evidence summaries into useful tools for shared decision-making.

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Finally, I would like to dedicate this work to

My husband,

My sister,

My parents.

A million thanks for your presence and your love.

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LIST OF ABBREVIATIONS

EBM / EBP:	Evidence-Based Medicine / Evidence-Based Practice
EMR:	Electronic Medical Record
GRADE:	Grading of Recommendations Assessment, Development and Evaluation (www.gradeworkinggroup.org)
IAM:	Impact Assessment Method
IPDAS:	International Patient Decision Aid Standards
MacPLUS FS:	McMaster PLUS Federated Search (http://plus.mcmaster.ca/MacPLUSFS)
MAGIC:	Making GRADE the Irresistible Choice research program and not-for-profit organization (www.magicproject.org). NB: This program, primarily based in Norway, is not the same as its homonym in the UK (Making Good Decisions in Collaboration – www.health.org.uk/areas-of-work/programmes/shared-decision-making).
MAGICapp:	MAGIC Application (www.magicapp.org)
PICO:	Population – Intervention(s) – Comparator – Outcome(s)
PLUS:	Premium LiteratUre Service (http://hiru.mcmaster.ca/hiru/HIRU_McMaster_PLUS_projects.aspx)
RR:	Relative Ratio
SDM:	Shared Decision Making
95% CI:	95% Confidence Interval

DECLARATION OF ACADEMIC ACHIEVEMENT

I was the main contributor and first author for all studies. Detailed lists of author contributions are provided at the end of each study (see Chapter Sections 2.8; 3.9; 4.9; 5.9; 6.9).

This dissertation is a “sandwich” thesis, composed of 5 papers, of which 2 manuscripts have already been published. The first manuscript (see chapter 2) was published in *Implementation Science (impact factor: 4.12)*. The last manuscript (see chapter 6) was published in the *BMJ (impact factor: 17.4)*. The remaining 3 manuscripts (see chapter 3 to 5) are being submitted to peer-reviewed journals.

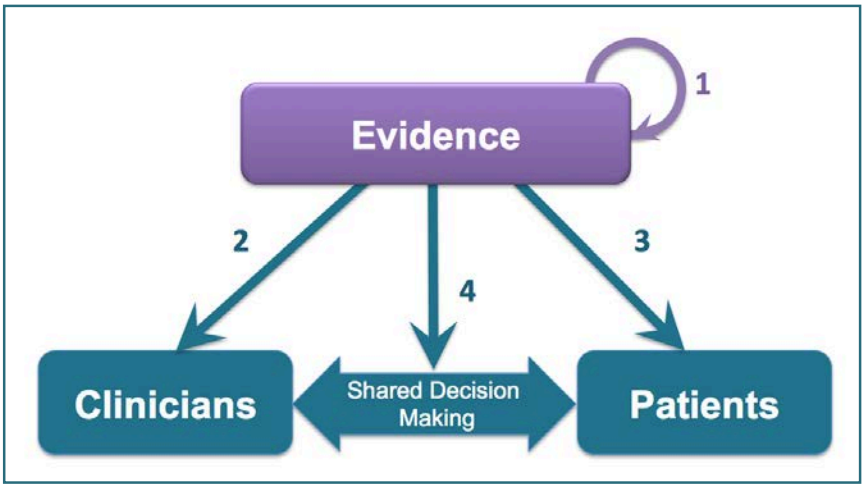
CHAPTER 1

1.1 INTRODUCTION

Since its beginnings, more than 20 years ago, the Evidence Based Medicine movement (EBM) triggered an audacious paradigm shift in the way we approach health care practice.[1-3] With its subsequent widespread uptake, it led to considerable progress in question formulation, evidence processing, critical appraisal and summarization.[4,5] However, even when current best evidence is optimally aggregated, synthesized and continuously updated, it can still often remain in its ivory tower, far from daily clinical practice and patients' concerns.[6-8] This dissertation combines 5 papers (2 of which have already been published[9,10]) that explored innovative ways to enhance the dissemination, access and use of current best evidence at the point of care.

Evidence dissemination can have different routes, and strategies will differ if they are aimed at clinicians looking for answers, patients who access it on their own, or for direct use by both clinicians and patients during the clinical encounter (see Figure 1.1.1). The first 4 papers (i.e. Chapter 2 to Chapter 5) focus on strategies for dissemination to clinicians. This involves both helping them finding current best evidence ('pull'-services) and staying alert to new evidence ('push'-services).[11-13]

Figure 1.1.1 Routes for Evidence Dissemination



Legend: (1) Evidence synthesis and appraisal; (2) Dissemination to clinicians (e.g. evidence-based resources, search engines and alerting services); (3) Dissemination to patients and citizens (e.g. patient decision aids); (4) Dissemination in the clinical encounter for collaborative deliberation (e.g. encounter decision aids).

For this research, we used as our "laboratory" an online tool developed at the McMaster's University Health Information Research Unit, the *MacPLUS Federated Search (MacPLUS FS)*.[9,11] This tool allows busy clinicians to search multiple top EBM resources simultaneously and display a 1-page output with the most clinically useful results at the top, to rapidly find the best available answers to their questions.[9] Guided by effective models for the teaching of clinical skills at the point of care, we designed 3 web-based interventions addressing logistical and educational barriers to increase the quantity and quality of searching for current best evidence (see Chapter 2). We then tested these interventions in several factorial randomized-controlled trials among 1,868 heath care professionals and students currently registered in MacPLUS FS, namely: 477

medical faculty members (see Chapter 3), 431 postgraduate medical trainees (see Chapter 4), 725 nursing students and 235 medical students (see Chapter 5).

However evidence retrieval through enhanced dissemination only partially addresses challenges of point-of-care implementations. Once the appropriate evidence is found, the next issue is to be able to actually use it in practice to inform patient care. Evidence summaries and clinical practice guidelines have traditionally been tailored to meet the educational needs of clinicians, but are seldom provided in a format that supports shared decision making.[10] The last paper in this dissertation explores a potential solution (see Chapter 6). In a project called *SHARE-IT* [10], we developed a new framework and online prototype for the generic production of decision aids, which can bring evidence summaries directly into the clinical encounter (see Figure 1.1.1).

SHARE-IT builds on several recent developments in EBM.[4,5] A first important development is the GRADE approach (for Grading of Recommendations Assessment, Development and Evaluation), which provides a more structured and transparent approach for the creation of trustworthy evidence summaries, and further highlights the importance patients' values and preferences in guiding recommendations and decision-making.[14] A second development lies in new methods and formats for the creation of encounter decision aids, to support collaborative deliberation between patients and clinicians.[10] Finally new authoring

and publications platforms for evidence summaries offer the opportunity for a larger scale production and updating of such decision aids.[7,10]

Taken together, the projects included in this dissertation, although at various stages of development, could contribute to a reduction of the evidence-to-practice gap among health care providers and their patients.

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CHAPTER 2

First manuscript

Increasing the quantity and quality of searching for current best evidence to answer clinical questions: protocol and intervention design of the MacPLUS FS Factorial Randomized Controlled Trials

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Published Article (Full text in PDF format available in Appendix 2.11 – see page 66):

Agoritsas et al.: **Increasing the quantity and quality of searching for current best evidence to answer clinical questions: protocol and intervention design of the MacPLUS FS Factorial Randomized Controlled Trials**. *Implementation Science* 2014 9:125.[1]

2.1 ABSTRACT

Background & Aims:

Finding current best evidence for clinical decisions remains challenging. With 3000 new studies published every day, no single evidence-based resource provides all answers or is sufficiently updated. McMaster Premium LiteratUre Service – Federated Search (MacPLUS FS) addresses this issue by looking in multiple high quality resources simultaneously and displaying results in a one-page pyramid with the most clinically useful at the top. Yet, additional logistical and educational barriers need to be addressed to enhance point-of-care evidence retrieval. This trial seeks to test three innovative interventions, among clinicians registered to MacPLUS FS, to increase the quantity and quality of searching for current best evidence to answer clinical questions.

Methods & Design:

In a user-centered approach, we designed 3 interventions embedded in MacPLUS FS: (A) a web-based Clinical Question Recorder; (B) an Evidence Retrieval Coach composed of eight short educational videos; (C) an Audit, Feedback and Gamification approach to evidence retrieval, based on the allocation of “badges” and “reputation scores”.

We will conduct a randomized factorial controlled trial among all the 904 eligible medical doctors currently registered to MacPLUS FS at the hospitals affiliated

with McMaster University, Canada. Postgraduate trainees (n=429) and clinical faculty/staff (n=475) will be randomized to each of the three following interventions in a factorial design (AxBxC). Utilization will be continuously recorded through clinicians' accounts that track logins and usage, down to the level of individual keystrokes. The primary outcome is the rate of searches per month per user during the six months of follow-up. Secondary outcomes, measured through the validated Impact Assessment Method questionnaire, include: utility of answers found (meeting clinicians' information needs), use (application in practice), and perceived usefulness on patient outcomes.

Discussion:

Built on effective models for the point-of-care teaching, these interventions approach evidence retrieval as a clinical skill. If effective, they may offer the opportunity to enhance it for a large audience, at low cost, providing better access to relevant evidence across many top EBM resources in parallel.

Trial Registration: ClinicalTrials.Gov NCT02038439

2.2 BACKGROUND

Translation of new knowledge from research into evidence-informed health care is a shared obligation of the clinical and the scientific communities. Unfortunately, studies investigating quality of care continue to show that this goal is substantially unrealized. Clinicians' uptake of validated best care procedures remains stubbornly around 50% or less for most advances in therapeutics.[2,3] Combined with a similar rate of patient adherence with self-administered treatments[4], the average effectiveness of therapies reaches typically only about a quarter (50% x 50%) of their potential.

One main barrier to achieving evidence-based care by clinicians is lack of quick and easy identification, appraisal and synthesis of current best evidence. Clinicians' information needs are considerable – with an average of five to eight questions about individual patients per daily shift[5-7], thus making evidence retrieval an essential skill in clinical practice.[8] However about 3000 articles are published in Medline every day[9], including 75 randomized controlled trials and 11 systematic reviews.[10] Numerous Evidence-Based Medicine (EBM) resources have been developed to filter and disseminate the evidence. But although increasingly used by clinicians[11-13], each resource offers a fragmented and scattered view of the information, and none provides comprehensive topic coverage[14,15] or consistent and satisfactory updating.[16,17] As a result, up to 64%

of clinical questions remain unanswered, and many answers are not based on current best evidence.[18-20]

To address these problems, the McMaster's University Health Information Research Unit has developed and implemented the MacPLUS Federated Search (MacPLUS FS). This novel resource provides a unique one-stop simultaneous search of multiple current best EBM resources for use at the point of care (see Table 2.6.1). It also organizes information according to the *pyramid of EBM resources*, displaying results in one page output with the most clinically useful at the top[21] (see Figure 2.7.1). Thus, MacPLUS FS simultaneously retrieves evidence from online *summaries* in the top layers (e.g., DynaMed, UpToDate, Best Practice, ACP Smart Medicine), then *pre-appraised research* in the middle layers (i.e., Systematic reviews, Studies and their Synopses when available, selected in McMaster PLUS database for methodological rigor and clinical relevance[22]), and finally *non-pre-appraised research* in the bottom layers, both filtered[23] and unfiltered from PubMed. In addition to the federated search, MacPLUS FS provides users with alerts to new research in their chosen disciplines[24] (similar content to the widely accessed BMJ EvidenceUpdates[25]), as well as numerous clinical and EBM practical links (see Table 2.6.1). Structurally, MacPLUS FS supplies evidence from research that is relevant to the clinical needs of students, postgrads, and independent practitioners.

However combining features of the current best EBM resources is not enough to increase prompt and reasonable use of current best evidence, as shown by the

relatively low utilization of searching features by the 2800 clinicians registered with MacPLUS FS, in contrast with their high utilization of the alerting system. Additional well-known barriers that need to be overcome include logistical barriers (time constraints, forgotten questions, and simplicity of using one's single preferred, albeit limited, resource), as well as educational barriers (e.g., lack of awareness of the "architecture" of evidence and limits of non-federated single resources, lack of knowledge and experience of what federated searches can offer, limited searching skills, and lack of reference standards among peers for finding best evidence).[20,26-30]

2.3 STUDY AIMS

The trials described in this paper seek to test three innovative interventions among clinicians registered to MacPLUS FS to overcome these logistical and educational barriers and thus potentially increase the quantity and quality of searching for current best evidence to answer clinical questions.

We have designed these interventions based on effective models for the teaching of clinical skills at the point of care, to facilitate using the search engine as a clinical tool, presenting evidence retrieval skills as true clinical skills. Results from these trials may thus provide insight into whether finding current best evidence can be learned and enhanced for a large audience of clinicians through online search engines.

2.4 METHODS

2.4.1 OVERVIEW OF STUDY DESIGN

We plan to conduct two separate factorial randomized control trials among medical doctors registered in MacPLUS FS, one among the postgraduate trainees and one among the faculty members. Participants will be randomized to the three following web-based interventions, all linked to MacPLUS FS, in a factorial design (A x B x C):

- Intervention A – Clinical Question Recorder, linked to MacPLUS FS
- Intervention B – Evidence Retrieval Coach, embedded in MacPLUS FS
- Intervention C – Audit, feedback and gamification on searching behaviors in MacPLUS FS

Thus half our sample will be exposed to each intervention, all possible permutations resulting in eight distinct groups of registrants receiving or not each intervention (see Table 2.6.2). Postgraduate and faculty MDs will be randomized in two separate trials. The primary outcome of interest is *utilization* of MacPLUS FS, namely the number of searches/month/user to answer their questions. This primary outcome will be continuously recorded from automatic monitoring of MacPLUS FS use. Secondary questions include measures of *utility* (satisfaction in meeting users' information needs), *use* (application of evidence in practice), and perceived *usefulness* in patient care and outcomes, as well as changes in

the *pattern of use* of specific resources according to the EBM pyramid (frequency and time trends in utilization).

In the next method section we describe the development of the three interventions: our theoretical framework; user-testing of their different iterations; and the final features that we will test in the trials. The third method section details the methodology of the factorial randomized controlled trials.

2.4.2 DEVELOPMENT OF THE INTERVENTIONS

2.4.2.1 Theoretical framework

To overcome the aforementioned logistical and educational barriers to answering clinical questions with current best evidence[20,26-30], we have built the general framework for our three interventions on effective models for teaching clinical skills at the point of care. We have opted for that approach so that clinicians are facilitated in perceiving evidence retrieval skills as true clinical skills, and encouraged to use MacPLUS FS as the most comprehensive clinical tool for evidence retrieval, in terms of topic coverage, optimal updating, signal to noise ratio and time-management.

Many models have been developed to teach clinical skills at the point of care, but one that has been consistently shown as effective in randomized control trials, and then most widely adopted by clinical teachers, is the "One-minute preceptor model", also known as the "5-step Microskills".[31-35] As shown in Table 2.6.3, we have adapted the teaching steps of this model for the purpose of enhancing evidence retrieval as follows: identifying searching opportunities; prompting searches to answer clinical questions; providing general knowledge, skills and feedback; and inviting reflective practice. We have developed our three interventions (A, B & C) to map these teaching steps.

2.4.2.2 Intervention A – Clinical Question Recorder

2.4.2.2.1 Development methods

The purpose of this web-based intervention is to allow clinicians to: i) easily record their questions at the point of care; ii) receive periodic reminders of unanswered questions, thus providing asynchronous opportunity for evidence retrieval[36]; iii) and keep track of their questions and evidence-based answers in a virtual logbook to enhance their reflective practice. To achieve these objectives, we designed initial mock-ups and a web-based prototype of the recorder, to be linked to the clinician's individual MacPLUS FS account and accessible across a

wide range of devices (primarily smartphones for point of care use, but also tablets and computer desktops).

This intervention requires the active participation of clinicians. To maximize the likelihood that they engage, we focused our development on a user-centered approach based on iterative user-testing of sequential prototypes.[37,38] We recruited independent testers, gave them access to the prototype on their smartphone, and exposed them to nine real-life scenarios that evaluate different aspects of the intervention during one-hour "think out loud" sessions. Using a standardized interview guide (see Appendix 2.10.1), we observed and collected their user experience based on Peter Morville's honeycomb framework.[39] We thus identified major and minor problems and suggestions for improvements on the following dimensions: findability, accessibility, usability, understandability, usefulness, credibility, desirability, and identification. Based on that feedback, we refined the prototype after every two to three user-tests until the problems were overcome and the intervention was intuitive and satisfactory for the users. We then implemented it on the MacPLUS FS interface, with a final check of online usability by the same users accessing it remotely from their setting.

2.4.2.2.2 User-testing

We recruited eight independent testers (three practicing MDs, one student MD, three masters students in Health Research Methodology and one medical

librarian), who underwent 12 full user-tests. We also performed numerous shorter usability tests on four team members. This process identified 34 significant issues – mainly around accessibility, usability, understandability, usefulness, and desirability – which resulted in 38 modifications of the prototype, across 5 major iterations (4 to 11 issues and 3 to 13 changes made per iterations). Consistently fewer refinements were necessary as use of the recorder became more intuitive and users were more satisfied. Final remote usability testing did not identify any remaining issues.

2.4.2.2.3 Results: description of the final features

The main features of the final Clinical Question Recorder are listed in Table 2.6.4 and illustrated in Figure 2.7.2. By simply clicking on “Add New Question”, clinicians can type in and record their clinical questions directly on the web-based interface (Figure 2.7.2-A). Clicking the "Answer" button next to each question triggers a comprehensive search in MacPLUS FS according to the pyramid of EBM resources (Figure 2.7.2-B). Links to relevant evidence can be bookmarked and saved with each clinical question for subsequent access and reading (Figure 2.7.2-C), along with clinicians’ short answers. Periodic reminders of the list of unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence (Figure 2.7.2-D) – clicking on them or the “Answer” button similarly triggers a search in MacPLUS FS.

2.4.2.3 Intervention B - Evidence Retrieval Coach

2.4.2.3.1 Development methods, feedback and usability

The purpose of this intervention is to facilitate the retrieval of current best evidence by providing guidance, “small bites“ of knowledge and skills through short videos. These videos are both embedded in MacPLUS FS and sent via e-mails according to each the clinician’s specific patterns of utilization and search.

We started this development by identifying specific teaching content that may help clinicians to benefit from available EBM resources in finding current best evidence. For that, we built on the strong expertise of our multi-disciplinary team in the Health Information Research Unit (HiRU), which has been one of the leading groups in evidence processing and retrieval, has contributed to many top EBM information resources over the past two decades and has conceived MacPLUS FS. We wrote short scripts and mock-ups, and worked closely with an instructional designer (MP) to optimize language and presentation and produce the short videos.

We then asked our eight user-testers to provide independent feedback, particularly on understandability, usefulness and satisfaction with the content and presentation. After two iterations, the videos were implemented in MacPLUS FS. We then asked our testers to check online usability while using the platform remotely.

2.4.2.3.2 Results: description of the final features

The main features and the content of the videos within the *Evidence Retrieval Coach* are listed in Table 2.6.4. The intervention is composed of eight short videos lasting less than one and a half minute each. The videos are embedded in MacPLUS FS and accessible on smartphones, tablets and desktop versions (see Figure 2.7.3). The content covered includes an overview of the "architecture" of evidence (pyramid), advantages and limits of individual resources (see Table 2.6.1), and how MacPLUS FS's unique features overcome these limits and save time and effort (parallel comprehensive search, critical appraisal, organized presentation of complementary evidence). Special emphasis is put on showing how MacPLUS FS can be used for real-life evidence-based practice (e.g., to translate clinical questions and rapidly get reliable answers).

Moreover, the display of the videos is tailored to clinician's individual patterns of behaviors, according to predefined triggers (see Appendix 2.10.2). After clinicians watch a video, they will receive its link by e-mail as an opportunity to watch it again later. These e-mails will be sent also on a weekly basis as the trial unfolds.

2.4.2.4 Intervention C – Audit, Feedback and Gamification

2.4.2.4.1 Development methods, feedback and usability

Based on behavioral theory, the purpose of this third intervention is to provide clinicians with timely feedback on their current search utilization compared to their peers. However, in a recent Cochrane review on 140 randomized trials, this approach showed only a 4.3% absolute increase in compliance with desired practice (95% CI 0.5%-16%), with feedback being more effective when baseline performance is low and when it is provided regularly.[40] In light of these results, we decided to combine an audit and feedback intervention with a *gamification* approach[41], based on allocation of *badges* popping-up immediately after a desired behavior. These badges result in *reputation scores* that can be compared to peers on an interactive and playful interface within MacPLUS FS. Such approaches can enhance utilization and learning based people's natural desires for “competition, achievement, self-expression, and closure”, and has been successfully used in many other educational settings.[41]

We designed the online interface, badges and graphical presentation with the help of a user experience designer (AC). After internal usability testing of the features implemented, we asked our eight user-testers to evaluate the intervention while using the platform remotely, and provide independent feedback on usability, understandability, and satisfaction with the content and presentation.

2.4.2.4.2 Results: description of the final features

The main features of the final audit, feedback and gamification interventions are listed in Table 2.6.4 and illustrated in Figure 2.7.4. All features are accessible within MacPLUS FS on a "reputation tab" (Figure 2.7.4-A). We generated about 50 badges rewarding the following behaviors: total and weekly frequencies of searches, frequencies of access to the top layers of the EBM resource pyramid (summaries), to the middle layers (pre-appraised research), and to bottom layers (non-pre-appraised research), number of complementary resources accessed per search, number of alerts to new evidence accessed, number of questions recorded (for users also allocated to the Clinical Question Recorder), and number of videos watched (for those allocated to the Evidence Retrieval Coach).

Each badge was assigned a reputation score based on the desirability of the behavior it reinforces. Badges pop-up online after a specific behavior (Figure 2.7.4-E), award their reputation score to the user, and can be accessed again later (Figure 2.7.4-D). Clinician's resulting reputation score can be compared to peers through percentiles displayed in interactive pictographs (Figure 2.7.4-B), and followed graphically across time (Figure 2.7.4-C). Finally, clinicians can explore their access to each EBM resource, mapped according to the EBM pyramid (Figure 2.7.4-A).

2.4.3 PROTOCOL OF THE RANDOMIZED CONTROLLED TRIALS

2.4.3.1 Setting and study participants

We will conduct the trials described in this protocol in the teaching hospitals and clinics affiliated with McMaster University, Ontario, Canada. This amounts to two major academic hospital systems, operating ten hospitals in the Hamilton area, as well as two regional campuses in Niagara and Waterloo, Ontario.

Currently about 2800 clinicians and students are registered in MacPLUS FS. The first trial will be conducted among all postgraduate trainees, and the second trial among all faculty registered in MacPLUS FS at the beginning of the trials, after exclusion of those no longer physically working at McMaster University affiliated hospitals. We will also exclude registrants that have never interacted with MacPLUS FS, either by logging in to read e-mail alerts or to perform a search, during the last 12 months counting back from the beginning of the trials, regardless of how long they have been registered. These broad eligibility criteria reflect our choice to perform pragmatic effectiveness trials, rather than focusing only on high-frequency users. Indeed, our objective is precisely to increase the quantity and quality of searches among low-frequency users in real clinical practice. Nevertheless we are excluding registrants with a very high probability of being unexposed or insensitive to our web-based interventions, either because

they are no longer at our institution or have repeatedly ignored MacPLUS FS over a prolonged period.

By December 31st 2013, these eligibility criteria were met by 904 clinicians – 429 postgraduate and 475 faculty MDs (see Table 2.6.5) – after exclusion of 211 registrants no longer working at McMaster University, and 284 who never interacted with MacPLUS FS during the last year. About two-thirds of eligible users interacted with MacPLUS FS only through e-mail alerts, while one-third performed at least one search in that period. About 16% of eligible clinicians work in the field of internal medicine, 32% work in family medicine, while the other half of the sample works in a wide array of other specialties (see Table 2.6.5).

2.4.3.2 Randomization

Participants will be randomized to our three web-based interventions in a factorial design (see overview of study design & Table 2.6.2). Postgraduates and faculty MDs will be randomized separately and further stratified according to time since last search (<= 365 days vs. >365 days, see Table 2.6.5), as an overall proxy of their baseline frequency searches in MacPLUS FS. Right before the beginning of the trials, participants will be randomly allocated to each factorial group (2^3 = 8 groups), balancing on blocks of 16 within each stratum (=2 x 8). Our information technology programmers, in charge of MacPLUS FS system administration, will perform randomization using a computer-based pseudo-random number

generator. They will maintain a secure master list of the randomization codes and assignments, and conceal allocation from the analysts.

2.4.3.3 Blinding and control group

Although participants cannot be blinded to the interventions, they will not be informed of the different interventions that are being offered. In addition, all participants, including the control group with no intervention, will be exposed to new minor features one month prior to the beginning of the trial. These include: small changes in the web design (simplification of available tabs and navigation), waiting time features displaying all resources searched in parallel in MacPLUS FS (see Figure 2.7.1), and a novel "single citation matcher" (see Table 2.6.1). These minor new features would thus further minimize the risk of contamination between the intervention arms from users becoming aware of interventions they are missing. Moreover, the interventions cannot be shared, as they are linked to individuals' accounts, so that it is unlikely that registrants who are not offered an intervention would increase their utilization just by hearing about it.

2.4.3.4 Outcomes

2.4.3.4.1 Primary outcome

Our primary question is whether each intervention increases the quantity of searches to answer questions – i.e., search *utilization* (not counting logins to e-mail alerts or to access other resources). This will be measured by (i) rate of searches/month/user, (ii) and corresponding proportions of "super-searchers" (> five searches/month), "regular-searchers" (one to five searches/month), "occasional-searchers" (<one search/month), and "alert-only-users" (no searches/month). The primary outcome will be averaged over six months, but continuously recorded as participants will be signed on through their individual user account that tracks logins and use of EBM resources, down to individual keystrokes.

Table 2.6.5 shows the baseline utilization data during the six months prior to the start of the trial, from July to December 2013. Postgraduates MDs (n=429) searched MacPLUS FS 935 times in total, corresponding to about 0.46 searches/month/user, whereas they accessed 4064 alerts to new evidence, corresponding to 1.65 alerts/month/user, and consulted other web-resources in MacPLUS FS 0.52 times/month/user. About 66.9% of postgrads users were "alert-only-users", while 10.5% were "regular-searchers" and 1.9% "super-searchers".

The utilization patterns were different for Faculty MDs (n=475) who searched MacPLUS FS half as much, about 423 times in total, corresponding to about 0.20 searches/month/user, whereas they accessed almost twice as many alerts to new evidence, 7092 alerts in total, corresponding to 2.54 alerts/month/user, and consulted other web-resources in MacPLUS FS 0.32 times/month/user. About 78,9% of faculty used were “alert-only-users”, while 5.1% were “regular-searchers” and 0.8% “super-searchers”.

2.4.3.4.2 Secondary outcomes and questions

We will assess whether each intervention can increase the *utility* of the evidence retrieved (satisfaction in meeting users’ information needs, expected impact on one’s general practice), the *use* of the evidence (the extent of use when caring for a specific patient), and its perceived *usefulness* in patient care and outcomes (perceived benefits of applying the evidence for a specific patient). Utility, use and usefulness of the evidence retrieved will be assessed using an adapted version of the Impact Assessment Method (IAM)[42-44], which was specifically developed for assessing how clinicians use information, based on the Acquisition-Cognition-Application-Outcome Model.[43-45] This validated six-item questionnaire takes less than one minute to complete online and will be sent by e-mail for online completion following a pre-defined automatic algorithm. The first invitation will be sent out one month after the participant’s first online exposure to one or more interventions, with one reminder after 24 hours. The next invitation

will be sent following the next search, but after a two weeks delay. This process will be repeated until one filled questionnaire for a clinical question is returned, or the trial ends (see details and full questionnaire in Appendix 2.10.3). Perceived *usefulness* will be analyzed as the "number needed to benefit from evidence", defined as the number of patients for whom the evidence has to be retrieved to observe or expect health benefits for one patient.[46]

Other secondary questions that we plan to address include whether each intervention efficacy varies across time within the six months trial (e.g., persistent, transient, increasing or decreasing effect), and whether the interventions have an impact on non-searching utilization of MacPLUS FS (i.e., frequency of alerts read, frequency of web logins for other clinical resources).

Finally, we will explore if the interventions modify the patterns of use of the different EBM resources, and in particular if they increase the accesses to higher levels of evidence, such as summaries and pre-appraised research, compared to non-pre-appraised research. Table 2.6.6 displays the baseline distribution of access across the pyramid of EBM resources among clinicians that have adopted MacPLUS FS, that is, "regular-searchers" and "super-searchers". With 1025 searches, these users have conducted about 75% of all searches in MacPLUS FS, and accessed one of its resources 1390 times in total. All resources in the federated search were consulted: summaries were accessed 53.2% of the times, pre-appraised research in 16.1%, and non-pre-appraised research in 30.6% of

the times. Postgraduates searched less summaries than faculty did (49.0% vs. 63.8%), and more non-pre-appraised resources (35.3% vs. 19.3%).

2.4.3.5 Hypotheses and statistical analysis

The two trials are separate and will be analyzed as such. We have three primary hypotheses for each trial: that the clinical question recorder will be more effective than the control; that the evidence retrieval coach will be more effective than the control; and that audit, feedback and gamification will be more effective than the control. Each of these hypotheses will be tested separately (half of the sample compared to the other half). The effect of each intervention will be tested by regressing the average number of searches per month over the trial's six-month time period for each user onto dummy variables for each intervention, controlling for search frequency at baseline. The distribution of the number of searches per user is not known at present, but baseline data suggests excess zeros with extra-Poisson variation. We will attempt to capture the distribution parametrically, but in the event that it is not possible to do this accurately we will use ordinary least squares to estimate the regression coefficients together with heteroscedasticity-robust standard errors.

2.4.3.5.1 Potential subgroup effects

Prior to the start of the trial, we hypothesized that the impact of the intervention on our primary outcome may differ according to specialty type – e.g., more effective in clinicians practicing internal medicine than family medicine or other specialties – and according to baseline frequency of search during the six months prior to the trial – e.g., higher frequency searchers would tend to be more responsive to each intervention (see Table 2.6.5 for the baseline data for these two pre-specified subgroups). In an exploratory analysis will test for subgroup effects, using tests of interactions between the dummy variables for intervention and subgroup variables.

2.4.3.5.2 Potential interactions between the interventions

Our primary analysis will be at the margins, that is, looking at each effect independently, but we will also test for interactions among the interventions. We expect that combining them will have an additive effect, and that an interaction is unlikely, particularly a sub-additive one (e.g., one intervention being effective alone, but less effective or even ineffective in combination with another). We cannot formally exclude any synergistic interaction (beyond additivity), but we have no reason to expect it *a priori*.[47] Moreover, observing a synergistic effect would not jeopardize our results, as we are more interested in finding any "signal" of effect of the interventions, rather than estimating their independent effect with

maximal accuracy. By analogy with drug trials, this study would be a phase II rather than a phase III randomized trial, given the current state of research in the field.

2.4.3.5.3 Power calculation

Since we anticipated that interactions among the interventions are unlikely, we have powered the trials assuming no such interactions. Before the trials began, we had 904 participants eligible for the study, of whom 429 were postgraduates and 475 were faculty (see Table 2.6.5). Baseline data indicated a mean of 0.46 searches per month per user (SD 1.42) among postgraduates and 0.20 searches per month per used (SD 0.83) among faculty. Appendix 2.10.4 shows power curves for the faculty and for the postgraduates. These indicate that among the postgraduates, we will have 80% power to detect an increase of 0.9 in the mean number of searches per month, and among the faculty we will have 80% power to detect an increase of 0.5 in the mean number of searches per month.

2.4.3.5.4 Analysis of secondary questions

An exploratory analysis will investigate time trends in intervention efficacy. Rather than using the average number of searches per user per month over the six months of the trial, we will conduct a longitudinal analysis using the number of searches per user for each of the six months of the trial as the dependent

variable, regressed onto time, dummy variables for each of the interventions, the interaction between time and intervention, together with search frequency at baseline. This regression model will be fitted using a Generalized Estimating Equation (GEE).

Finally, we will compare the distribution of answers on the IAM questionnaire (i.e. utility, use and usefulness of the evidence retrieved), as well as the distribution of access to the different EBM resources, using chi-squared tests.

2.4.3.6 Ethics and registration

Upon registration to MacPLUS FS users will consent to participate in its evaluation. Namely they will agree that their use of MacPLUS FS will be measured for frequency and type of use, and that they will receive periodic online evaluation questionnaires. No individual identifiers will be stored in the monitored databases. The Hamilton Integrated Research Ethics Board has approved this project (REB Project #05-186), as well as a specific waiver for additional informed consent for registrants to be randomized to the different interventions, as no risk is involved and it is necessary to preserve blinding to provide an unbiased utilization measurement (primary outcome). The trials have been registered at ClinicalTrials.gov before randomization (ClinicalTrials.Gov NCT02038439)

2.4.3.7 Trial administration and data management

The trials will be conducted at the Health Information Research Unit, at McMaster University, which designed and is hosting MacPLUS FS. Before the trials start, research staff (EI) and the principal investigator (TA) will check eligibility criteria of the registrants, verify their affiliation to McMaster, profession and training level, and crosscheck the information stated at registration with official administrative medical databases.

The administration of interventions, outcome measurements, and the sending of periodic online IAM questionnaires will all be programmed before randomization and further handled automatically as they will be built into the MacPLUS FS online infrastructure.

The trials will start simultaneously for all participants. All interactions with MacPLUS FS, including any click-through links within e-mails, will automatically sign participants on through their individual user account that tracks logins and use of EBM resources. Primary and secondary outcomes will be recorded from this automatic monitoring of the system, and stored in a specific and secure database within MacPLUS FS.

The research staff (EI) and the principal investigator (TA) will review overall utilization data collected on a weekly basis, looking for completeness of data and navigational bugs. However, no interim analysis will be performed before the trial end.

2.5 DISCUSSION

The three interventions in these two factorial randomized trials are innovative in at least three different ways. First, although widely used in other fields such as education, task management, business, or customer user-centered services, we are not aware that any of these approaches have been applied thus far to clinical evidence retrieval. Second, the interventions use web-based technology to facilitate low cost implementation at a broad scale, for all types of devices. Smartphones and tablets are transforming the way we live, practice medicine and intuitively learn new skills.[48,49] Third, the general framework for these interventions is based on effective models for teaching clinical skills at the point of care. These models have changed the way we teach clinical examination or diagnostic reasoning - embedded in our daily practice[31-35] - but have not yet been used to teach how to find current best evidence in the point of care, a skill that has nevertheless become designated “as essential as the stethoscope”.[9]

Our trials have also inherent limitations. First, although MacPLUS FS includes most top EBM resources currently widely used by clinicians (see Table 2.6.1), participants may still opt to access individual resources directly rather than through MacPLUS FS. However, although this may result in an apparent low frequency of search, the randomization should balance the distributions of such behaviors across study arms and not jeopardize the conclusion from the trials.

Second, although the validated IAM will try to capture the secondary outcomes of utility, use and perceived usefulness of the retrieved, these surveys may suffer from suboptimal response rates. Ideally, we would assess the effect on directly measured patient important outcomes, but this is beyond the feasibility of the current study, and particularly challenging at hospital-levels across a very wide array of potential clinical questions. In any event, the justification for doing a larger multi-centered trial with direct measurement of patient outcomes would be the observation of a sufficient *utilization* rate associated with a substantial effect on evidence *use* and *usefulness* in the present trial. By analogy with drug trials, this study would be a phase II trial.

Third, the interventions are primarily mediated through e-mails with direct login access to MacPLUS FS, and as such, their potential impact may be diluted in the numerous competing solicitations clinicians continuously receive through e-mails. Moreover, the Clinical Question Recorder (Intervention A) requires clinicians to actively record their questions. To maximize the chances they engage, we focused our efforts upstream in the user-centered design, implementation and testing of the recorder. Actual use in real life settings remains uncertain, although simply offering the intervention may also have some indirect effect on searches.

Finally, baseline data showed that search rates heavily fluctuate across time. Lower rates at certain periods (e.g., holidays, vacation days, or exam periods) may affect the assessment of the interventions, although utilization averaged

over six months of follow-up should allow a reasonable comparison between study arms.

The main advantages of this study rely on the feasibility of the administration of the interventions and the outcomes measurements for a large number of clinicians, as these will be handled automatically in MacPLUS FS online system, with no possibility of crossover, and virtually no loss of follow-up for primary outcome data.

In conclusion, the trials will answer whether these innovations have the potential of enhancing knowledge translation through a clinician's timely access to current best evidence. The MacPLUS FS interface allows a broad implementation for registrants, in a sustainable way, with limited additional costs. If effective, these interventions can further be broadly implemented beyond the McMaster community, using the twin version of MacPLUS FS – called ACCESSSS FS (http://plus.mcmaster.ca/ACCESSSS), and enhance the access to current best evidence for a large audience, across many top EBM resources in parallel, and tied directly to clinical questions.

2.6 TABLES

Table 2.6.1 EBM Resources accessible through MacPLUS Federated Search (MacPLUS FS)

	Description	Specific resources available**
Summaries*	Summary of the body of evidence at a topic-level (not just a research question) Regularly updated (variable frequency) May provide actionable recommendations	DynaMed UpToDate Best Practice ACP PIER
Pre-appraised research*	Continuously updated and appraised	
Synopses of systematic reviews	One-page description of selected reviews with commentaries from experts	ACP Journal Club (selected via PLUS), Database of Abstracts of Reviews of Effects (DARE)
Systematic reviews	Selected reviews rated by clinicians for relevance & novelty	McMaster PLUS (including Cochrane)
Synopses of studies	One-page description of selected studies with commentaries from experts	ACP Journal Club (selected via PLUS)
Studies	Selected studies rated by clinicians for relevance & novelty	McMaster PLUS
Non-pre-appraised research*	Always requires independent own appraisal	
Filtered studies	Selection of studies using empirically derived methodological filters	Clinical Queries in PubMed
Unfiltered studies	Unselected studies from large databases	PubMed (MEDLINE)

Alerts to new evidence updates	E-mail alerts to new evidence Customized to areas of interest	McMaster PLUS (same as BMJ EvidenceUpdates)
Additional resources	Available alongside the search functions	
Single citation matcher	Helps finding specific citations	PubMed matcher and McMasterPLUS
Clinical vital links	Prescribing information Patient information Medical calculators and tool sets	Compendium of Pharmaceuticals MedlinePlus MedCalc3000
Other EBM links	Guidance for EBM practice Toolboxes & appraisal spreadsheets	EBM Toolbox (Oxford Centre for EBM) JAMAevidence (McGraw-Hill) Centre for EBM (Univ. Health Network) Bandolier

* These layers, adapted from the 6-S pyramid of EBM resources [21,50], are searched simultaneously in MacPLUS FS. Results are displayed on one page output in that order, i.e. with the most clinically useful hits at the top (see Figure 2.7.1).

** Broad full-text access at all McMaster affiliated clinical institutions participating in the trials is provided on-site through McMaster University or Hamilton Health Sciences institutional licenses. Remote access is allowed through VPN (except for UpToDate), or depends on each user's individual subscriptions. Searching features remain always free, as well as access to all McMaster PLUS and to any open-access content.

Table 2.6.2 Factorial randomization scheme of the three interventions

Interventions *			Random group allocation
A *Clinical Question Recorder*	**B** *Evidence Retrieval Coach*	**C** *Audit, Feedback & Gamification*	
1	**1**	**1**	Group 1
1	**1**	0	Group 2
1	0	**1**	Group 3
1	0	0	Group 4
0	**1**	**1**	Group 5
0	**1**	0	Group 6
0	0	**1**	Group 7
0	0	0	Group 8

* For each intervention, half of the sample is randomized to receiving the intervention [1] and the other half to not receiving it [0]. All factorial combinations of the intervention result in eight allocation groups (2^3=8).

Table 2.6.3 Correspondence between the One-minute Preceptor Model, and the interventions developed for the MacPLUS FS trial

	One-minute Preceptor Teaching "steps"	**Corresponding Facilitators for Evidence Retrieval in MPFS trial**	**Interventions in the trial**
1	Identify teaching opportunities	Identify searching opportunities by recording clinical questions	**A** *Clinical Question Recorder*
2	Get a commitment	Prompt search by helping recall unanswered clinical questions	**A** *Clinical Question Reminder*
3	Probe for evidence supporting clinical practice	Facilitate appropriate use of pyramid of EBM resources through continuous guidance	**B** *Evidence Retrieval Coach*
4	Teach general rules	Provide tailored short videos of "small bites" of teaching & tips on evidence retrieval	**B** *Evidence Retrieval Coach*
5	Feedback (Reinforce what was done right / Correct mistakes)	Provide feedback on frequency of searches and depth of use, compared to peers. Engage with gamification	**C** *Audit, Feedback & Gamification*
6	Identify next objectives Reflective practice	Keep track of questions answered in a virtual logbook	**A** *Clinical Question Recorder*

Table 2.6.4 Description of the features available in the three interventions

A	**Clinical Question Recorder** (See also Figure 2.7.2)	Web-based interface, linked to MacPLUS FS account, and accessible on any smartphone, tablet and desktop computer Easy recording and listing of clinical questions Clicking the "Answer" button next to each question triggers a comprehensive search in MacPLUS FS Browsing of citations retrieved according to the pyramid of EBM resources Bookmarking of links to relevant citations, saved along with the question Recording of short answer to the question Organizing of questions: setting priorities, sorting and classifying into folders Reminders and links to unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence Answered questions and bookmarked evidence are saved and accessible in a virtual logbook of EBM practice
B	**Evidence Retrieval Coach** (See also Figure 2.7.3)	Composed of 8 short videos, embedded in MacPLUS FS Display is tailored to clinician's patterns of behaviors, according to predefined triggers or sent on a weekly basis as the trial unfolds The title of each video [and gist of their content] are the following: 1. MacPLUS FS - Why use it? [Answering questions with information overload] 2. Enhancing Evidence-Based Clinical Practice [Using a parallel search in pre-appraised resources] 3. A pyramid of resources [Overview of the architecture of evidence] 4. Is one summary enough? [Top layers: Summaries] 5. New and critically appraised evidence [Middle layers: Pre-appraised research] 6. PubMed & the Clinical Queries [Bottom layers: Non-pre-appraised research] 7. Preparing searchable questions [Using the PICO framework] 8. Academic work [Using a federated search for presentations, grants and research]

C	***Audit, Feedback & Gamification*** *(See also Figure 2.7.4)*	Allocation of badges, popping up online after a specific desired behavior, and also sent by e-mail (about 50 badges available) Each badge is associated with an increase in reputation score, depending on the desirability of the behavior It also provides a short positively-framed feedback on the behavior, the number of time it was allocated to peers, and an upgraded reputation score Clicking on the badges lead to a Reputation tab in MacPLUS FS providing the following features: Comparison of reputation with peers using pictographs (percentiles) List of badges obtained, clicking on them displays the full badge again Graphical representation of daily reputation Frequency of access to each EBM resources and mapping according to the pyramid

Table 2.6.5 Baseline utilization among the eligible 904 MDs during the six months prior to the trial

	Postgraduates (n = 429*)	Faculty (n = 475*)	Total MD (n = 904*)
Specialty type – n (%)			
Internal Medicine	82 (19.1%)	66 (13.9%)	148 (16.4%)
Family Medicine	107 (24.9%)	184 (38.7%)	291 (32.2%)
Other Specialties	240 (55.9%)	225 (47.4%)	465 (51.4%)
Total number of searches	935	423	1358
Searches/month/user - Mean (SD)	0.46 (1.42)	0.20 (0.83)	0.32 (1.16)
Categories of search frequency - n (%)			
> 5 *(Super-searchers)*	8 (1.9%)	4 (0.8%)	12 (1.3%)
1 to 5 *(Regular-searchers)*	45 (10.5%)	24 (5.1%)	69 (7.6%)
< 1 *(Occasional-searchers)*	89 (20.7%)	72 (15.2%)	161 (17.8%)
0 *(Alert-only-users)*	287 (66.9%)	375 (78.9%)	662 (73.2%)
Time since last search - n (%)			
<= 365 days	163 (38.0%)	143 (30.1%)	306 (33.8%)
> 365 days	266 (62.0%)	332 (69.9%)	598 (66.2%)
Total number of e-mail alerts read	4064	7092	11156
E-mail alerts read/month/user - Mean (SD)	1.65 (2.99)	2.54 (6.03)	2.12 (4.85)
Total number of other weblogins	1163	740	1903
Other weblogins/month/user - Mean (SD)	0.52 (4.10)	0.32 (2.85)	0.41 (3.50)

* 4 additional participants (2 postgraduates and 2 faculty) are missing from this count, as they registered in Jan 2014, just before the beginning of the trial.

Table 2.6.6 Baseline frequency of access to EBM resources (% of all accesses), among "regular-searchers" and "super-searchers" *

	Postgraduates (n = 53)	**Faculty** (n = 28)	**Total** (n = 81)
	739 searches	286 searches	1025 searches
Summaries	**485 (49.0%)**	**255 (63.8%)**	**740 (53.2%)**
DynaMed	174 (17.6%)	39 (9.8%)	213 (15.3%)
UpToDate	120 (12.1%)	128 (32.0%)	248 (17.8%)
Best Practice	147 (14.8%)	71 (17.8%)	218 (15.7%)
ACP PIER	44 (4.4%)	17 (4.3%)	61 (4.4%)
Pre-appraised research	**156 (15.8%)**	**68 (17.0%)**	**224 (16.1%)**
Synopses of systematic reviews	23 (2.3%)	17 (4.3%)	40 (2.9%)
Systematic reviews	66 (6.7%)	21 (5.3%)	87 (6.3%)
Synopses of studies	10 (1.0%)	4 (1.0%)	14 (1.0%)
Studies	57 (5.8%)	26 (6.5%)	83 (6.0%)
Non-pre-appraised research	**349 (35.3%)**	**77 (19.3%)**	**426 (30.6%)**
Filtered studies	257 (26.0%)	60 (15.0%)	317 (22.8%)
Unfiltered studies	92 (9.3%)	17 (4.3%)	109 (7.8%)
Total number of accesses	**990 (100%)**	**400 (100%)**	**1390 (100%)**

* i.e., clinicians who conducted more than 1 search/month on average.

2.7 FIGURES

Figure 2.7.1 MacPLUS FS search output

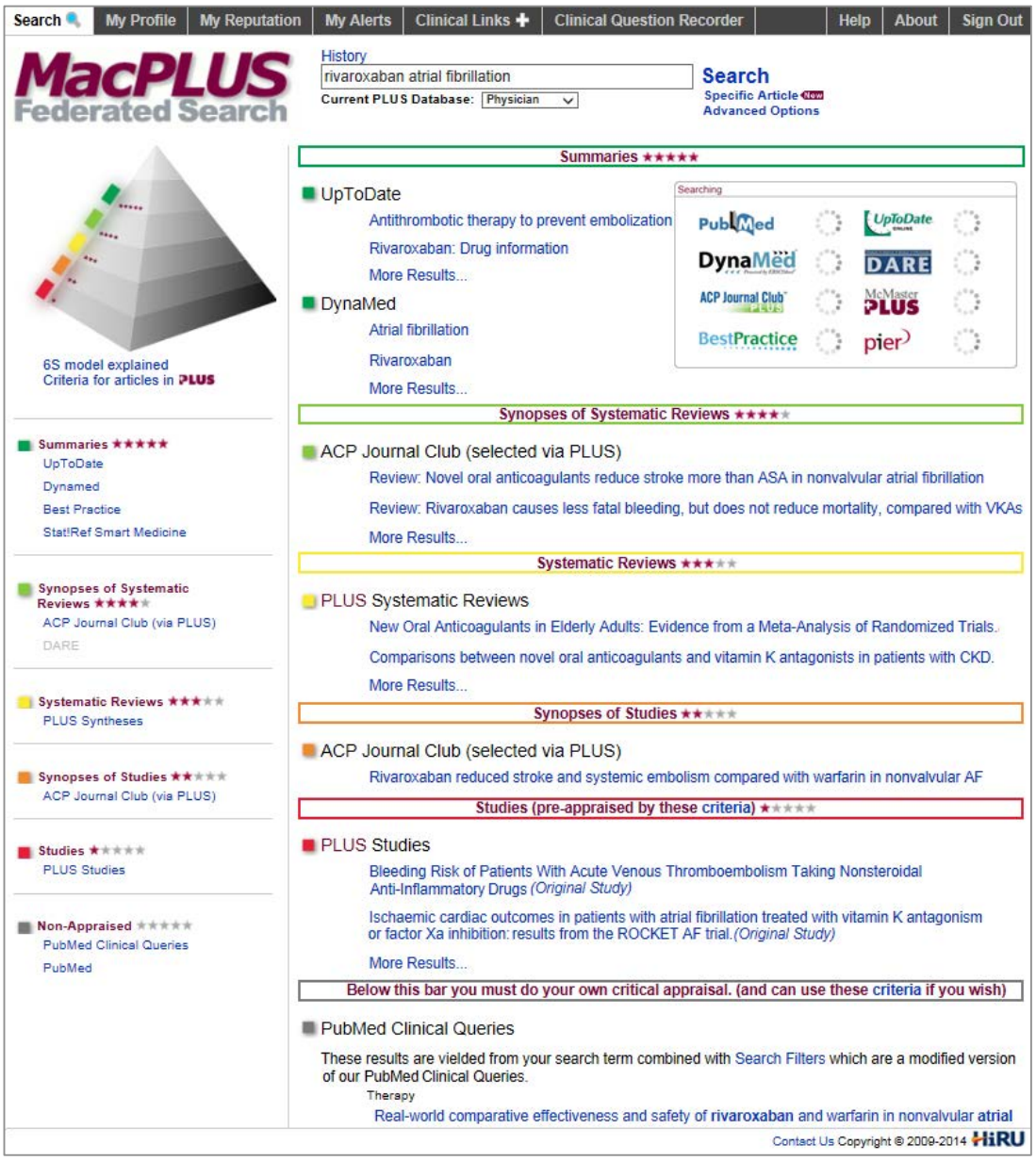
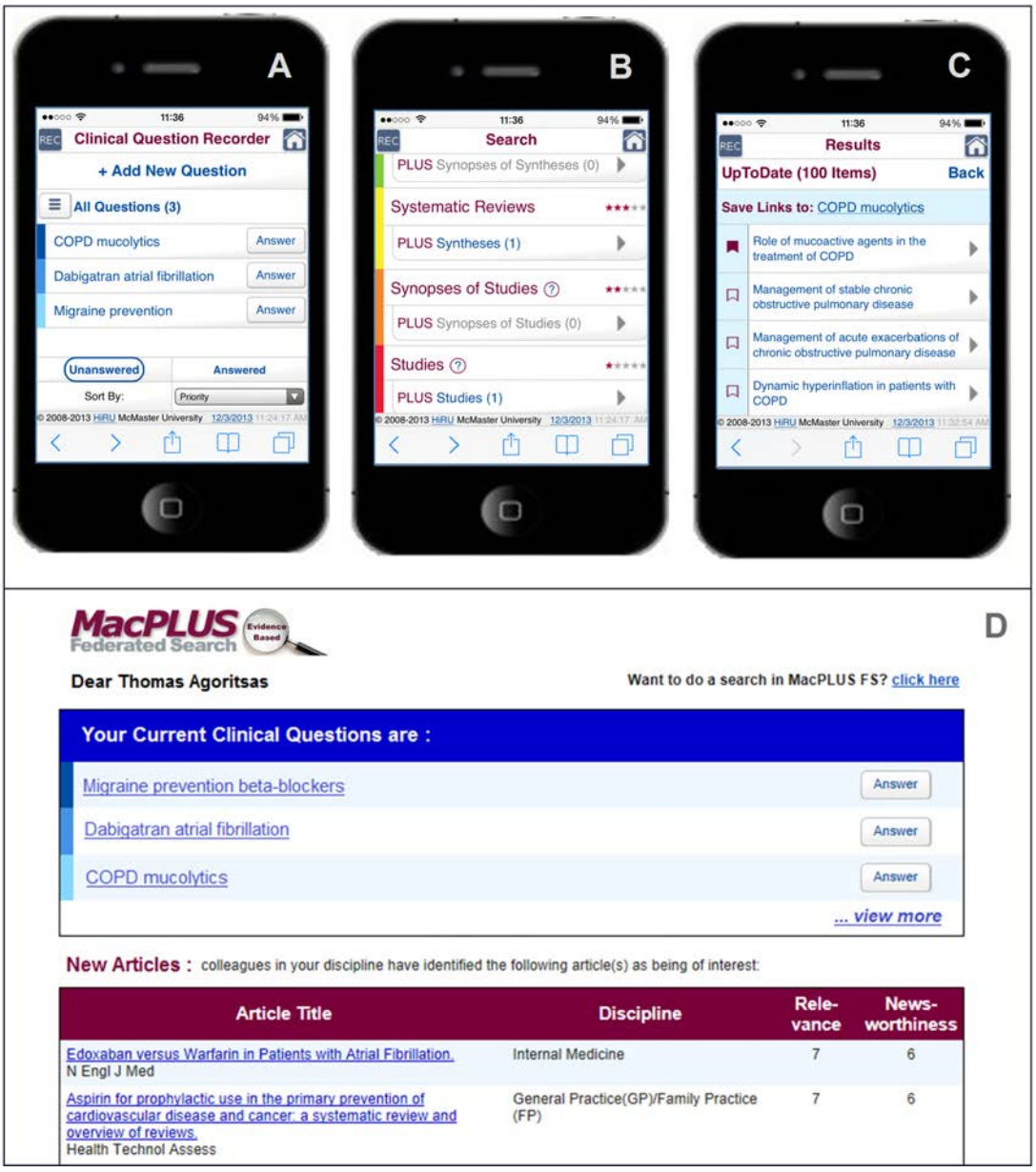


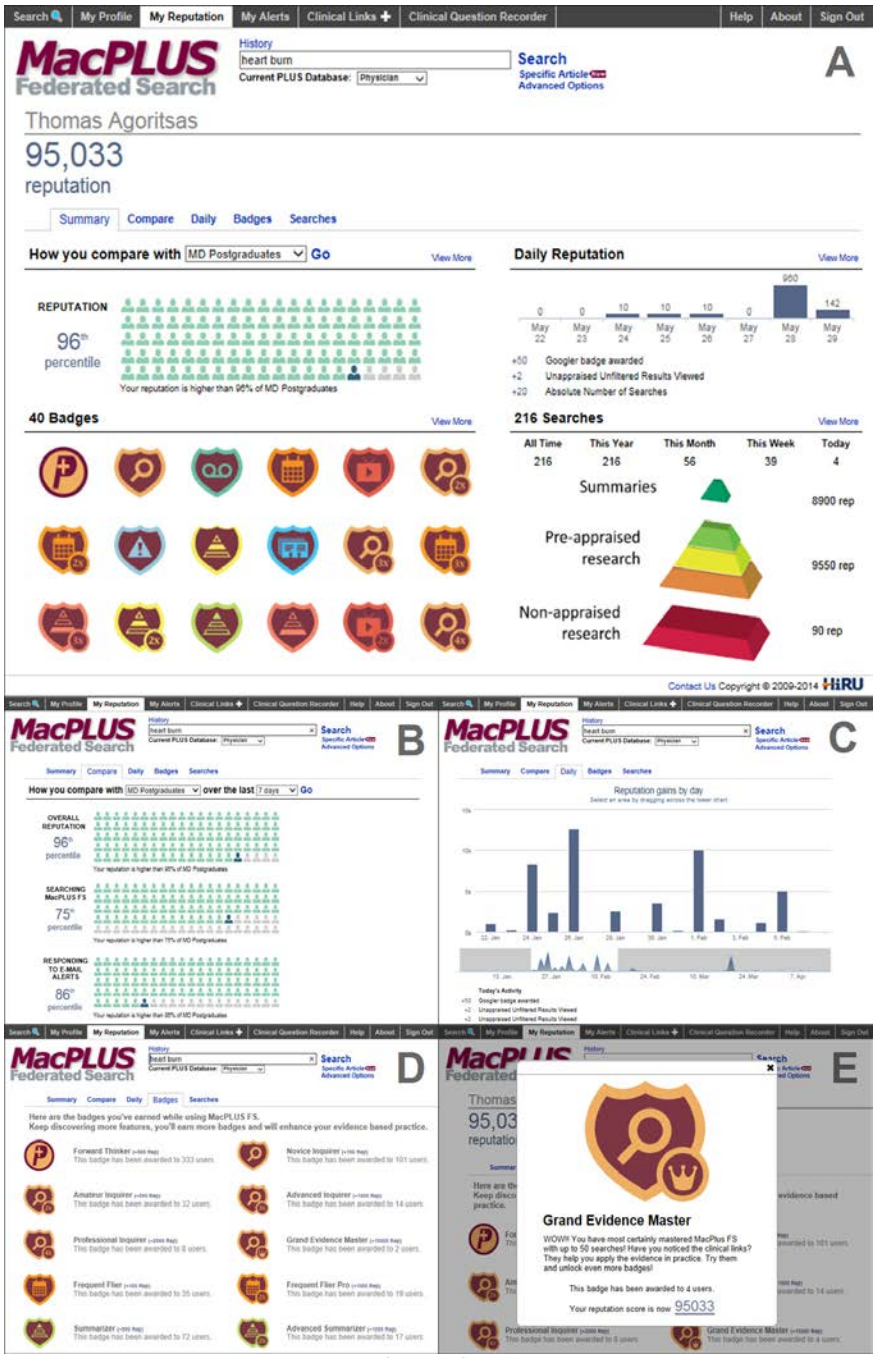
Figure 2.7.2 Illustration of the Clinical Question Recorder and Reminder



A, B, C, D: For a detailed description of each feature displayed, see the result section in the section "Intervention A - clinical question recorder".

Figure 2.7.3 Illustration a video embedded in MacPLUS FS in the Evidence Retrieval Coach

Figure 2.7.4 Illustration of the components of the Audit, Feedback & Gamification



A – E: For a detailed description of each feature displayed, see results in the section "Intervention C – audit, feedback and gamification".

2.8. AUTHORS' CONTRIBUTIONS, ACKNOWLEDGMENTS & COMPETING INTERESTS

Authors' contribution

Conception of the interventions and study design: TA, with significant contributions from BH, NW, and AI. Specific design of intervention A (*Clinical Question Recorder*): TA and NH. Specific design of intervention B (*Evidence Retrieval Coach*): TA, MP, EI and PR. Specific design of intervention C (*Audit, Feedback & Gamification*): TA, NC, AC. IT programming: NH, RP and CC. Conduct of the user-testing: TA. Analysis of baseline data: TA and EI. Statistical analysis plan: TA and EP. Overall supervision: BH. Draft of the manuscript: TA. Critical revision of the manuscript for important intellectual content: EI, NH, NC, AC, PR, MP, CC, RP, EP, NW, AI and BH. All authors read and approved the final manuscript. TA had full access to all the data presented in the manuscript and takes responsibility for its integrity and accuracy.

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Competing Interests

The Health Information Research Unit (HiRU), McMaster University, to which many authors are affiliated (TA, EI, NH, MP, CC, RP, NW, AI, and BH), has developed and implemented the MacPLUS Federated Search. The intellectual property belongs to McMaster University, a non-profit publicly funded institution. One of the main missions of HiRU is the development of new information resources to support evidence-based health care, and the evaluation of various innovations in overcoming health care information problems. Its McMaster Premium LiteratUre Service (PLUS) contributes to many other EBM resources worldwide, including: BMJ EvidenceUpdates, ACP Journal Club, ACP Smart Medicine, Best Practice, Clinical Access, Clinical Evidence, DynaMed, e-Therapeutics, Evidence-Based Medicine Reviews (Duodecim), First Consult (Elsevier), Helsebiblioteket (Norway), National Board of Medical Examiners, Stat!Ref (Teton Data Systems), all under contract with McMaster University.

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2.10 APPENDICES

Appendix 2.10.1 User-testing interview guide

MacPLUS FS Trial - Clinical Question Recorder (Intervention A)

Adapted from templates available at http://www.usability.gov, U.S. Dept. of Health and Human Services. The Research-Based Web Design & Usability Guidelines, Enlarged/Expanded edition. Washington: U.S. Government Printing Office, 2006.

Notetaker:	**Location / Date:**	**Iteration**:
Participant #	**Initials**:	**Gender** :
Profession/Background:		
Type of smarphone:		

Test Facilitator Guide:

Welcome and Purpose

Thank you for agreeing to participate in the evaluation of this App. Today I am asking you to serve as an evaluator of this App and to complete a set of scenarios. My goal is to see how easy or difficult you find the App to use. We will record your reactions and opinions; so, we may ask you to clarify statements that you make from time to time.

Test Facilitator's Role

I'm here to record your reactions and comments of the App you'll view. During this session I will not be able to offer any suggestions or hints. There may be times, however, when I'll ask you to explain why you said or did something.

Test Participant's Role

I will ask you to search for information on this App to learn if it works well for you. We'll do this by giving you scenarios or tasks to complete on the site. You also will be asked a series of questions about your experience at the end of this session.

Things to Keep in Mind

Here are some things that you should know about your participation:

- This is not a test of you; you're testing the App. So don't worry about making mistakes.
- There is no right or wrong answer. We really just want to know if we designed the App well for you.
- If you ever feel that you are lost or cannot complete a scenario with the information that you have been given, please let me know. I'll ask you what you might do in a real-world setting and then either put you on the right track or move you on to the next scenario.
- (We will be audio recording this session for further study if needed. Your name will not be associated or reported with data or findings from this evaluation. Please fill out the audio release form.)
- Finally, as you use the App, please do so as you would in real life. I do ask that when looking for information, you do so as quickly and as accurately as you can.

Do you have any questions before we begin?

Usability features to be tested:

1. Connect through your smartphone
2. Explore the CQR App.
3. Enter a clinical question
4. Answer a clinical question
5. Set/change priority for a question
6. Select relevant citations
7. Record an answer
8. Create a folder
9. Find again an old question and re-run a search

A. Pre Test Questions

- Just from looking at this Clinical Recorder App, what do you expect to find in it? What usefulness to you expect? Please be specific.

- Who do you think this site is designed for? Why? (Probe: MD, nurses, undergrad, postgrad, faculty, rehab)

- Have you ever used some similar App? Which one and in what context?

- If you were to envision your ideal CQR App, what features should it have? What would it look and act like? How would it be organized?

B. Participant Tasks

Task 1

- Can you access the Clinical Question Recorder with the link you've been provided?
- Can you create an icon on your desktop to access it more easily later.

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Connect through your smartphone Create an icon on the phone? Optional Find MPFS (google)?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 2

- Can you explore the App intuitively, without any instruction. Please describe what you see and "think aloud" ("What's this button? I wonder? When I click here…"). Be specific.

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Explore the app, can go as far as create a question and answer.	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 3

- You are an MD student doing your internship in internal medicine. During the rounds, you examine a patient with a facial paresis. Your instructor tells you it is a Bell palsy and you discuss with her its specific signs and diagnostic procedure. You then wonder what are the treatment options, but have no time to do an extensive search right now.
- Using the Clinical Question Recorder App, can you record your question. When you feel you have completed this task, please say so.

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Add new question Enter question (edit question) Type search terms/full question? Save Navigate back <u>Optional</u> Set priority? Choose folder (if already exists)?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 4

- Later after Lunch, you remember your question about the treatment of Bell palsy. You decide do go back in the recorder and answer your question.

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Click Answer Goes to MPFS Phone version Assess (in)adequacy of search terms <u>Optional</u> Explore results from the pyramid Bookmark options.	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 5

- In the afternoon the same day, you follow a fellow during outpatients consultations. Several questions occur and you use the Clinical Question Recorder to record them.
- Questions include the prevention of migraine, the usefulness of mucolytics for COPD patients, the use of rivaroxban for the prophylaxis of thrombo-embolic events in cancer patients.
- You wonder if you can quickly classify them by priority? And sort them alphabetically?

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Edit questions Set priority <u>Optional</u> Explore sorting options?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 6

- To answer your question about migraine prevention, you rapidly screen citations retrieved by MacPLUS FS. Can you select the one that are potentially relevant? Can you do that for other questions?

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Click + sign to bookmark Bookmark on different pyramid layers. Navigate back to the question display to see saved citations. <u>Optional</u> Sorting options?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 7

- After a quick reading of 1 min, you want to answer your question in a short note. Do so in the Clinical Question Recorder. After you're done, can you edit your question?

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Select question Click unanswered Type answer Save <u>Optional</u> Edit the question?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 8

- At the end of the day, your supervisor tells you would have to present a topic at the end of the month. You think 2-3 of the questions you've recorder might be a good topic. Can you create a folder named "presentation" and class your question within?

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Create a folder Click on folder symbol Add new folder Enter a name Save Close Navigate back and access the folder presentation <u>Optional</u> Class a question in the folder?	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

Task 9

- 3 weeks later, the time has come to make your presentation. Assuming there might be new evidence, you want to re-run the search for your question of interest

Pathway(s)	**Success (Circle 1)**	**Notes/Observations** (Note why was the user successful or not successful, e.g., wrong pathways, confusing page layout, navigation issues, terminology)
Find again an old question and re-run a search Click unsanswered Select a question Click on search	0 Not completed 1 Completed with difficulty or help 2 Easily completed	

C. Post Test Interview

- What is your overall impression to this CQR App?
- If you had to give the site a grade, from 10 to 0, where 10 was exemplary and 0 was failing, what grade would you give it, and why?
- What did you like best about the site?
- What did you like least about the site?
- Is there anything that you feel is missing on this site? (Probe: content or site features/functions)
- If you were the website developer, what would be the first thing you would do to improve the App?
- Would you recommend this App site to a colleague? To a friend?
- If you were to describe this App to a colleague in a sentence or two, what would you say?
- Would you use this App your own in the future? Why/why not?
- Do you have any other questions or comments about the Web site or your experiences with it?

IDENTIFICATION OF ISSUES:

For each of the above scenarios, we will identify identifying major and minor problems and suggestions for improvements, according to the following coding:

Xxx **Show-stoppers**

Xx **Big problems/frustration (but eventually figured it out)**

X **Minor frustrations or cosmetic things**

0 **Positive feedback**

00 **Suggestions for improvement**

ID **Personal idea arising from testing**

We will further categorize these issues of users' experience according to **Peter Morville's revised honeycomb framework of user experience:**

Rosenbaum SE, Glenton C, Nylund HK, Oxman AD: User testing and stakeholder feedback contributed to the development of understandable and useful Summary of Findings tables for Cochrane reviews. J Clin Epidemiol 2010, 63:607-619.

Findability: can this person locate the product or the content that they are looking for?

Accessibility: are there physical barriers to actually gaining access, also for people with handicaps, like color blindness?

Usability: how easy and satisfying is this product to use?

Usefulness: does this product have practical value for this person?

Credibility: is the product/content experienced as trustworthy?

Desirability: is the product something this person wants? Has a positive emotional response to?

Understandability: does this person comprehend correctly both *what kind* of product this is, and comprehend the content correctly? Is this person's subjective experience of whether or not they understand in line with their actual (correct or incorrect) understanding?

Identification: does this person identify with the product, on a personal or a social level? Or is it alienating, experienced as being not designed for "someone like me".

Appendix 2.10.2 Evidence Retrieval Coach: tailoring the educational videos to clinicians pattern of use

- The coach is composed of 8 short educational videos, lasting 1 to 1.30 minutes.
- Two types of triggers are implemented:
    - Specific triggers that try and tailor the display of the video to users specific behaviours
    - Weekly time triggers, as the trial unfolds.

Name of short educational video	**1. Specific Triggers**	**2. Triggers**
1. Why use it? *[Answering questions with information overload]*	*No trigger, sent at by e-mail and visible on the search page at the beginning of the trial	Time 0
2. Enhancing Evidence-Based Clinical Practice *[Using parallel search in pre-appraised resources]*	*Available on the "Clinical Vital Links"	After 1 week
3. A pyramid of resources *[Overview of the architecture of evidence]*	* When clicking on the link under the pyramid: "6S model explained"	After 2 weeks
4. Is one summary enough? *[Top layers: Summaries]*	* After 2 searches when only PubMed links are clicked (regardless of whether filtered or unfiltered) * After 2 searches when only the same summary is clicked (if this is too specific to be implemented, change to when 3 summaries are clicked.	After 3 weeks
5. New and critically appraised evidence *[Middle layers: Preappraised research]*	* After 4 searches when clicking on PubMed only (filtered or unfiltered)	After 4 weeks
6. PubMed & the Clinical Queries *[Bottom layers: Non-preappraised research]*	*After 6 searches clicking only on unfiltered PubMed (if this is too specific to be implemented, change to after 6 searches clicking only on PubMed)	After 5 weeks
7. Preparing searchable questions *[Using the PICO framework]*	* After 2 searches without clicking on any citation. *After 2 searches with no citations retrieved in middle layers (i.e. excluding summaries and PubMed)	After 7 weeks
8. Academic work *[Using a federated search for presentations, grants and research]*	*When trying to download citations	After 8 weeks
[Any video]	Then display random video	Weekly until the end of the trial

Appendix 2.10.3 Online administration of Impact Assessment Method (IAM questionnaire)

- The first invitation will be sent after the first search, one month following the first exposure to the intervention(s), i.e. one month after the participant had any interaction with MacPLUS FS.
- If no answer, one reminder will be sent at 24 hours.
- Once a questionnaire is filled (qualifies as filled if Q1+Q2+Q3 are answered), no further questionnaire is sent.
- If not, another survey will be sent following the next search after a 2 weeks delay, until a filled questionnaire is returned, or the trial ends.
- IAM is adapted from:
    - Grad R, Pluye P, Granikov V, Johnson-Lafleur J, Shulha M, Sridhar, S. B.: **Physicians' assessment of the value of clinical information: Operationalization of a theoretical model.** *Journal of the American Society for Information Science and Technology* 2011, 62:1884-1891.
    - Pluye P, Grad RM, Granikov V, Jagosh J, Leung K: **Evaluation of email alerts in practice: part 1 - review of the literature on clinical emailing channels**. *J Eval Clin Pract* 2010, 16:1227-1235.
    - Pluye P, Grad RM, Johnson-Lafleur J, Bambrick T, Burnand B, Mercer J, Marlow B, Campbell C: **Evaluation of email alerts in practice: Part 2 - validation of the information assessment method.** *J Eval Clin Pract* 2010, 16:1236-1243.

A. Invitation e-mail

Dear Doctor [Agoritsas],

On [date] at about [time] you searched for "[search string]" in MacPLUS FS.

We would like to ask a few quick questions about that search. This brief survey includes 1 to 6 questions that would take < 1 minute of your time to answer:

- Yes I agree to participate to the brief survey
- No thanks

We appreciate your help in improving access to current best evidence through MacPLUS FS.

Thank you,

R. Brian Haynes, MD, PhD, FRCPC, FRSC
Chief, Health Information Research Unit (http://hiru.mcmaster.ca)
Faculty of Health Science

B. IAM Survey

Dear Doctor Agoritsas,

On [date] at about [time] you searched for "[searchstring]" in MacPLUS FS.

Q1. Do the term(s) in this search represent an attempt you made to answer a question of relevance to your clinical interests?

- ○ Yes
- ○ No

Q2. Why did you do this search for information? *Please check all that apply.* *Note: You can check more than one objective.*

- ☐ To address a clinical question (problem) about a specific patient
- ☐ To fulfill a personal educational objective
- ☐ To satisfy curiosity or for personal interest
- ☐ To look up something I had forgotten
- ☐ To share information with a patient, their family, or home health aides
- ☐ To exchange information with other health professionals (e.g., a colleague)
- ☐ To manage aspects of patient care with other health professionals

Q3. Did you find relevant information that partially or completely met your objective(s)?

- ○ Yes
- ○ No

Q4. What is the impact of this information on you or your practice? *Please check all that apply.* *Note: You can check more than one type of impact.*

- ☐ My practice was (will be) changed and improved
- ☐ I learned something new
- ☐ This information confirmed I did (am doing) the right thing

☐ I am reassured

☐ I am reminded of something I already knew

☐ I am dissatisfied

☐ There is a problem with the presentation of this information

☐ I disagree with the content of this information

☐ This information is potentially harmful

Q5. Did you (will you) use this information for a specific patient?

○ Yes ○ No ○ Possibly

Please check all that apply. *Note: You can check more than one type of use.*

☐ As a result of this information I managed (or will manage) this patient differently

☐ I had several options for this patient, and I used (will use) this information to justify a choice

☐ I did not know what to do, and I used (will use) this information to manage this patient

☐ I thought I knew what to do, and I used this information to be more certain about the management of this patient

☐ I used this information to better understand a particular issue related to this patient

☐ I used (will use) this information in a discussion with this patient, or with other health professionals about this patient

☐ I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change for this patient

(if no or possibly, skip to Q7)

Q6. For this patient, did you observe (or do you expect) any health benefits as a result of applying this information?

○ Yes ○ No ◉ Possibly

Please check all that apply. *Note: You can check more than one type of health benefit.*

☐ This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors)

☐ This information helped to prevent (will help to prevent) a disease or worsening of disease for this patient

☐ This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient

☐ This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention

☐ This information helped to increase this patient's knowledge, or their family or home health aides' knowledge

C. Note after answering "no" to the invitation e-mail

Want to do a search in MacPLUS FS? click here

Thank you for your answer. We understand that you were not able answer our brief survey this time. As we continuously aim to improve the clinical usefulness of MacPLUS FS we may invite you to a future survey in a few weeks.

Thank you in advance for considering,

R. Brian Haynes, MD, PhD, FRCPC, FRSC
Chief, Health Information Research Unit (http://hiru.mcmaster.ca)
Faculty of Health Science

D. Note after answering "no" to Q1

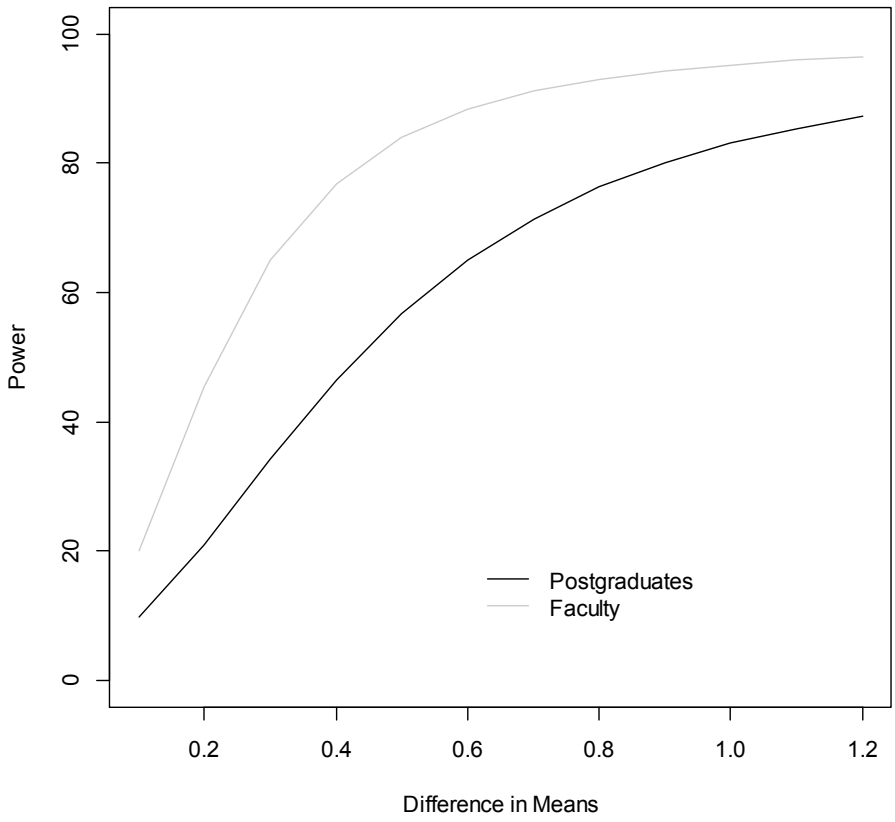
Want to do a search in MacPLUS FS? click here

Thank you for your answer. As we continuously aim to improve the clinical usefulness of MacPLUS FS we may invite you to a future survey in a few weeks.

Thank you in advance for considering,

R. Brian Haynes, MD, PhD, FRCPC, FRSC
Chief, Health Information Research Unit (http://hiru.mcmaster.ca)
Faculty of Health Science

Appendix 2.10.4 Power as a function of difference in means, separately for our samples of postgraduates (n=429) and faculty (n=475)



The distribution of searches is such that the standard deviation varies with the mean; baseline data suggested a linear relationship, with the standard deviation of searches in any given month being approximately 0.15 + 4.84*mean. Since the primary analysis will use the mean number of searches per individual over a 6-month time frame, the actual standard deviation will be smaller than this; the standard deviation in this case is made up of within-individual variability and between-individual variability, and averaging over several months will diminish the within-individual variability. Baseline data suggested that taking 6-month averages reduced the standard deviation by 30%, and therefore the standard deviation was modeled as (0.15 + 4.84*mean)*0.7. Power calculations use a two-sample t-test for unequal variances. The planned analysis will use regression to adjust for stratifying baseline variables, making this analysis slightly conservative.

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Increasing the quantity and quality of searching for current best evidence to answer clinical questions: protocol and intervention design of the MacPLUS FS Factorial Randomized Controlled Trials

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Abstract

Background & aims: Finding current best evidence for clinical decisions remains challenging. With 3,000 new studies published every day, no single evidence-based resource provides all answers or is sufficiently updated. McMaster Premium LiteratUre Service – Federated Search (MacPLUS FS) addresses this issue by looking in multiple high quality resources simultaneously and displaying results in a one-page pyramid with the most clinically useful at the top. Yet, additional logistical and educational barriers need to be addressed to enhance point-of-care evidence retrieval. This trial seeks to test three innovative interventions, among clinicians registered to MacPLUS FS, to increase the quantity and quality of searching for current best evidence to answer clinical questions.

Methods & design: In a user-centered approach, we designed three interventions embedded in MacPLUS FS: (A) a web-based Clinical Question Recorder; (B) an Evidence Retrieval Coach composed of eight short educational videos; (C) an Audit, Feedback and Gamification approach to evidence retrieval, based on the allocation of 'badges' and 'reputation scores.'

We will conduct a randomized factorial controlled trial among all the 904 eligible medical doctors currently registered to MacPLUS FS at the hospitals affiliated with McMaster University, Canada. Postgraduate trainees (n = 429) and clinical faculty/staff (n = 475) will be randomized to each of the three following interventions in a factorial design (A x B x C). Utilization will be continuously recorded through clinicians' accounts that track logins and usage, down to the level of individual keystrokes. The primary outcome is the rate of searches per month per user during the six months of follow-up. Secondary outcomes, measured through the validated Impact Assessment Method questionnaire, include: utility of answers found (meeting clinicians' information needs), use (application in practice), and perceived usefulness on patient outcomes.

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Discussion: Built on effective models for the point-of-care teaching, these interventions approach evidence retrieval as a clinical skill. If effective, they may offer the opportunity to enhance it for a large audience, at low cost, providing better access to relevant evidence across many top EBM resources in parallel.

Trial registration: ClinicalTrials.Gov NCT02038439.

Keywords: Evidence-based medicine, Evidence retrieval, Knowledge translation, Audit and feedback, Web-based resources, Search engines

Background

Translation of new knowledge from research into evidence-informed health care is a shared obligation of the clinical and the scientific communities. Unfortunately, studies investigating quality of care continue to show that this goal is substantially unrealized. Clinicians' uptake of validated best care procedures remains stubbornly around 50% or less for most advances in therapeutics [1,2]. Combined with a similar rate of patient adherence with self-administered treatments [3], the average effectiveness of therapies reaches typically only about a quarter (50% × 50%) of their potential.

One main barrier to achieving evidence-based care by clinicians is lack of quick and easy identification, appraisal and synthesis of current best evidence. Clinicians' information needs are considerable – with an average of five to eight questions about individual patients per daily shift [4-6], thus making evidence retrieval an essential skill in clinical practice [7]. However, about 3,000 articles are published in Medline every day [8], including 75 randomized controlled trials and 11 systematic reviews [9]. Numerous Evidence-Based Medicine (EBM) resources have been developed to filter and disseminate the evidence. But although increasingly used by clinicians [10-12], each resource offers a fragmented and scattered view of the information, and none provides comprehensive topic coverage [13,14] or consistent and satisfactory updating [15,16]. As a result, up to 64% of clinical questions remain unanswered, and many answers are not based on current best evidence [17-19].

To address these problems, the McMaster's University Health Information Research Unit has developed and implemented the MacPLUS Federated Search (MacPLUS FS). This novel resource provides a unique one-stop simultaneous search of multiple current best EBM resources for use at the point of care (see Table 1). It also organizes information according to the 'pyramid of EBM resources,' displaying results in one-page output with the most clinically useful at the top [20] (see Figure 1). Thus, MacPLUS FS simultaneously retrieves evidence from online summaries in the top layers (*e.g.*, DynaMed, UpToDate, Best Practice, ACP Smart Medicine), then pre-appraised research in the middle layers (*i.e.*, Systematic reviews, Studies and their Synopses when available, selected in McMaster PLUS database for methodological rigor and clinical relevance [21]), and finally non-pre-appraised research in the bottom layers, both filtered [22] and unfiltered from PubMed. In addition to the federated search, MacPLUS FS provides users with alerts to new research in their chosen disciplines [23] (similar content to the widely accessed BMJ EvidenceUpdates [24]), as well as numerous clinical and EBM practical links (see Table 1). Structurally, MacPLUS FS supplies evidence from research that is relevant to the clinical needs of students, postgrads, and independent practitioners.

However, combining features of the current best EBM resources is not enough to increase prompt and reasonable use of current best evidence, as shown by the relatively low utilization of searching features by the 2,800 clinicians registered with MacPLUS FS, in contrast with their high utilization of the alerting system. Additional well-known barriers that need to be overcome include logistical barriers (time constraints, forgotten questions, and simplicity of using one's single preferred, albeit limited, resource), as well as educational barriers (*e.g.*, lack of awareness of the 'architecture' of evidence and limits of non-federated single resources, lack of knowledge and experience of what federated searches can offer, limited searching skills, and lack of reference standards among peers for finding best evidence) [19,25-29].

Study aims

The trials described in this paper seek to test three innovative interventions among clinicians registered to MacPLUS FS to overcome these logistical and educational barriers and thus potentially increase the quantity and quality of searching for current best evidence to answer clinical questions.

We have designed these interventions based on effective models for the teaching of clinical skills at the point of care, to facilitate using the search engine as a clinical tool, presenting evidence retrieval skills as true clinical skills. Results from these trials may thus provide insight into whether finding current best evidence can be learned and enhanced for a large audience of clinicians through online search engines.

Table 1 EBM Resources accessible through MacPLUS Federated Search (MacPLUS FS)

	Description	Specific resources available**
Summaries*	Summary of the body of evidence at a topic-level (not just a research question). Regularly updated (variable frequency).	DynaMed
		UpToDate
		Best Practice
	May provide actionable recommendations.	ACP PIER
Pre-appraised research*	Continuously updated and appraised.	
Synopses of systematic reviews	One-page description of selected reviews with commentaries from experts.	ACP Journal Club (selected via PLUS), Database of Abstracts of Reviews of Effects (DARE)
Systematic reviews	Selected reviews rated by clinicians for relevance & novelty.	McMaster PLUS (including Cochrane)
Synopses of studies	One-page description of selected studies with commentaries from experts.	ACP Journal Club (selected via PLUS)
Studies	Selected studies rated by clinicians for relevance & novelty.	McMaster PLUS
Non-pre-appraised research*	Always requires independent own appraisal.	
Filtered studies	Selection of studies using empirically derived methodological filters.	Clinical Queries in PubMed
Unfiltered studies	Unselected studies from large databases.	PubMed (MEDLINE)
Alerts to new evidence updates	Email alerts to new evidence.	McMaster PLUS
	Customized to areas of interest.	(same as BMJ EvidenceUpdates)
Additional resources	Available alongside the search functions.	
Single citation matcher	Helps finding specific citations.	PubMed matcher and McMasterPLUS
Clinical vital links	Prescribing information.	Compendium of Pharmaceuticals
	Patient information.	MedlinePlus
	Medical calculators and tool sets.	MedCalc3000
Other EBM links		EBM Toolbox (Oxford Centre for EBM)
	Guidance for EBM practice.	JAMAevidence (McGraw-Hill)
	Toolboxes & appraisal spreadsheets.	Centre for EBM (Univ. Health Network) Bandolier

*These layers, adapted from the 6-S pyramid of EBM resources [20,49], are searched simultaneously in MacPLUS FS. Results are displayed on one page output in that order, *i.e.*, with the most clinically useful hits at the top (see Figure 1).
**Broad full-text access at all McMaster affiliated clinical institutions participating in the trials is provided on-site through McMaster University or Hamilton Health Sciences institutional licenses. Remote access is allowed through VPN (except for UpToDate), or depends on each user's individual subscriptions. Searching features remain always free, as well as access to all McMaster PLUS and to any open-access content.

Methods

I. Overview of study design

We plan to conduct two separate factorial randomized control trials among medical doctors registered in MacPLUS FS, one among the postgraduate trainees and one among the faculty members. Participants will be randomized to the three following web-based interventions, all linked to MacPLUS FS, in a factorial design (A x B x C):

1. Intervention A – Clinical Question Recorder, linked to MacPLUS FS
2. Intervention B – Evidence Retrieval Coach, embedded in MacPLUS FS
3. Intervention C – Audit, Feedback and Gamification on searching behaviors in MacPLUS FS

Thus, half our sample will be exposed to each intervention, all possible permutations resulting in eight distinct groups of registrants receiving or not each intervention (see Table 2). Postgraduate and faculty MDs will be randomized in two separate trials. The primary outcome of interest is utilization of MacPLUS FS, namely the number of searches/month/user to answer their questions. This primary outcome will be continuously recorded from automatic monitoring of MacPLUS FS use. Secondary questions include measures of utility (satisfaction in meeting users' information needs), use (application of evidence in practice), and perceived usefulness in patient care and outcomes, as well as changes in the pattern of use of specific resources according to the EBM pyramid (frequency and time trends in utilization).

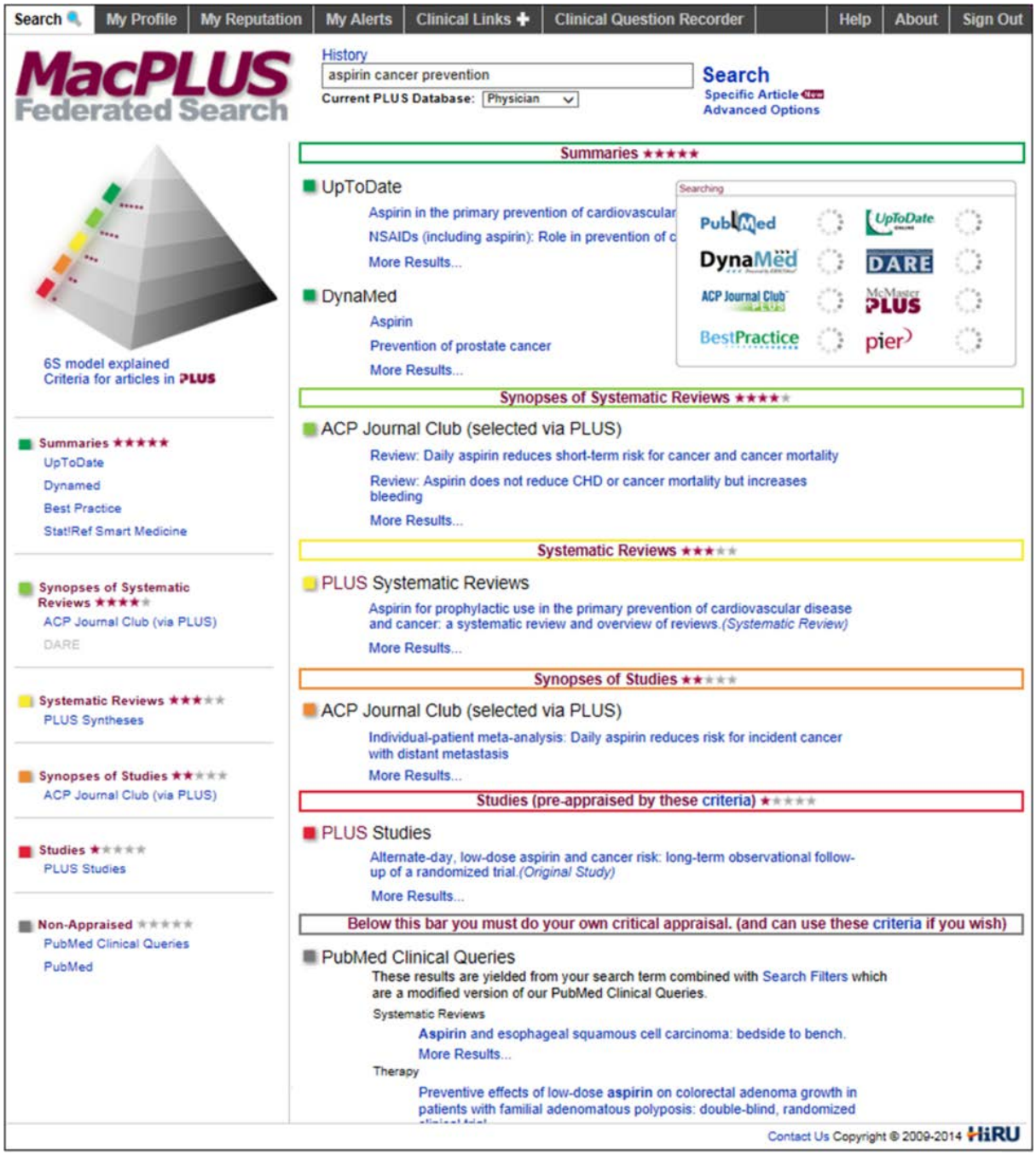

Figure 1 MacPLUS FS search output.

In the next section, we describe the development of the three interventions: our theoretical framework; user-testing of their different iterations; and the final features that we will test in the trials. The third section details the methodology of the factorial randomized controlled trials.

II. Development of the interventions

Theoretical framework

To overcome the aforementioned logistical and educational barriers to answering clinical questions with current best evidence [19,25-29], we have built the general framework for our three interventions on effective models for

Table 2 Factorial randomization scheme of the three interventions

Interventions*			
A	**B**	**C**	**Random group allocation**
Clinical Question Recorder	***Evidence Retrieval Coach***	***Audit, Feedback & Gamification***	
1	**1**	**1**	Group 1
1	**1**	0	Group 2
1	0	**1**	Group 3
1	0	0	Group 4
0	**1**	**1**	Group 5
0	**1**	0	Group 6
0	0	**1**	Group 7
0	0	0	Group 8

*For each intervention, half of the sample is randomized to receiving the intervention [1] and the other half to not receiving it [0]. All factorial combinations of the intervention result in eight allocation groups ($2^3 = 8$).

teaching clinical skills at the point of care. We have opted for that approach so that clinicians are facilitated in perceiving evidence retrieval skills as true clinical skills, and encouraged to use MacPLUS FS as the most comprehensive clinical tool for evidence retrieval, in terms of topic coverage, optimal updating, signal to noise ratio and time-management.

Many models have been developed to teach clinical skills at the point of care, but one that has been consistently shown as effective in randomized control trials, and then most widely adopted by clinical teachers, is the 'One-minute preceptor model,' also known as the '5-step Microskills' [30-34]. As shown in Table 3, we have adapted the teaching steps of this model for the purpose of enhancing evidence retrieval as follows: identifying searching opportunities; prompting searches to answer clinical questions; providing general knowledge, skills and feedback; and inviting reflective practice. We have developed our three interventions (A, B & C) to map these teaching steps.

Intervention A – clinical question recorder

Development methods

The purpose of this web-based intervention is to allow clinicians to: i) easily record their questions at the point of care; ii) receive periodic reminders of unanswered questions, thus providing asynchronous opportunity for evidence retrieval [35]; and iii) keep track of their questions and evidence-based answers in a virtual logbook to enhance their reflective practice. To achieve these objectives, we designed initial mock-ups and a web-based prototype of the recorder, to be linked to the clinician's individual MacPLUS FS account and accessible across a wide range of devices (primarily smartphones for point of care use, but also tablets and computer desktops).

This intervention requires the active participation of clinicians. To maximize the likelihood that they engage, we focused our development on a user-centered approach based on iterative user-testing of sequential prototypes [36,37]. We recruited independent testers, gave them access to the prototype on their smartphone, and exposed them to nine real-life scenarios that evaluate different aspects of the intervention during one-hour 'think out loud' sessions. Using a standardized interview guide (see Additional file 1), we observed and collected their user experience based on Peter Morville's honeycomb framework [38]. We thus identified major and minor problems and suggestions for improvements on the following dimensions: findability, accessibility, usability, understandability, usefulness, credibility, desirability, and identification. Based on that feedback, we refined the prototype after every two to three user-tests until the problems were overcome and the intervention was intuitive and satisfactory for the users. We then implemented it on the MacPLUS FS interface,

Table 3 Correspondence between the one-minute preceptor model, and the interventions developed for the MacPLUS FS trial

	One-minute preceptor teaching "steps"	Corresponding facilitators for evidence retrieval in MPFS trial	Interventions in the trial
1	Identify teaching opportunities	Identify searching opportunities by recording clinical questions.	**A** *Clinical Question Recorder*
2	Get a commitment	Prompt search by helping recall unanswered clinical questions.	**A** *Clinical Question Reminder*
3	Probe for evidence supporting clinical practice	Facilitate appropriate use of pyramid of EBM resources through continuous guidance.	**B** *Evidence Retrieval Coach*
4	Teach general rules	Provide tailored short videos of 'small bites' of teaching & tips on evidence retrieval.	**B** *Evidence Retrieval Coach*
5	Feedback (Reinforce what was done right/Correct mistakes)	Provide feedback on frequency of searches and depth of use, compared to peers. Engage with gamification.	**C** *Audit, Feedback & Gamification*
6	Identify next objectives Reflective practice	Keep track of questions answered in a virtual logbook.	**A** *Clinical Question Recorder*

with a final check of online usability by the same users accessing it remotely from their setting.

User-testing

We recruited eight independent testers (three practicing MDs, one student MD, three master's students in Health Research Methodology and one medical librarian), who underwent 12 full user-tests. We also performed numerous shorter usability tests on four team members. This process identified 34 significant issues – mainly around accessibility, usability, understandability, usefulness, and desirability – which resulted in 38 modifications of the prototype, across 5 major iterations (4 to 11 issues and 3 to 13 changes made per iterations). Consistently fewer refinements were necessary as use of the recorder became more intuitive and users were more satisfied. Final remote usability testing did not identify any remaining issues.

Results: description of the final features

The main features of the final Clinical Question Recorder are listed in Table 4 and illustrated in Figure 2. By simply clicking on 'Add New Question,' clinicians can type in and record their clinical questions directly on the web-based interface (Figure 2A). Clicking the 'Answer' button next to each question triggers a comprehensive search in MacPLUS FS according to the pyramid of EBM resources (Figure 2B). Links to relevant evidence can be bookmarked and saved with each clinical question for subsequent access and reading (Figure 2C), along with clinicians' short answers. Periodic reminders of the list of unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence (Figure 2D) – clicking on them or the 'Answer' button similarly triggers a search in MacPLUS FS.

Intervention B - evidence retrieval coach

Development methods, feedback and usability

The purpose of this intervention is to facilitate the retrieval of current best evidence by providing guidance, 'small bites' of knowledge and skills through short videos. These videos are both embedded in MacPLUS FS and sent via e-mails according to each the clinician's specific patterns of utilization and search.

We started this development by identifying specific teaching content that may help clinicians to benefit from available EBM resources in finding current best evidence. For that, we built on the strong expertise of our multi-disciplinary team in the Health Information Research Unit (HiRU), which has been one of the leading groups in evidence processing and retrieval, has contributed to many top EBM information resources over the past two decades, and has conceived MacPLUS FS. We wrote short scripts and mock-ups, and worked closely with an instructional designer (MP) to optimize language and presentation and produce the short videos.

We then asked our eight user-testers to provide independent feedback, particularly on understandability, usefulness, and satisfaction with the content and presentation. After two iterations, the videos were implemented in MacPLUS FS. We then asked our testers to check online usability while using the platform remotely.

Results: description of the final features

The main features and the content of the videos within the Evidence Retrieval Coach are listed in Table 4. The intervention is composed of eight short videos lasting less than one and a half minute each. The videos are embedded in MacPLUS FS and accessible on smartphones, tablets and desktop versions (see Figure 3). The content covered includes an overview of the 'architecture' of evidence (pyramid), advantages and limits of individual resources (see Table 1), and how MacPLUS FS's unique features overcome these limits and save time and effort (parallel comprehensive search, critical appraisal, organized presentation of complementary evidence). Special emphasis is put on showing how MacPLUS FS can be used for real-life evidence-based practice (*e.g.*, to translate clinical questions and rapidly get reliable answers).

Moreover, the display of the videos is tailored to clinician's individual patterns of behaviors, according to predefined triggers (see Additional file 2). After clinicians watch a video, they will receive its link by e-mail as an opportunity to watch it again later. These e-mails will be sent also on a weekly basis as the trial unfolds.

Intervention C – audit, feedback and gamification

Development methods, feedback and usability

Based on behavioral theory, the purpose of this third intervention is to provide clinicians with timely feedback on their current search utilization compared to their peers. However, in a recent Cochrane review on 140 randomized trials, this approach showed only a 4.3% absolute increase in compliance with desired practice (95% CI 0.5% to 16%), with feedback being more effective when baseline performance is low and when it is provided regularly [39]. In light of these results, we decided to combine an audit and feedback intervention with a gamification approach [40], based on allocation of badges popping-up immediately after a desired behavior. These badges result in reputation scores that can be compared to peers on an interactive and playful interface within MacPLUS FS. Such approaches can enhance utilization and learning based on people's natural desires for 'competition, achievement, self-expression, and closure,' and has been successfully used in many other educational settings [40].

Table 4 Description of the features available in the three interventions

A	**Clinical Question Recorder** (See also Figure 2)	Web-based interface, linked to MacPLUS FS account, and accessible on any smartphone, tablet and desktop computer.
		Easy recording and listing of clinical questions.
		Clicking the 'Answer' button next to each question triggers a comprehensive search in MacPLUS FS.
		Browsing of citations retrieved according to the pyramid of EBM resources.
		Bookmarking of links to relevant citations, saved along with the question.
		Recording of short answer to the question.
		Organizing of questions: setting priorities, sorting and classifying into folders.
		Reminders and links to unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence.
		Answered questions and bookmarked evidence are saved and accessible in a virtual logbook of EBM practice.
B	**Evidence Retrieval Coach** (See also Figure 3)	Composed of eight short videos, embedded in MacPLUS FS.
		Display is tailored to clinician's patterns of behaviors according to predefined triggers, or sent on a weekly basis as the trial unfolds.
		The title of each video (and gist of their content) are the following:
		1. MacPLUS FS - Why use it? (Answering questions with information overload)
		2. Enhancing Evidence-Based Clinical Practice (Using a parallel search in pre-appraised resources)
		3. A pyramid of resources (Overview of the architecture of evidence)
		4. Is one summary enough? (Top layers: Summaries)
		5. New and critically appraised evidence (Middle layers: Pre-appraised research)
		6. PubMed & the Clinical Queries (Bottom layers: Non-pre-appraised research)
		7. Preparing searchable questions (Using the PICO framework)
		8. Academic work (Using a federated search for presentations, grants and research)
C	**Audit, Feedback & Gamification** (See also Figure 4)	Allocation of badges, popping up online after a specific desired behavior, and also sent by email (about 50 badges available).
		Each badge is associated with an increase in reputation score, depending on the desirability of the behavior.
		It also provides a short, positively-framed feedback on the behavior, the number of times it was allocated to peers, and an upgraded reputation score.
		Clicking on the badges lead to a Reputation tab in MacPLUS FS providing the following features:
		Comparison of reputation with peers using pictographs (percentiles);
		List of badges obtained, clicking on them displays the full badge again;
		Graphical representation of daily reputation;
		Frequency of access to each EBM resources and mapping according to the pyramid.

We designed the online interface, badges and graphical presentation with the help of a user experience designer (AC). After internal usability testing of the features implemented, we asked our eight user-testers to evaluate the intervention while using the platform remotely, and provide independent feedback on usability, understandability, and satisfaction with the content and presentation.

Results: description of the final features

The main features of the final audit, feedback and gamification interventions are listed in Table 4 and illustrated in Figure 4. All features are accessible within MacPLUS FS on a 'reputation tab' (Figure 4A). We generated about 50 badges rewarding the following behaviors: total and weekly frequencies of searches, frequencies of access to the top layers of the EBM resource pyramid (summaries), to the middle layers (pre-appraised research), and to bottom layers (non-pre-appraised research), number of complementary resources accessed per search, number of alerts to new evidence accessed, number of questions recorded (for users also allocated to the Clinical Question Recorder), and number of videos watched (for those allocated to the Evidence Retrieval Coach).

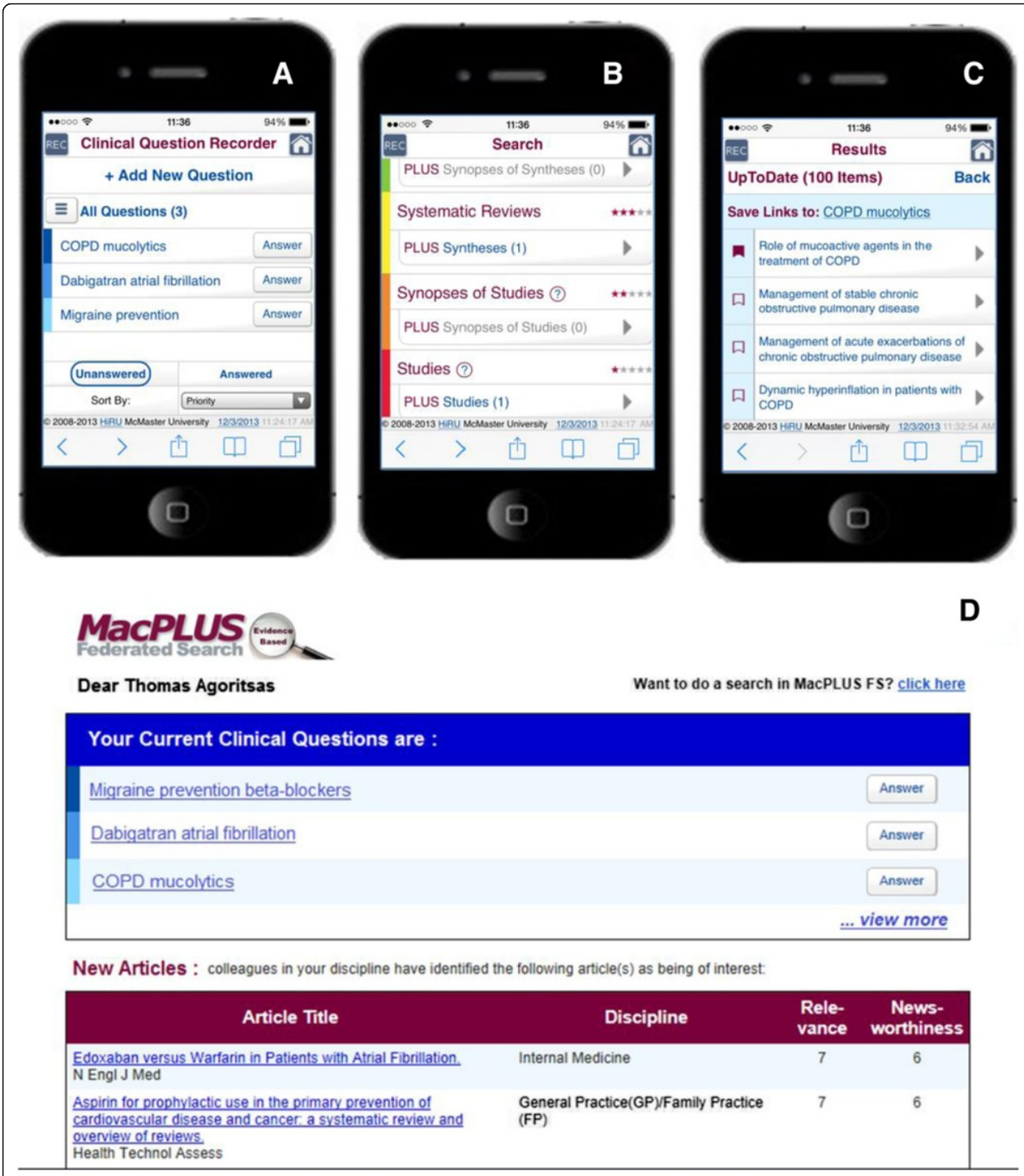

Figure 2 Illustration of the Clinical Question Recorder and Reminder. A,**B**,**C**,**D**: For a detailed description of each feature displayed, see the result section in the section "Intervention A - clinical question recorder".

Each badge was assigned a reputation score based on the desirability of the behavior it reinforces. Badges pop-up online after a specific behavior (Figure 4E), award their reputation score to the user, and can be accessed again later (Figure 4D). Clinician's resulting reputation score can be compared to peers' through percentiles displayed in interactive pictographs (Figure 4B), and followed graphically across time (Figure 4C). Finally, clinicians can explore their access to each EBM resource, mapped according to the EBM pyramid (Figure 4A).

Figure 3 Illustration of a video embedded in MacPLUS FS in the Evidence Retrieval Coach.

III. Protocol of the randomized controlled trials

Setting and study participants

We will conduct the trials described in this protocol in the teaching hospitals and clinics affiliated with McMaster University, Ontario, Canada. This amounts to 2 major academic hospital systems, operating 10 hospitals in the Hamilton area, as well as 2 regional campuses in Niagara and Waterloo, Ontario.

Currently about 2,800 clinicians and students are registered in MacPLUS FS. The first trial will be conducted among all postgraduate trainees, and the second trial among all faculty registered in MacPLUS FS at the beginning of the trials, after exclusion of those no longer physically working at McMaster University affiliated hospitals. We will also exclude registrants who have never interacted with MacPLUS FS, either by logging in to read email alerts or to perform a search, during the last 12 months counting back from the beginning of the trials, regardless of how long they have been registered. These broad eligibility criteria reflect our choice to perform pragmatic effectiveness trials, rather than focusing only on high-frequency users. Indeed, our objective is precisely to increase the quantity and quality of searches among low-frequency users in real clinical practice. Nevertheless, we are excluding registrants with a very high probability of being unexposed or insensitive to our web-based interventions, either because they are no longer at our institution or have repeatedly ignored MacPLUS FS over a prolonged period.

By December 31, 2013, these eligibility criteria were met by 904 clinicians – 429 postgraduate and 475 faculty MDs (see Table 5) – after exclusion of 211 registrants no longer working at McMaster University, and 284 who never interacted with MacPLUS FS during the last year. About two-thirds of eligible users interacted with MacPLUS FS only through email alerts, while one-third performed at least one search in that period. About 16% of eligible clinicians work in the field of internal medicine, 32% work in family medicine, while the other half of the sample works in a wide array of other specialties (see Table 5).

Randomization

Participants will be randomized to our three web-based interventions in a factorial design (see overview of study design and Table 2). Postgraduates and faculty MDs will be randomized separately and further stratified according to time since last search (<= 365 days vs. >365 days; see Table 5), as an overall proxy of their baseline frequency searches in MacPLUS FS. Right before the beginning of the trials, participants will be randomly allocated to each factorial group ($2^3 = 8$ groups), balancing on blocks of 16 within each stratum (=2 × 8). Our information technology

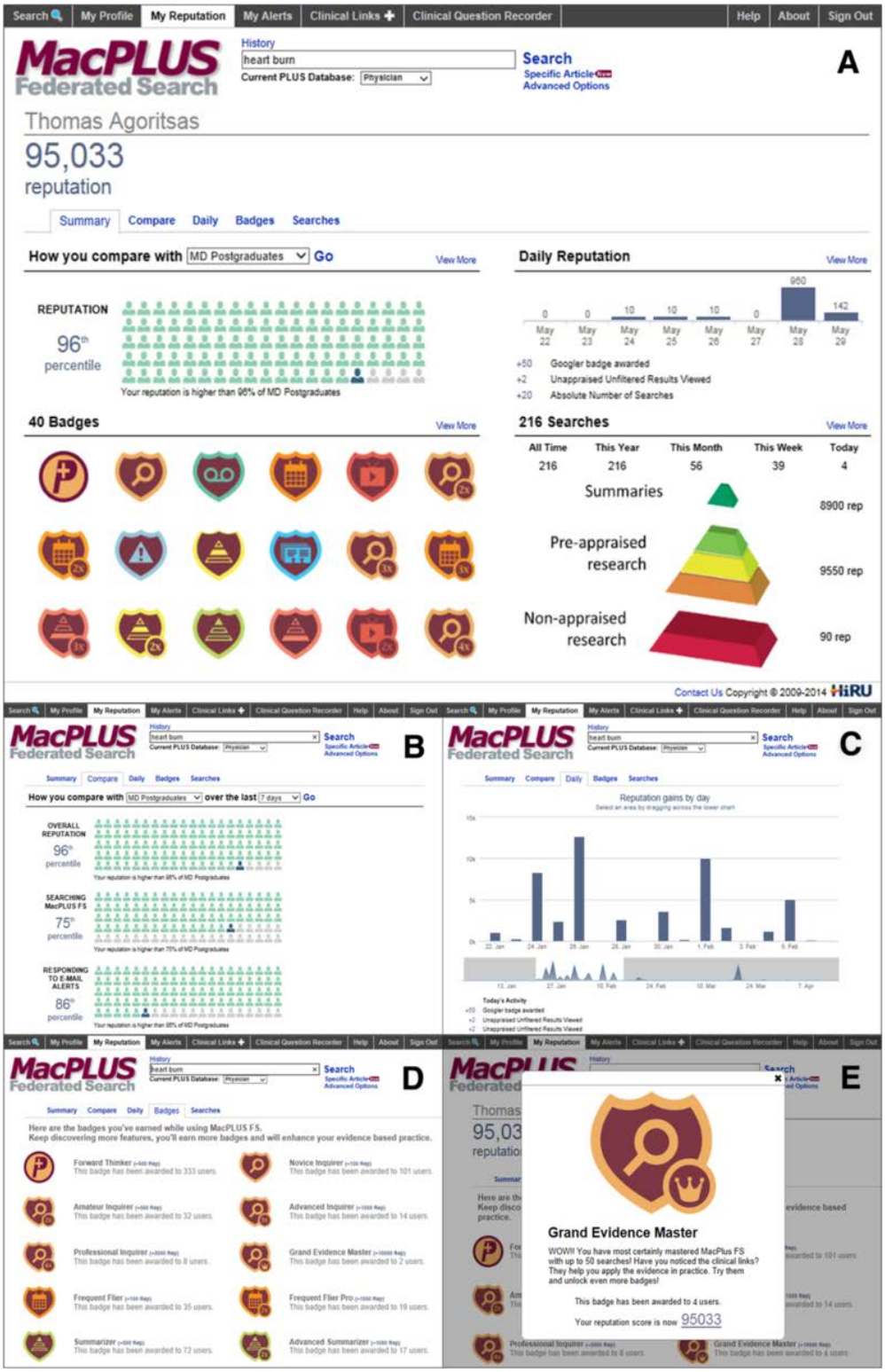

Figure 4 Illustration of the components of the Audit, Feedback & Gamification. A - **E**: For a detailed description of each feature displayed, see the result section in the section "Intervention C - audit, feedback and gamification.

Table 5 Baseline utilization among the eligible 904 MDs during the six months prior to the trial

	Postgraduates (n = 429*)	Faculty (n = 475*)	Total MD (n = 904*)
Specialty type – n (%)			
Internal Medicine	82 (19.1%)	66 (13.9%)	148 (16.4%)
Family Medicine	107 (24.9%)	184 (38.7%)	291 (32.2%)
Other Specialties	240 (55.9%)	225 (47.4%)	465 (51.4%)
Total number of searches	935	423	1,358
Searches/month/user - Mean (SD)	0.46 (1.42)	0.20 (0.83)	0.32 (1.16)
Categories of search frequency - n (%)			
>5 *(Super-searchers)*	8 (1.9%)	4 (0.8%)	12 (1.3%)
1 to 5 *(Regular-searchers)*	45 (10.5%)	24 (5.1%)	69 (7.6%)
<1 *(Occasional-searchers)*	89 (20.7%)	72 (15.2%)	161 (17.8%)
0 *(Alert-only-users)*	287 (66.9%)	375 (78.9%)	662 (73.2%)
Time since last search - n (%)			
<= 365 days	163 (38.0%)	143 (30.1%)	306 (33.8%)
>365 days	266 (62.0%)	332 (69.9%)	598 (66.2%)
Total number of e-mail alerts read	4,064	7,092	11,156
E-mail alerts read/month/user - Mean (SD)	1.65 (2.99)	2.54 (6.03)	2.12 (4.85)
Total number of other weblogins	1163	740	1903
Other weblogins/month/user - Mean (SD)	0.52 (4.10)	0.32 (2.85)	0.41 (3.50)

*Four additional participants (two postgraduates and two faculty) are missing from this count, as they registered in Jan 2014, just before the beginning of the trial.

programmers, in charge of MacPLUS FS system administration, will perform randomization using a computer-based pseudo-random number generator. They will maintain a secure master list of the randomization codes and assignments, and conceal allocation from the analysts.

Blinding and control group

Although participants cannot be blinded to the interventions, they will not be informed of the different interventions that are being offered. In addition, all participants, including the control group with no intervention, will be exposed to new minor features one month prior to the beginning of the trial. These include: small changes in the web design (simplification of available tabs and navigation), waiting time features displaying all resources searched in parallel in MacPLUS FS (see Figure 1), and a novel 'single citation matcher' (see Table 1). These minor new features would thus further minimize the risk of contamination between the intervention arms from users becoming aware of interventions they are missing. Moreover, the interventions cannot be shared, as they are linked to individuals' accounts, so that it is unlikely that registrants who are not offered an intervention would increase their utilization just by hearing about it.

Outcomes

Primary outcome

Our primary question is whether each intervention increases the quantity of searches to answer questions – *i.e.*, search utilization (not counting logins to e-mail alerts or to access other resources). This will be measured by (i) rate of searches/month/user, (ii) and corresponding proportions of 'super-searchers' (>five searches/month), 'regular-searchers' (one to five searches/month), 'occasional-searchers' (<one search/month), and 'alert-only-users' (no searches/month). The primary outcome will be averaged over six months, but continuously recorded as participants will be signed on through their individual user account that tracks logins and use of EBM resources, down to individual keystrokes.

Table 5 shows the baseline utilization data during the six months prior to the start of the trial, from July to December 2013. Postgraduates MDs (n = 429) searched MacPLUS FS 935 times in total, corresponding to about 0.46 searches/month/user, whereas they accessed 4,064 alerts to new evidence, corresponding to 1.65 alerts/month/user, and consulted other web-resources in MacPLUS FS 0.52 times/month/user. About 66.9% of postgrads users were 'alert-only-users,' while 10.5% were 'regular-searchers' and 1.9% 'super-searchers.'

The utilization patterns were different for Faculty MDs (n = 475) who searched MacPLUS FS half as much, about 423 times in total, corresponding to about 0.20 searches/month/user, whereas they accessed almost twice as many alerts to new evidence, 7,092 alerts in total, corresponding to 2.54 alerts/month/user, and consulted other web-resources in MacPLUS FS 0.32 times/month/user. About 78.9% of faculty used were 'alert-only-users,' while 5.1% were 'regular-searchers' and 0.8% 'super-searchers.'

Secondary outcomes and questions

We will assess whether each intervention can increase the utility of the evidence retrieved (satisfaction in meeting users' information needs, expected impact on one's general practice), the use of the evidence (the extent of use when caring for a specific patient), and its perceived usefulness in patient care and outcomes (perceived benefits of applying the evidence for a specific patient). Utility, use and usefulness of the evidence retrieved will be assessed using an adapted version of the Impact Assessment Method (IAM) [41-43], which was specifically developed for assessing how clinicians use information, based on the Acquisition-Cognition-Application-Outcome Model [42-44]. This validated six-item questionnaire takes less than one minute to complete online and will be sent by e-mail for online completion following a pre-defined automatic algorithm. The first invitation will be sent out one month after the participant's first online exposure to one or more interventions, with one reminder after 24 hours. The next invitation will be sent following the next search, but after a two-week delay. This process will be repeated until one filled questionnaire for a clinical question is returned, or the trial ends (see details and full questionnaire in Additional file 3). Perceived usefulness will be analyzed as the 'number needed to benefit from evidence,' defined as the number of patients for whom the evidence has to be retrieved to observe or expect health benefits for one patient [45].

Other secondary questions that we plan to address include whether each intervention efficacy varies across time within the six-month trial (*e.g.*, persistent, transient, increasing or decreasing effect), and whether the interventions have an impact on non-searching utilization of MacPLUS FS (*i.e.*, frequency of alerts read, frequency of web logins for other clinical resources).

Finally, we will explore if the interventions modify the patterns of use of the different EBM resources, and in particular if they increase the accesses to higher levels of evidence, such as summaries and pre-appraised research, compared to non-pre-appraised research. Table 6 displays the baseline distribution of access across the pyramid of EBM resources among clinicians that have adopted MacPLUS FS, that is, 'regular-searchers' and 'super-searchers.' With 1,025 searches, these users have conducted about 75% of all searches in MacPLUS FS, and accessed one of its resources 1,390 times in total. All resources in the federated search were consulted: summaries were accessed 53.2% of the times, pre-appraised research in 16.1%, and non-pre-appraised research in 30.6% of the times. Postgraduates searched less summaries than faculty did (49.0% vs. 63.8%), and more non-pre-appraised resources (35.3% vs. 19.3%).

Table 6 Baseline frequency of access to EBM resources (% of all accesses), among 'regular-searchers' and 'super-searchers'*

	Postgraduates (n = 53)	Faculty (n = 28)	Total (n = 81)
	739 searches	286 searches	1,025 searches
Summaries	**485 (49.0%)**	**255 (63.8%)**	**740 (53.2%)**
DynaMed	174 (17.6%)	39 (9.8%)	213 (15.3%)
UpToDate	120 (12.1%)	128 (32.0%)	248 (17.8%)
Best Practice	147 (14.8%)	71 (17.8%)	218 (15.7%)
ACP PIER	44 (4.4%)	17 (4.3%)	61 (4.4%)
Pre-appraised research	**156 (15.8%)**	**68 (17.0%)**	**224 (16.1%)**
Synopses of systematic reviews	23 (2.3%)	17 (4.3%)	40 (2.9%)
Systematic reviews	66 (6.7%)	21 (5.3%)	87 (6.3%)
Synopses of studies	10 (1.0%)	4 (1.0%)	14 (1.0%)
Studies	57 (5.8%)	26 (6.5%)	83 (6.0%)
Non-pre-appraised research	**349 (35.3%)**	**77 (19.3%)**	**426 (30.6%)**
Filtered studies	257 (26.0%)	60 (15.0%)	317 (22.8%)
Unfiltered studies	92 (9.3%)	17 (4.3%)	109 (7.8%)
Total number of accesses	**990 (100%)**	**400 (100%)**	**1,390 (100%)**

**i.e.*, clinicians who conducted more than one search per month on average.

Hypotheses and statistical analysis

The two trials are separate and will be analyzed as such. We have three primary hypotheses for each trial: that the clinical question recorder will be more effective than the control; that the evidence retrieval coach will be more effective than the control; and that audit, feedback and gamification will be more effective than the control. Each of these hypotheses will be tested separately (half of the sample compared to the other half). The effect of each intervention will be tested by regressing the average number of searches per month over the trial's six-month time period for each user onto dummy variables for each intervention, controlling for search frequency at baseline. The distribution of the number of searches per user is not known at present, but baseline data suggests excess zeros with extra-Poisson variation. We will attempt to capture the distribution parametrically, but in the event that it is not possible to do this accurately, we will

use ordinary least squares to estimate the regression coefficients together with heteroscedasticity-robust standard errors.

Potential subgroup effects

Prior to the start of the trial, we hypothesized that the impact of the intervention on our primary outcome may differ according to specialty type – *e.g.*, more effective in clinicians practicing internal medicine than family medicine or other specialties – and according to baseline frequency of search during the six months prior to the trial – *e.g.*, higher frequency searchers would tend to be more responsive to each intervention (see Table 5 for the baseline data for these two pre-specified subgroups). In an exploratory analysis, we will test for subgroup effects, using tests of interactions between the dummy variables for intervention and subgroup variables.

Potential interactions between the interventions

Our primary analysis will be at the margins, that is, looking at each effect independently, but we will also test for interactions among the interventions. We expect that combining them will have an additive effect, and that an interaction is unlikely, particularly a sub-additive one (*e.g.*, one intervention being effective alone, but less effective or even ineffective in combination with another). We cannot formally exclude any synergistic interaction (beyond additivity), but we have no reason to expect it *a priori* [46]. Moreover, observing a synergistic effect would not jeopardize our results, as we are more interested in finding any 'signal' of effect of the interventions, rather than estimating their independent effect with maximal accuracy. By analogy with drug trials, this study would be a phase II rather than a phase III randomized trial, given the current state of research in the field.

Power calculation

Since we anticipated that interactions among the interventions are unlikely, we have powered the trials assuming no such interactions. Before the trials began, we had 904 participants eligible for the study, of whom 429 were postgraduates and 475 were faculty (see Table 5). Baseline data indicated a mean of 0.46 searches per month per user (SD 1.42) among postgraduates and 0.20 searches per month per used (SD 0.83) among faculty. Additional file 4 shows power curves for the faculty and for the postgraduates. These indicate that among the postgraduates, we will have 80% power to detect an increase of 0.9 in the mean number of searches per month, and among the faculty we will have 80% power to detect an increase of 0.5 in the mean number of searches per month.

Analysis of secondary questions

An exploratory analysis will investigate time trends in intervention efficacy. Rather than using the average number of searches per user per month over the six months of the trial, we will conduct a longitudinal analysis using the number of searches per user for each of the six months of the trial as the dependent variable, regressed onto time, dummy variables for each of the interventions, the interaction between time and intervention, together with search frequency at baseline. This regression model will be fitted using a Generalized Estimating Equation (GEE).

Finally, we will compare the distribution of answers on the IAM questionnaire *(i.e.*, utility, use and usefulness of the evidence retrieved), as well as the distribution of access to the different EBM resources, using chi-squared tests.

Ethics and registration

Upon registration to MacPLUS FS, users will consent to participate in its evaluation. Namely, they will agree that their use of MacPLUS FS will be measured for frequency and type of use, and that they will receive periodic online evaluation questionnaires. No individual identifiers will be stored in the monitored databases. The Hamilton Integrated Research Ethics Board has approved this project (REB Project #05-186), as well as a specific waiver for additional informed consent for registrants to be randomized to the different interventions, as no risk is involved and it is necessary to preserve blinding to provide an unbiased utilization measurement (primary outcome). The trials have been registered at ClinicalTrials.gov before randomization (ClinicalTrials.Gov NCT02038439).

Trial administration and data management

The trials will be conducted at the Health Information Research Unit, at McMaster University, which designed and is hosting MacPLUS FS. Before the trials start, research staff (EI) and the principal investigator (TA) will check eligibility criteria of the registrants, verify their affiliation to McMaster, profession and training level, and crosscheck the information stated at registration with official administrative medical databases.

The administration of interventions, outcome measurements, and the sending of periodic online IAM questionnaires will all be programmed before randomization and further handled automatically as they will be built into the MacPLUS FS online infrastructure.

The trials will start simultaneously for all participants. All interactions with MacPLUS FS, including any click-through links within emails, will automatically sign participants on through their individual user account that tracks logins and use of EBM resources. Primary and secondary outcomes will be recorded from this automatic monitoring of the system, and stored in a specific and secure database within MacPLUS FS.

The research staff (EI) and the principal investigator (TA) will review overall utilization data collected on a weekly basis, looking for completeness of data and navigational bugs. However, no interim analysis will be performed before the trial end.

Trial status

The trial is currently ongoing at the time of submission of this manuscript. We have not begun and will not perform any data cleaning, analysis or interim reports before the trial ends.

Discussion

The three interventions in these two factorial randomized trials are innovative in at least three different ways. First, although widely used in other fields such as education, task management, business, or customer user-centered services, we are not aware that any of these approaches have been applied thus far to clinical evidence retrieval. Second, the interventions use web-based technology to facilitate low cost implementation at a broad scale, for all types of devices. Smartphones and tablets are transforming the way we live, practice medicine, and intuitively learn new skills [47,48]. Third, the general framework for these interventions is based on effective models for teaching clinical skills at the point of care. These models have changed the way we teach clinical examination or diagnostic reasoning - embedded in our daily practice [30-34] - but have not yet been used to teach how to find current best evidence in the point of care, a skill that has nevertheless become designated 'as essential as the stethoscope' [8].

Our trials have also inherent limitations. First, although MacPLUS FS includes most top EBM resources currently widely used by clinicians (see Table 1), participants may still opt to access individual resources directly rather than through MacPLUS FS. However, although this may result in an apparent low frequency of search, the randomization should balance the distributions of such behaviors across study arms and not jeopardize the conclusion from the trials.

Second, although the validated IAM will try to capture the secondary outcomes of utility, use and perceived usefulness of the retrieved, these surveys may suffer from suboptimal response rates. Ideally, we would assess the effect on directly measured patient important outcomes, but this is beyond the feasibility of the current study, and particularly challenging at hospital-levels across a very wide array of potential clinical questions. In any event, the justification for doing a larger multi-centered trial with direct measurement of patient outcomes would be the observation of a sufficient utilization rate associated with a substantial effect on evidence use and usefulness in the present trial. By analogy with drug trials, this study would be a phase II trial.

Third, the interventions are primarily mediated through emails with direct login access to MacPLUS FS, and as such, their potential impact may be diluted in the numerous competing solicitations clinicians continuously receive through emails. Moreover, the Clinical Question Recorder (Intervention A) requires clinicians to actively record their questions. To maximize the chances they engage, we focused our efforts upstream in the user-centered design, implementation and testing of the recorder. Actual use in real life settings remains uncertain, although simply offering the intervention may also have some indirect effect on searches.

Finally, baseline data showed that search rates heavily fluctuate across time. Lower rates at certain periods (*e.g.*, holidays, vacation days, or exam periods) may affect the assessment of the interventions, although utilization averaged over six months of follow-up should allow a reasonable comparison between study arms.

The main advantages of this study rely on the feasibility of the administration of the interventions and the outcomes measurements for a large number of clinicians, as these will be handled automatically in MacPLUS FS online system, with no possibility of crossover, and virtually no loss of follow-up for primary outcome data.

In conclusion, the trials will answer whether these innovations have the potential of enhancing knowledge translation through a clinician's timely access to current best evidence. The MacPLUS FS interface allows a broad implementation for registrants, in a sustainable way, with limited additional costs. If effective, these interventions can further be broadly implemented beyond the McMaster community, using the twin version of MacPLUS FS – called ACCESSSS FS (http://plus.mcmaster.ca/ACCESSSS), and enhance the access to current best evidence for a large audience, across many top EBM resources in parallel, and tied directly to clinical questions.

Additional files

Additional file 1: User-testing interview guide for the development of the Clinical Question Recorder.

Additional file 2: Evidence Retrieval Coach: tailoring the educational videos to clinicians pattern of use.

Additional file 3: Online administration of Impact Assessment Method (IAM) questionnaire.

Additional file 4: Power curves for the primary outcome.

Abbreviations

EBM: Evidence-based medicine; MacPLUS FS: MacPLUS federated search; PLUS: Premium literature service; IAM: Impact assessment method; PICO: Population – Intervention(s) – Comparator – Outcome(s).

Competing interests
The Health Information Research Unit (HiRU), McMaster University, to which many authors are affiliated (TA, EI, NH, MP, CC, RP, NW, AI, and BH), has developed and implemented the MacPLUS Federated Search. The intellectual property belongs to McMaster University, a non-profit, publicly funded institution. One of the main missions of HiRU is the development of new information resources to support evidence-based healthcare, and the evaluation of various innovations in overcoming healthcare information problems. Its McMaster Premium LiteratUre Service (PLUS) contributes to many other EBM resources worldwide, including: BMJ EvidenceUpdates, ACP Journal Club, ACP Smart Medicine, Best Practice, Clinical Access, Clinical Evidence, DynaMed, e-Therapeutics, Evidence-Based Medicine Reviews (Duodecim), First Consult (Elsevier), Helsebiblioteket (Norway), National Board of Medical Examiners, Stat!Ref (Teton Data Systems), all under contract with McMaster University.

Authors' contributions
Conception of the interventions and study design: TA, with significant contributions from BH, NW, and AI. Specific design of intervention A (Clinical Question Recorder): TA and NH. Specific design of intervention B (Evidence Retrieval Coach): TA, MP, EI and PR. Specific design of intervention C (Audit, Feedback & Gamification): TA, NC, AC. IT programming: NH, RP and CC. Conduct of the user-testing: TA. Analysis of baseline data: TA and EI. Statistical analysis plan: TA and EP. Overall supervision: BH. Draft of the manuscript: TA. Critical revision of the manuscript for important intellectual content: EI, NH, NC, AC, PR, MP, CC, RP, EP, NW, AI and BH. All authors read and approved the final manuscript. TA had full access to all the data presented in the manuscript and takes responsibility for its integrity and accuracy.

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CHAPTER 3

Second manuscript

Enhancing the Searching for Current Best Evidence to Answer Clinical Questions by Medical Faculty: Results from the MacPLUS FS Factorial Randomized Controlled Trials

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Tables: 4 / Figures: 3 / Appendices: 6

3.1 ABSTRACT

Background:

Questions constantly arise from physicians' interactions with their patients, but more than 60% remain unanswered. No single evidence-based resource provides all answers or is sufficiently updated. McMaster PLUS – Federated Search addresses this issue by looking in multiple high quality resources simultaneously and displaying results in 1 page, starting with the most clinically relevant.

Objective:

This trial tested 3 web-based interventions addressing logistical and educational barriers, to increase the quantity and quality of searching for current best evidence to answer clinical questions.

Methods:

We conducted a randomized-controlled trial among 477 medical faculty currently registered to MacPLUS FS at the hospitals affiliated to the McMaster University Faculty of Health Sciences. Physicians were randomized to each of the 3 following interventions in a factorial design (AxBxC): (A) a web-based Clinical Questions Recorder and Reminder; (B) an Evidence Retrieval Coach composed of 8 short videos embedded in MacPLUS; (C) a Gamified Audit & Feedback based on the allocation of "badges" and "reputation scores". We recorded

utilization continuously through individual accounts that track logins and use. The primary outcome was the rate of searches/user over 6 months. Secondary outcomes included frequency of access to pre-appraised evidence and to new evidence alerts.

Results:

The interventions resulted to a 2 to 4-fold increase in search frequency – with a relative increase of 4.24 (95% confidence interval 2.46 to 7.20) for the 3 interventions combined. Similarly, the interventions resulted on average in a 2 to 4-fold increase in access to pre-appraised resources, and doubled physicians' access to new evidence alerts.

Conclusion:

These online interventions successfully increased the quantity and quality evidence retrieval among medical faculty. They offer the opportunity to enhance online evidence support for a large clinical audience, at low cost, by linking to most current high quality evidence resources.

Trial Registration: ClinicalTrials.Gov NCT02038439

3.2 INTRODUCTION

Questions constantly arise from physicians' interactions with their patients, as they face the complexity and uncertainty of clinical care. Family practice, for example, involves hundreds of clinical problems from acute care to prevention, from pediatrics to geriatrics.[1,2] Across medical specialties clinicians have on average 4 to 8 questions for every 10 patients[3-6], and being able to answer them is an essential clinical skill.[7]

In parallel, considerable research efforts are made to reduce uncertainty and inform patients and clinicians. Medline expands rapidly by about 3000 new publications every day[8], including 11 systematic reviews and 75 randomized trials[9], thus continuously changing the conclusions we can draw from the body of evidence.[10-13] Numerous Evidence-Based Medicine (EBM) resources identify, appraise, and synthesize current best evidence to help clinicians find answers and stay up-to-date.[7,14] However, each resource offers a scattered and fragmented view of the evidence, and none provides consistent updating[11-13] or comprehensive topic coverage.[15,16] Physicians pursue only about 50% of their questions[3], while more than 60% remain unanswered, and many answers are not based on current best evidence.[3,17-20] Unsurprisingly, evidence uptake remains stubbornly suboptimal and 40-45% of clinical encounters do not provide appropriate care.[21]

One way to address these limitations is to combine the advantages of several EBM resources. We have previously described a novel online tool developed at the McMaster's University Health Information Research Unit, the MacPLUS Federated Search (MacPLUS FS).[7,22] This resource combines unique features that help busy clinicians efficiently navigate across multiple top resources in a simultaneous search to rapidly get the best available answers. Results are organized according to the *pyramid of EBM resources*[23], displaying a 1 page output with the most clinically useful results at the top (see Figure 3.8.1). Thus, MacPLUS FS simultaneously retrieves evidence from online *summaries* in the top layers (e.g., DynaMed, UpToDate, Best Practice).[22] If no satisfactory answer is found, clinicians have then access to *pre-appraised research* in the middle layers (i.e., Systematic reviews, Studies and their Synopses when available, selected in McMaster PLUS database for methodological rigor and clinical relevance[24]). Evidence from PLUS provides new and different conclusions than existing summaries for about 25-50% of clinical topics.[11] Finally *non-pre-appraised research* from PubMed complements the search at the bottom layers, both with and without the validated "Clinical Queries" filters.[25] In addition to the federated search, MacPLUS FS provides users with alerts to new research in their chosen disciplines[26,27] (same content is also disseminated to the BMJ EvidenceUpdates, widely accessed by about 65'000 clinicians worldwide[28]), as well as numerous clinical and EBM practical links.[22]

Having addressed the structural limitations of single EBM resources, MacPLUS FS offers an opportunity to address additional logistical barriers (e.g., time constraints, forgotten questions), as well as educational barriers (e.g., limited searching skills, lack of knowledge and experience of what federated searches can offer, and lack of reference standards for evidence retrieval among peers).[22,29-34]

This randomized trial tested 3 innovative web-based interventions among physicians registered to MacPLUS FS. Based on effective models for the teaching of clinical skills at the point of care[22], these interventions aim at overcoming these logistical and educational barriers and thus increase the quantity and quality of searching for current best evidence to answer clinical questions.

3.3 METHODS

3.3.1 STUDY DESIGN

The MacPLUS FS Factorial Randomized Controlled Trials consist of 3 trials, conducted separately in 3 different populations of health care providers registered in MacPLUS FS: (i) medical faculty members, (ii) postgraduates medical trainees (i.e., residents and fellows), (iii) nursing and medical students. Each trial tested the same 3 web-based interventions in a factorial design (AxBxC). We report here the results of the first trial among medical faculty members.

The study was registered at ClinicalTrials.gov before randomization (NCT02038439), and approved by the Hamilton Integrated Research Ethics Board. Details of the trial objectives, design, and methods were previously published in an open-access protocol [also available in Chapter 2], along with the development and full description of the 3 web-based interventions.[22] We summarize the methods and interventions briefly here.

3.3.2 THE WEB-BASED INTERVENTIONS

In a user-centered approach, we designed 3 interventions based on effective models for the teaching of clinical skills at the point of care, to facilitate using the

search engine as a clinical tool, and to present evidence retrieval skills as true clinical skills:

- Intervention A – Clinical Question Recorder and Reminder
- Intervention B – Evidence Retrieval Coach
- Intervention C – Audit, feedback and gamification on searching behaviors

These interventions, embedded in MacPLUS FS are web-based adaptations of the "One-minute preceptor model" (also known as the "5-step Microskills" [35-39]), tailored to enhance evidence retrieval by identifying searching opportunities, prompting searches to answer clinical questions, providing general knowledge, skills and feedback, and inviting reflective practice. More details on our rationale, theoretical framework and user-centered development are described in our published protocol [22] [see also Chapter 2].

3.3.2.1 Intervention A – Clinical Question Recorder and Reminder

We designed an online platform directly linked to participants' individual MacPLUS FS accounts and accessible across a wide range of devices, including smartphones, tablets and computer desktops (see Figure 3.8.2-A). This platform allows participants to: i) record their clinical questions on the fly, at the point of care; ii) easily answer them by triggering full searches in MacPLUS FS, iii) receive periodic reminders of unanswered questions along with evidence alerts, thus providing asynchronous opportunity for evidence retrieval[40]; iv) and keep track of their questions and short evidence-based answers along with

bookmarked citations, in a virtual logbook for reflective practice (see Appendix 3.11.1).

3.3.2.2 Intervention B – Evidence Retrieval Coach

This intervention provides physicians with guidance with evidence retrieval, through 8 short videos (< 90 seconds each), which are both embedded in MacPLUS FS as well as sent via weekly e-mails according to each the clinician's specific patterns of utilization and search (see Figure 3.8.2-B). The videos provide "small bites" of knowledge and skills on evidence-based practice (e.g., to translate clinical questions to answerable questions), on the "architecture" of evidence (i.e., pyramid of EBM resources), advantages and limits of individual resources, and how MacPLUS FS can help overcome them (see Appendix 3.11.1).

3.3.2.3 Intervention C – Audit, Feedback and Gamification

The purpose of this third intervention is to provide physicians with timely feedback on their current search utilization compared to their peers. We used a *gamification* approach[41], based on allocation of *badges* (about 50 in total) popping-up online immediately after a desired searching behavior (e.g., frequency of searches, or access to pre-appraised resources). These badges result in *reputation scores,* which are based on the desirability of the behavior they reinforce and can be compared to peers on an interactive and playful interface within MacPLUS FS (see Figure 3.8.2-C, & Appendix 3.11.1).

3.3.3 SETTING AND STUDY PARTICIPANTS

We conducted the present trial from January 2014 to June 2014 (6 months duration) in the teaching hospitals and clinics affiliated with McMaster University, Ontario, Canada, which comprises 2 major academic hospital systems, operating ten hospitals in the Hamilton area, as well as 2 regional campuses in Niagara and Waterloo, Ontario.

Eligible participants were all physician faculty members who had registered in MacPLUS FS prior to the trial. Both registration and use of MacPLUS FS are free on all campus areas. Physicians were invited to register through e-mail and flyer advertisement on campus, presentations at clinical rounds, and by word of mouth, and provided consent for MacPLUS FS' evaluation upon registration. Of the 743 faculty registered by January 2014, 477 were deemed eligible for the trial (see Figure 3.8.3), after exclusion of 55 who were no longer working in the institutions and 211 who never interacted with MacPLUS FS during the last year (either by logging in to read e-mail evidence alerts or to perform a search) and thus had almost no chance of being exposed to the web-based interventions.

3.3.4 RANDOMIZATION, CONCEALMENT & BLINDING

The trial was coordinated from the Health Information Research Unit, at McMaster University, which designed and hosts MacPLUS FS. At the start of the trial, the independent programmer, in charge of MacPLUS FS administration, randomized all the 477 eligible physicians to the 3 web-based interventions

through their individual accounts, using a computer-based random number generator (thus ensuring concealment of randomization). In a factorial design (AxBxC), half of the participants were randomly allocated to each intervention, with all possible permutations resulting in 8 factorial groups (2^3=8 groups – see Figure 3.8.3). Randomization was balanced on blocks of 16 within each stratum (= 2 x 8) and further stratified according to time since last search in MacPLUS FS (<= 365 days vs. >365 days, the latter only logged in to read e-mail evidence alerts). The programmer maintained a secure master list of the randomization codes; the analyst was blind to allocation.

Although participants could not be blinded to the interventions, they were not informed of the different interventions being offered, and all participants, including the no intervention group, were exposed to new minor features in MacPLUS FS presentation and navigation 1 month prior to the beginning of the trial.[22]

3.3.5 OUTCOME MEASURES

The primary outcome of interest was *utilization* of MacPLUS FS to search for evidence over the 6 months duration of the trial (i.e., not counting logins to e-mail new evidence alerts or to access other resources). We also assessed 2 secondary *utilization* outcomes to capture the quality of the searches and MacPLUS FS use. First, we measured frequency of access to higher levels of evidence – i.e., summing the accesses to online summaries level (e.g., DynaMed, UpToDate, Best Practice) as well as accesses to individual pre-

appraised research (systematic reviews, synopses of studies or reviews). Finally, we recorded the frequency of accesses to new evidence email alerts, independently of searching. All utilization outcomes were automatically and continuously recorded over the duration of the trial, as participants were signed on through their individual user account that tracked down to individual keystrokes.

The trial included 2 additional surveys. The first survey was an adapted version of the Impact Assessment Method (IAM)[42-44], which assesses the *utility* of the evidence retrieved (meeting users' information needs), its *use* (application of in practice), and its perceived *usefulness* for a specific patient's care and outcomes. We sent periodic online IAM questionnaires by e-mail according to an automatic algorithm built into MacPLUS FS. The first invitation was sent out 1 month after the participant's first online exposure the intervention(s), with 1 reminder after 24 hours. The next invitation was sent following the next search, but after a 2 weeks delay, repeating this process until the return of 1 filled questionnaire for a clinical question or the trial's end. We sent the second post hoc survey by e-mail after the end of the trial (with up to 3 reminders), to inquire about the resources users typically search outside MacPLUS FS in their practice.

3.3.6 STATISTICAL ANALYSIS

Although we anticipated the primary analysis to be at the margins, that is, looking at the effect of each intervention independently[22], actual analysis revealed 3-way

statistically significant interactions. Consequently, we regressed the number of searches over the trial's 6-month time period for each participant onto all combinations of interventions (i.e., 8 allocation groups) controlling for time since last search at baseline (i.e., the stratifying variable). We used marginal models, applying generalized estimating equations (GEE) with Poisson distribution and a log link function. These analyses provided relative ratio estimates, which can be interpreted as the multiplicative factor of search rates with each combination of intervention (groups 1 to 7 – see Figure 3.8.3) compared to no intervention (group 8). We repeated the same analysis with the 2 secondary utilization outcomes: frequency of access to pre-appraised resources, and access to new evidence alerts.

For the primary outcome, we also conducted our 2 predefined subgroup analyses[22], to explore whether the interventions' effect on searching would differ according to baseline frequency (i.e., 6 months prior to the trial) and to specialty type (internal medicine vs. family medicine vs. other specialties). In a longitudinal analysis, we explored whether each intervention's effect varied across time during the course of the trial.[22] Finally, we analyzed the 2 surveys, comparing the distribution of answers using chi-squared tests. We performed all analyses using SPSS 22.0.0.1 software.

3.4 RESULTS

3.4.1 PARTICIPANTS FLOW AND CHARACTERISTICS

In January 2014, 477 medical faculty members were randomized to the 8 allocation groups (59-60 participants per group), with half the sample allocated to each intervention in a factorial design (see Figure 3.8.3). All were followed-up for primary and secondary utilization outcomes, over the 6 months of the trial. The sample included a wide array of specialties, with about 39% working in family medicine, 14% in general internal medicine and 23% in internal medicine subspecialties (see Table 3.7.1). During the 6 months prior to the trial, about 79% of eligible users interacted with MacPLUS FS only through e-mail alerts, while 15% were occasional-searchers (average < 1/month) and 6% were regular or super-searchers (average >= 1/month). This corresponded to a time since last search of more than 1 year for 70% of participants. All baseline variables (specialty type, baseline search frequency, and time since last search) showed similar distributions across the 8 allocation groups (see Appendix 3.11.2).

3.4.2 PRIMARY OUTCOME: SEARCH UTILIZATION

All 3-way interactions between the Clinical Question Recorder (Intervention A), the Evidence Retrieval Coach (Intervention B), and the Audit, Feedback and Gamification (Intervention C) were statistically significant, so that the effect of

each varied depending on whether it was presented on its own or in combination. Participants who were allocated to no interventions (group 8: 0-0-0) conducted on average 0.28 searches over the course of the trial. Compared to this group, almost all combinations of intervention(s), showed a 2- to 4-fold increase in search frequency (see Table 3.7.2). For example, the 3 interventions together increased the estimated rate to 1.20 searches – more than 4 times the baseline rate – corresponding to a Relative Ratio (RR) of 4.24, 95% confidence interval (CI) ranging from 2.46 to 7.20. Comparable effects were observed with the Clinical Question Recorder alone (RR 4.27; 95% CI 2.51 to 7.26) or the Evidence Retrieval Coach alone (RR 4.88; 95% CI 2.89 to 8.24). Only 1 combination (group 5: 0-1-1) showed no statistically significant effect, and no intervention resulted in fewer searches (see Table 3.7.2).

3.4.3 SECONDARY UTILIZATION OUTCOMES

Results followed a similar pattern for the frequency of access to pre-appraised resources. Compared to the no-intervention group, most combinations of intervention resulted in about a 2- to 4-fold increase in accesses to pre-appraised resources (see Table 3.7.3). Audit, Feedback & Gamification alone, as well as the 3 interventions together, showed the highest increase, with a RR of respectively 4.32 (95% CI: 2.69 to 6.96) and 3.74 (2.30 to 6.06). In contrast group 2 (1-1-0) and group 3 (1-0-1) showed no significant increase. Physicians accessed 450 resources during the course of the trial, using the whole range

offered in the federated search engine (see Appendix 3.11.3). About 60% of accessed resources were *Summaries* (UpToDate in 28% and DynaMed in 12%), 28% where *Pre-appraised research* (e.g., 11% of Synopsis of systematic reviews), while *Non Pre-appraised research* were accessed in 17% of the times (mostly using Clinical Queries filters).

Participating physicians accessed new evidence alerts on average 7.88 times in the no-intervention group. There was a 1.2- to 2.6-fold increase in access with either combination of intervention(s), increasing it up to 20.37 accesses (see Table 3.7.4). Across all allocation groups, the frequencies of access to alerts was more frequent that the frequency of searches (see Table 3.7.2 & 3.7.4).

3.4.4 SUBGROUP ANALYSES AND TIME-TRENDS

The effect of each intervention also varied according to baseline frequency of search: occasional searchers in MacPLUS FS (i.e., mean search rate < 1/month) were more responsive than regular or super-searchers (>= 1 search/month) or alerts-only users, except for the Evidence Retrieval Coach, which showed higher effects among alerts-only users (see Appendix 3.11.4). Although tests for statistical interactions were significant and this analysis was predefined, the directions of the subgroup effects were not as we hypothesized in our protocol.[22] They are thus of moderate credibility and only exploratory at this stage. This also applies to the differences observed across specialty types (see Appendix 3.11.4).

In longitudinal analysis, searches were higher in the first month of the trial compared to subsequent months during which they stabilized. This was observed in all allocation groups, and there was no statistically significant evidence that the extent of the decline differed among intervention groups.

3.4.5 RESULTS FROM THE SURVEYS

Due to the overall frequency of searches, our automatic algorithm sent only 52 IAM-questionnaires to 38 participants during the trial. Despite an 84% (32/38) response rate, only 7% of all participants ended up being surveyed, which was insufficient to assess the interventions' effect. Among 20 participants reporting on clinical question for an actual patient, the answer retrieved was associated with an 84% utility, 72% use in practice, and 67% perceived usefulness on patient outcomes (see Appendix 3.11.5).

One hundred and thirty participants (27.3%) answered the post-trial survey (with no significant difference in search rates between respondents and non-respondents). About 81% reported having searched for answers outside of MacPLUS FS in more than 5 times in the last 3 months. This was dominated by far by Google searches, but also included summaries (e.g., UpToDate or DynaMed) accessed outside of MacPLUS by 56% of respondents, as well as PubMed by 45% of respondents (see Appendix 3.11.6).

3.5 DISCUSSION

Among clinical faculty members, 3 web-based interventions, built on effective models for the teaching of clinical skills at the point of care, increased the quantity and quality of searching for current best evidence to answer clinical questions. The interventions resulted on average in a 2- to 4-fold increase in search frequency, and a similar increase in access to pre-appraised resources, as well as a 1.2- to 2.6-fold of access to new evidence alerts.

With 477 medical faculty included, this study is the largest trial on interventions to increase the use of electronic health information of which we are aware. A recent Cochrane review identified only 2 randomized trials and 4 observational studies, which included in total only 352 trained physicians in total, and reported inconsistent results.[45] One of the major strengths of our interventions is the feasibility and low cost of their implementation at a broad scale, as they are embedded into MacPLUS FS clinicians' account. Considerable effort was made to optimize the trial interfaces before their launch through iterative user-testing, in-house usability and beta testing.[22] Consequently, no system changes were needed after the launch of the trial.

In spite of the interventions' effect, the absolute frequency of searches remained relatively low, and a majority of participating physicians kept using MacPLUS FS mostly for its alerting system to new evidence (similar content to the widely accessed BMJ EvidenceUpdates[28]). There could be several explanations for this

phenomenon. First, medical faculty are not always on clinical service and may find MacPLUS FS less useful during their other academic or administrative activities. We were not able to test that hypothesis, as this would have required collecting independent data on when participants are on and off actual clinical work. Second, in spite of the limited response rate of our post-hoc survey, there was evidence that physicians accessed individual EBM resources outside of MacPLUS FS. They sought many answers in Google, Google Scholar[46] and Wikipedia, but also in resources that they could have accessed through MacPLUS, such as PubMed and summaries (e.g., UpToDate or DynaMed). This may be explained by lack of awareness of the advantage of searching through MacPLUS, or by personal habit or convenience. Nevertheless, our interventions, 2 of which actually provided incentives and information on the advantages of a federated search (i.e., Evidence Retrieval Coach and Audit–Feedback), did increase the quantity and quality of searches within MacPLUS FS. Moreover, the distributions of resources that were accessed suggested that physicians were interested in all layers of the federated search output, while favoring the top-layers (summaries and pre-appraised research).

All 3 tested interventions showed effectiveness. Although the magnitude of the effect somewhat varied depending on whether each intervention was presented on its own or in combination, these positive results may also be interpreted as an overall “class-effect”. Being all web-based, the interventions may have simply increased the likelihood of interacting with MacPLUS FS, which may in turn have

enhanced the quantity and quality of searches because it is structurally designed to meet clinicians' information needs.[22]

Alternatively, each intervention may have had a specific effect of its own. The idea of a Clinical Question Recorder and Reminder, and particularly the linking it to federated search engine, is novel, and may have helped physicians remember the value of their questions by providing asynchronous opportunity for evidence retrieval.[40] Others have published early reports of the educational merits of "working files", which are electronic forms meant to document the process from clinical question to an answer.[47] Regarding Audit and Feedback, a systematic review of 140 randomized trials showed only a marginal impact on compliance with desired practice (4.3% absolute increase, 95% CI 0.5%-16%), with feedback being more effective when baseline performance is low and when it is provided regularly.[48] In this trial, we were not able to assess the compliance with desired practice, as we did not have access to proportion of questions for which clinicians performed a search. Previous studies, although conducted among patients rather than physicians, have also shown some effectiveness in providing periodic e-mail prompts shortly after using internet-delivered information[49], as well as components of gamification.[50,51] Both the delivery of educational videos or "reputation" badges (intervention C) may have mediated similar effects.

Several limitations of our investigation should be borne in mind. First, this trial was conducted at McMaster University, which has played a central role in the development of EBM and results may have limited generalizability to other

contexts. However, our large sample ensures that we included medical faculty with diverse backgrounds and training. Second, the interventions may be intimately linked with MacPLUS FS architecture, which complements top summary recourses with the unique properties of PLUS that ensures selected evidence is methodologically sound and clinically relevant.[16,24,27] Results may not directly translate to other federated search engines.[7] Third, use of MacPLUS FS was provided free of charge to physicians, and our findings may not apply in circumstances where users must pay themselves.

Finally another limitation is that we did not assess the interventions' effect on directly measured patient important outcomes. This was beyond the feasibility of the study, and particularly challenging at hospital-levels across a very wide array of potential clinical questions. Indeed, no previous study assessing the use of evidence-based information was able to measure patient outcomes.[45] Instead, we attempted to capture the utility, use and perceived usefulness of the evidence retrieved through the administration of the Impact Assessment Method survey. Developed specifically for assessing how clinicians use information, based on the Acquisition-Cognition-Application-Outcome Model[43,44,52], this 6-item questionnaire takes less than 1 minute to complete online. Despite a response rate of 84%, only 7% of all participants ended up being surveyed, because of the absolute frequency of searches and the automatic algorithm designed not to overload physicians with a questionnaire after each search. This prevented the assessment of the interventions' effect on this outcome and highlights the

challenges of similar outcome measurements at the level of each participant. However, we did observe an effect on the frequency of access to pre-appraised resources (top EBM summaries, ACP journal club, DARE and PLUS). Arguably, because of the nature of their selection process, the evidence retrieved is more trustworthy than non-appraised research[7,24], and is more likely to improve rather than worsen the quality of care.

3.6 CONCLUSION

Finding current best evidence is challenging and requires specific skills that are often undervalued by practicing physicians. More than 50% of clinical questions are not pursued[3], and many practitioners still favor opinion-based sources, such as peers or personal experience, or industry-sponsored sources.[20] No single intervention to date has succeeded in a definitive shift in physicians' searching behaviors. However, results from this trial provide a proof of concept, finding that current best evidence can be enhanced directly through online search engines, with interventions that are based on effective models for the teaching of clinical skills at the point of care.[22]

The MacPLUS FS interface – and its twin version available internationally – called ACCESSSS FS (http://plus.mcmaster.ca/ACCESSSS) – allow a broad implementation of such interventions. This could enhance evidence retrieval for a

large audience, across many top EBM resources in parallel, and tied directly to clinical questions.

Future avenues for research include refining the interventions by tailoring them further to users' patterns of search, combining them with components of social media among colleagues and peers[53], and mobilizing self-directing learning by linking the use of searching platforms with continuous medical education incentives.[14]

3.7 TABLES

Table 3.7.1 Characteristics of participating medical faculty registered in MacPLUS FS

	Any Intervention (n = 417*)	No Intervention (n = 60**)	Total (n = 477**)
Specialty type			
Family Medicine	160 (38.4%)	24 (40.0%)	184 (38.6%)
Internal Medicine	61 (14.6%)	5 (8.3%)	66 (13.8%)
Internal Medicine specialities	92 (22.1%)	17 (28.3%)	109 (22.9%)
Pediatrics	25 (6.0%)	4 (6.7%)	29 (6.1%)
Psychiatry	15 (3.6%)	6 (10.0%)	21 (4.4%)
Surgery	34 (8.2%)	1 (1.7%)	35 (7.3%)
Anaesthesiology	14 (3.4%)	1 (1.7%)	15 (3.1%)
Diagnostic services	9 (2.2%)	2 (3.3%)	11 (2.3%)
Other specialties	7 (1.7%)	0 (0.0%)	7 (1.5%)
Baseline average search frequency§			
>=1/month (Regular & Super-searchers)	25 (6.0%)	3 (5.0%)	28 (5.9%)
< 1/month (Occasional-searchers)	62 (14.9%)	11 (18.3%)	73 (15.3%)
0 (Alert-only-users)	330 (79.1%)	46 (76.7%)	376 (78.8%)
Time since last search			
<= 365 days	126 (30.2%)	19 (31.7%)	145 (30.4%)
> 365 days	291 (69.8%)	41 (68.3%)	332 (69.6%)

* Combining physicians randomized to at least 1 of the 3 interventions, i.e., group 1 to 7 (see Figure 1)
** Physicians randomized to none of the three interventions, i.e., group 8 (see Figure 1)
§ Average rates during the 6 month prior to the trial

Table 3.7.2 Frequency of searches by medical faculty (primary outcome): estimated mean and relative ratio compared to the no intervention group

	Interventions			Overall Frequency of Searches		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ***	**Relative Ratio**	**(95% CI)****
Group 1	**Yes**	**Yes**	**Yes**	1.20	4.24	(2.49 – 7.20)
Group 2	**Yes**	**Yes**	No	0.84	2.99	(1.72 – 5.19)
Group 3	**Yes**	No	**Yes**	0.55	1.94	(1.08 – 3.49)
Group 4	**Yes**	No	No	1.21	4.27	(2.51 – 7.26)
Group 5	No	**Yes**	**Yes**	0.46	1.64	(0.89 – 3.00)
Group 6	No	**Yes**	No	1.38	4.88	(2.89 – 8.24)
Group 7	No	No	**Yes**	1.01	3.57	(2.08 – 6.13)
Group 8	No	No	No	0.28	*Reference*	

* Mean frequency of searches/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search
** CI - Confidence Interval

Table 3.7.3 Frequency of access to pre-appraised resources by medical faculty (secondary outcome): estimate mean and relative ratio compared to the no intervention group

	Interventions			Overall Access to Pre-appraised Resources		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ****	**Relative Ratio**	**(95% CI)***
Group 1	**Yes**	**Yes**	**Yes**	1.26	3.74	(2.30 – 6.06)
Group 2	**Yes**	**Yes**	No	0.57	1.68	(0.98 – 2.90)
Group 3	**Yes**	No	**Yes**	0.40	1.18	(0.66 – 2.12)
Group 4	**Yes**	No	No	0.64	1.88	(1.10 – 3.21)
Group 5	No	**Yes**	**Yes**	0.60	1.77	(1.03 – 3.03)
Group 6	No	**Yes**	No	0.97	2.87	(1.74 – 4.73)
Group 7	No	No	**Yes**	1.46	4.32	(2.69 – 6.96)
Group 8	No	No	No	0.34	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search
** CI - Confidence Interval

Table 3.7.4 Frequency of access to e-mail alerts to new evidence by medical faculty (secondary outcome): estimated mean and relative ratio compared to the no intervention group

	Interventions			**Overall Access to E-mail Alerts**		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ***	**Relative Ratio**	**(95% CI)****
Group 1	**Yes**	**Yes**	**Yes**	9.80	1.24	(1.10 – 1.41)
Group 2	**Yes**	**Yes**	No	20.37	2.59	(2.32 – 2.88)
Group 3	**Yes**	No	**Yes**	15.20	1.93	(1.72 – 2.16)
Group 4	**Yes**	No	No	13.25	1.68	(1.50 – 1.89)
Group 5	No	**Yes**	**Yes**	14.70	1.87	(1.66 – 2.09)
Group 6	No	**Yes**	No	15.89	2.02	(1.80 – 2.26)
Group 7	No	No	**Yes**	16.51	2.10	(1.87 – 2.34)
Group 8	No	No	No	7.88	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search
** CI - Confidence Interval

3.8 FIGURES

Figure 3.8.1 Summary of EBM resources provided in the federated search output of MacPLUS FS

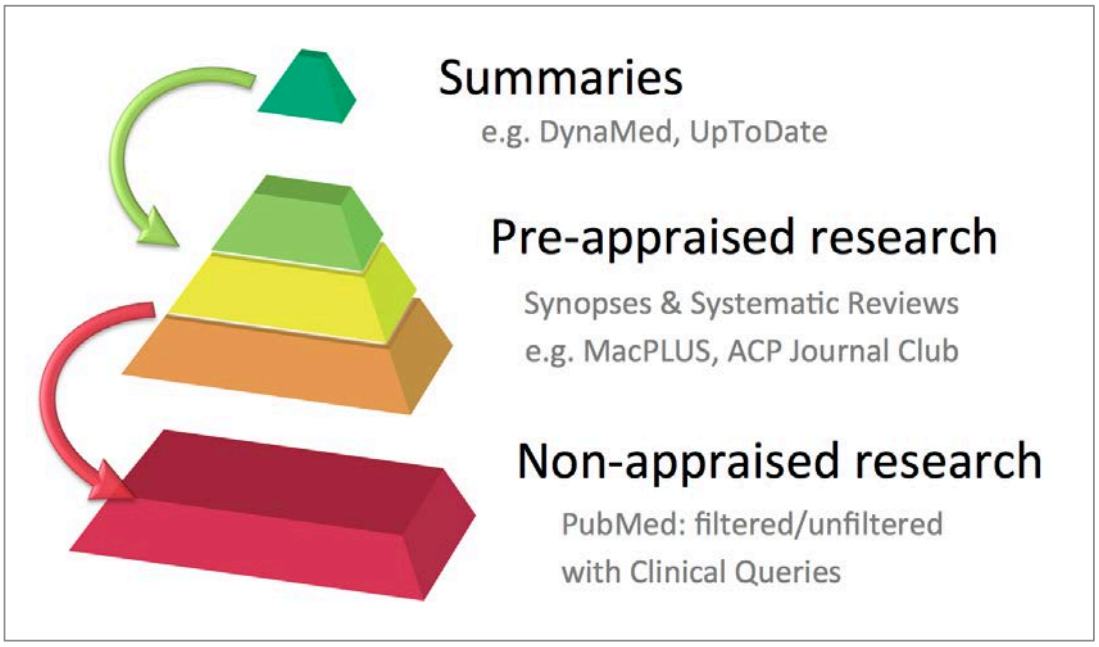
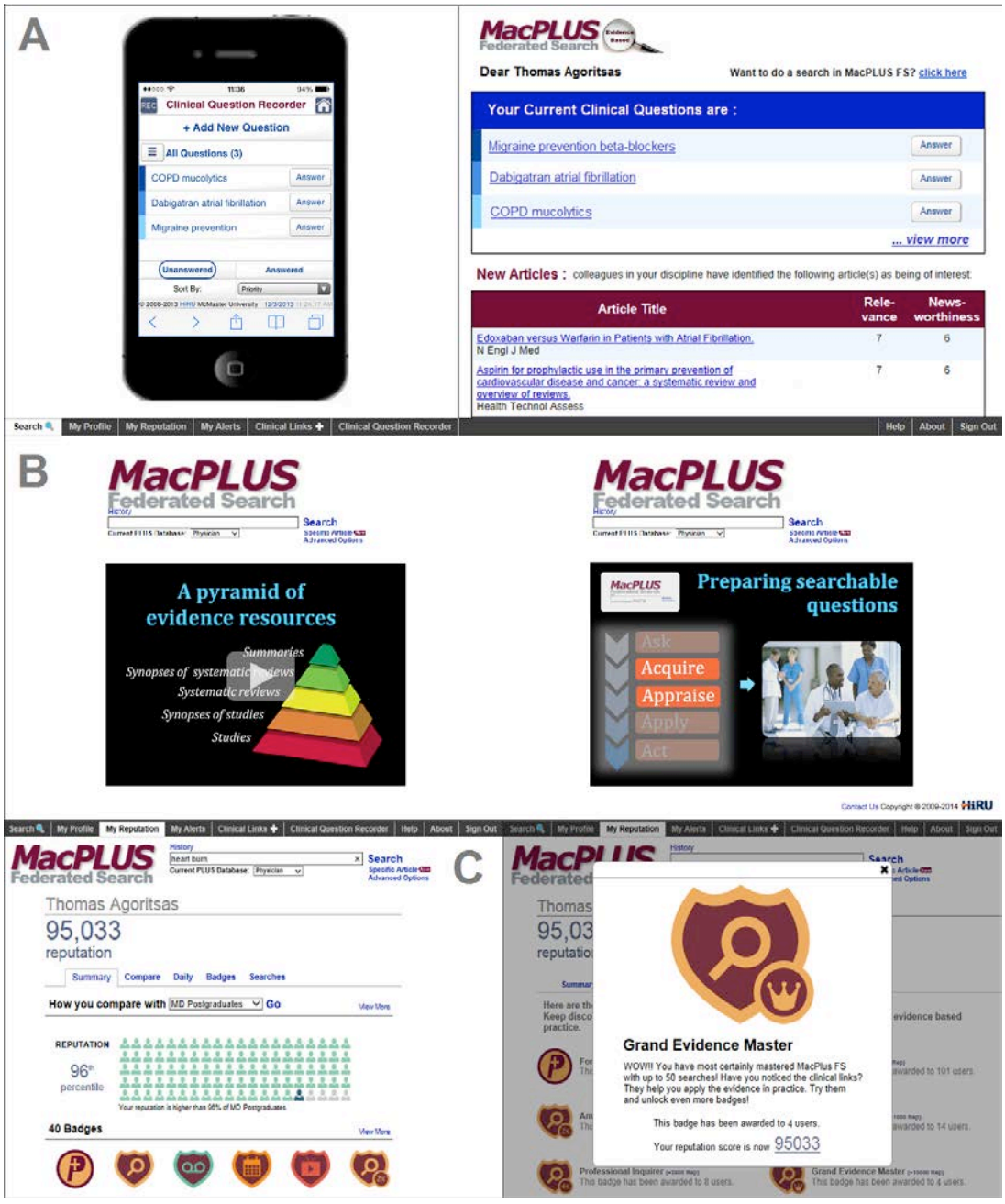
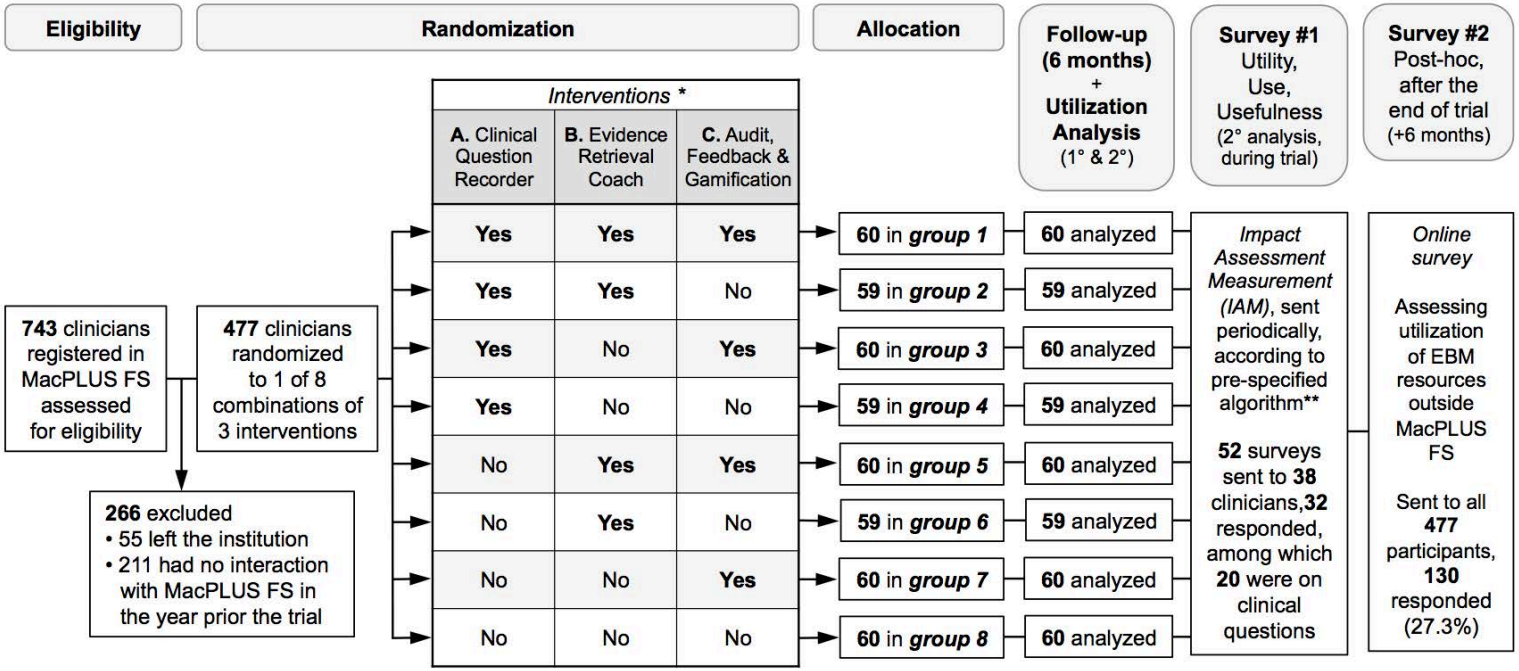


Figure 3.8.2 Illustrations of the three web-based interventions embedded in MacPLUS FS



Legend: (A) Clinical Question Recorder & Reminder; (B) Evidence Retrieval Coach; (C) Audit, Feedback and Gamification.

Figure 3.8.3 Participants flow



* For each intervention, half of the sample is randomized to receiving the intervention [Yes] and the other half to not receiving it [No]. All factorial combinations of the intervention result in 8 allocation groups (2^3=8).

** First invitation sent one month after the participants first online exposure to one or more interventions, with one reminder after 24 hours. Iterative invitation (but always after a two-weeks delay), until one filled questionnaire for clinical question is returned or trial ends.

3.9 AUTHORS' CONTRIBUTIONS, ACKNOWLEDGMENTS & COMPETING INTERESTS

Authors' contribution

Conception of the interventions and study design: TA, with significant contributions from BH, and AI. Specific design of intervention A (*Clinical Question Recorder*): TA and NH. Specific design of intervention B (*Evidence Retrieval Coach*): TA, EI and PR. Specific design of intervention C (*Audit, Feedback & Gamification*): TA, NC. Programming: NH, RP, CC. Data management and monitoring: TA and EI. Statistical analysis: TA and EP. Result interpretation: TA, BH. Draft of the manuscript: TA. Critical revision of the manuscript for important intellectual content: EI, NH, PR, CC, NC, RP, EP, AI and BH. Overall supervision: BH. All authors read and approved the final manuscript. TA had full access to all the data presented in the manuscript and takes responsibility for its integrity and accuracy.

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Competing Interests

The Health Information Research Unit (HiRU), McMaster University, to which many authors are affiliated (TA, EI, NH, CC, RP, AI, and BH), has developed and implemented the MacPLUS Federated Search. The intellectual property belongs to McMaster University, a non-profit publicly funded institution. One of the main missions of HiRU is the development of new information resources to support evidence-based health care, and the evaluation of various innovations in overcoming health care information problems. Its McMaster Premium LiteratUre Service (PLUS) contributes to many other EBM resources worldwide, including: BMJ EvidenceUpdates, ACP Journal Club, ACP Smart Medicine, Best Practice, Clinical Access, Clinical Evidence, DynaMed, e-Therapeutics, Evidence-Based Medicine Reviews (Duodecim), First Consult (Elsevier), Helsebiblioteket (Norway), National Board of Medical Examiners, Stat!Ref (Teton Data Systems), all under contract with McMaster University.

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3.11 APPENDICES

Appendix 3.11.1 Description of the features available in the 3 interventions

A	**Clinical Question Recorder**	Web-based interface, linked to MacPLUS FS account, and accessible on any smartphone, tablet and desktop computer Easy recording and listing of clinical questions Clicking the "Answer" button next to each question triggers a comprehensive search in MacPLUS FS Browsing of citations retrieved according to the pyramid of EBP resources Bookmarking of links to relevant citations, saved along with the question Recording of short answer to the question Organizing of questions: setting priorities, sorting and classifying into folders Reminders and links to unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence Answered questions and bookmarked evidence are saved and accessible in a virtual logbook of EBP
B	**Evidence Retrieval Coach**)	Composed of 8 short videos, embedded in MacPLUS FS Display is tailored to clinician's patterns of behaviors, according to predefined triggers or sent on a weekly basis as the trial unfolds The title of each video [and gist of their content] are the following: 1. MacPLUS FS - Why use it? [Answering questions with information overload] 2. Enhancing Evidence-Based Clinical Practice [Using a parallel search in pre-appraised resources] 3. A pyramid of resources [Overview of the architecture of evidence] 4. Is one summary enough? [Top layers: Summaries] 5. New and critically appraised evidence [Middle layers: Pre-appraised research] 6. PubMed & the Clinical Queries [Bottom layers: Non-pre-appraised research] 7. Preparing searchable questions [Using the PICO framework] 8. Academic work [Using a federated search for presentations, grants and research]

C	***Audit, Feedback & Gamification***	Allocation of badges, popping up online after a specific desired behavior, and also sent by e-mail (about 50 badges available) Each badge is associated with an increase in reputation score, depending on the desirability of the behavior It also provides a short positively-framed feedback on the behavior, the number of time it was allocated to peers, and an upgraded reputation score Clicking on the badges lead to a Reputation tab in MacPLUS FS providing the following features: Comparison of reputation with peers using pictographs (percentiles) List of badges obtained, clicking on them displays the full badge again Graphical representation of daily reputation Frequency of access to each EBP resources and mapping according to the pyramid

Appendix 3.11.2 Characteristics of participants across the 8 allocation groups

	Group 1 A+B+C* (n = 60)	Group 2 A+B* (n = 59)	Group 3 A+C* (n = 60)	Group 4 A* (n = 59)	Group 5 B+C* (n = 60)	Group 6 B* (n = 59)	Group 7 C* (n = 60)	Group 8 No interv. (n = 60)
Specialty type								
Family Medicine	17 (28.3%)	21 (35.6%)	28 (46.7%)	20 (33.9%)	20 (33.3%)	29 (49.2%)	25 (41.7%)	24 (40.0%)
Internal Medicine	11 (18.3%)	12 (20.3%)	6 (10.0%)	7 (11.9%)	11 (18.3%)	4 (6.8%)	10 (16.7%)	5 (8.3%)
Internal Medicine specialities	15 (25.0%)	12 (20.3%)	15 (25.0%)	13 (22.0%)	10 (16.7%)	15 (25.4%)	12 (20.0%)	17 (28.3%)
Pediatrics	3 (5.0%)	3 (5.1%)	4 (6.7%)	5 (8.5%)	6 (10.0%)	2 (3.4%)	2 (3.3%)	4 (6.7%)
Psychiatry	3 (5.0%)	3 (5.1%)	4 (6.7%)	3 (5.1%)	1 (1.7%)	1 (1.7%)	0 (0.0%)	6 (10.0%)
Surgery	4 (6.7%)	5 (8.5%)	1 (1.7%)	5 (8.5%)	8 (13.3%)	6 (10.2%)	5 (8.3%)	1 (1.7%)
Anaesthesiology	0 (0.0%)	2 (3.4%)	1 (1.7%)	4 (6.8%)	4 (6.7%)	1 (1.7%)	2 (3.3%)	1 (1.7%)
Diagnostic services	3 (5.0%)	1 (1.7%)	1 (1.7%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	3 (5.0%)	2 (3.3%)
Other specialties	4 (6.7%)	0 (0.0%)	0 (0.0%)	2 (3.4%)	0 (0.0%)	0 (0.0%)	1 (1.7%)	0 (0.0%)
Baseline search frequency**								
›=1 (Regular&Super-searchers)	3 (5.0%)	4 (6.8%)	5 (8.3%)	5 (8.5%)	3 (5.0%)	1 (1.7%)	4 (6.7%)	3 (5.0%)
< 1 (Occasional-searchers)	8 (13.3%)	6 (10.2%)	12 (20.0%)	8 (13.6%)	8 (13.3%)	9 (15.3%)	11 (18.3%)	11 (18.3%)
0 (Alert-only-users)	49 (81.7%)	49 (83.1%)	43 (71.7%)	46 (78.0%)	49 (81.7%)	49 (83.1%)	45 (75.0%)	46 (76.7%)
Time since last search								
<= 365 days	18 (30.0%)	18 (30.5%)	18 (30.0%)	18 (30.5%)	18 (30%)	18 (30.5%)	18 (30.0%)	19 (31.7%)
> 365 days	42 (70.0%)	41 (69.5%)	42 (70.0%)	41 (69.5%)	42 (70.0%)	41 (69.5%)	42 (70.0%)	41 (68.3%)

* A - Clinical Question Recorder; B - Evidence Retrieval Coach; C - Audit, Feedback & Gamification.
**During the 6 month prior to the trial

Appendix 3.11.3 Distribution of all accesses to EBM resources for all Medical Faculty in the course of the trial

		404 searches
Summaries		**266 (59.1%)**
	DynaMed	52 (11.6%)
	UpToDate	128 (28.4%)
	Best Practice	70 (15.6%)
	ACP PIER	16 (3.6%)
Pre-appraised research		**109 (24.2%)**
	Synopses of systematic reviews	48 (10.7%)
	Systematic reviews	35 (7.8%)
	Synopses of studies	5 (1.1%)
	Studies	21(4.7%)
Non-pre-appraised research		**75 (16.7%)**
	Filtered studies	60 (13.3%)
	Unfiltered studies	15 (3.3%)
Total number of accesses		**450 (100%)**

Appendix 3.11.4 Subgroup analyses on the frequency of searches per Medical Faculty (primary outcome)

Interventions		Super+Regular Searchers (>=1/month) RR (95% CI)*	Occasional Searchers (<1/month) RR (95% CI)*	Alerts-only Users (0/month) RR (95% CI)*
A. Clinical Question Recorder **	Yes	1.03 (0.68-1.54)	1.93 (1.31-2.84)	0.83 (0.62-1.11)
	No	*Reference*	*Reference*	*Reference*
B. Evidence Retrieval Coach§	Yes	0.66 (0.43-1.01)	1.76 (1.22-2.56)	2.16 (1.58-2.94)
	No	*Reference*	*Reference*	*Reference*
C. Audit, Feedback & Gamification¶	Yes	0.65 (0.44-0.97)	1.78 (1.19-2.65)	0.56 (0.42-0.76)
	No	*Reference*	*Reference*	*Reference*

* RR - Relative Ratio; CI - Confidence Interval

** Tests of interaction with Baseline search: p=0.002

§ Tests of interaction with Baseline search: p<0.001

¶ Tests of interaction with Baseline search: p<0.001

Interventions		Internal Medicine RR (95% CI)*	Family Medicine RR (95% CI)*	Other Speciatlites RR (95% CI)*
A. Clinical Question Recorder **	Yes	1.33 (0.83-2.13)	1.35 (0.91-2.00)	1.14 (0.88-1.48)
	No	*Reference*	*Reference*	*Reference*
B. Evidence Retrieval Coach§	Yes	0.40 (0.24-0.65)	0.53 (0.35-0.81)	3.06 (2.27-4.13)
	No	*Reference*	*Reference*	*Reference*
C. Audit, Feedback & Gamification¶	Yes	1.38 (0.86-2.22)	1.00 (0.68-1.48)	0.61 (0.47-0.80)
	No	*Reference*	*Reference*	*Reference*

* RR - Relative Ratio; CI - Confidence Interval

** Tests of interaction with Clinical specialty: p=0.736

§ Tests of interaction with Clinical specialty: p<0.001

¶ Tests of interaction with Clinical specialty: p=0.009

Appendix 3.11.5 Results from the Impact Assessment Measurement (IAM), for all Medical Faculty participating in the trial

		Total n (%)	Clinical Question Recorder			Evidence Retrieval Coach			Audit, Feedback, Gamification		
			Yes	No	*p-value**	Yes	No	*p-value**	Yes	No	*p-value**
UTILITY *Did you find relevant information that partially or completely met your objective?*	Yes	**16 (84%)**	8 (80%)	8 (89%)	*p=0.542*	9 (75%)	7 (100%)	*p=0.227*	9 (75%)	7 (100%)	*p=0.227*
	No	**3 (16%)**	2 (20%)	1 (11%)		3 (25%)	0 (0%)		3 (25%)	0 (0%)	
USE *Did you (will you) use this information for a specific patient?*	Yes, or possibly	**13 (72%)**	6 (67%)	7 (78%)	*p=0.500*	6 (60%)	7 (87%)	*p=0.225*	7 (64%)	6 (86%)	*p=0.324*
	No	**5 (28%)**	3 (33%)	2 (22%)		4 (40%)	2 (13%)		4 (36%)	1 (14%)	
USEFULNESS *For this patient, did you observe (or do you expect) any health benefits as a result of applying this information?*	Yes, or possibly	**6 (67%)**	2 (50%)	4 (80%)	*p=0.405*	1 (33%)	5 (83%)	*p=0.226*	6 (86%)	0 (0%)	*p=0.083*
	No	**3 (33%)**	2 (50%)	1 (20%)		2 (67%)	1 (17%)		1 (14%)	2 (100%)	

**=Fischer's exact test (one-sided)*

Appendix 3.11.6 Results from Survey#2 for Medical Faculty

"During the **last 3 months**, how many times have you searched the following resources **outside MacPLUS FS** for evidence to answer your **clinical questions**?"

EBM Resources (n=130 Faculty)	**> 10 times**	**6-10 times**	**1-5 times**	**Never**
UpToDate	29.2%	15.4%	30.8%	24.6%
DynaMed	8.5%	6.2%	23.8%	61.5%
Best Practice	3.1%	2.3%	12.3%	82.3%
ACP PIER	0%	0%	10.0%	90.0%
Clinical Evidence	1.5%	1.5%	16.9%	80.0%
Micromedex	0.8%	2.3%	6.9%	90.0%
OVID	12.3%	5.4%	21.5%	60.8%
TRIP	1.5%	3.1%	7.7%	87.7%
Epistemonikos	0%	0%	0%	100.0%
SumSearch	0%	0%	0.8%	99.2%
ACP Journal Club	1.5%	3.1%	29.2%	66.2%
Cochrane Library	6.9%	13.8%	49.2%	30.0%
DARE	1.5%	0.8%	7.7%	90.0%
PubMed–using Clinical Queries filters	16.9%	10.0%	31.5%	41.5%
PubMed–without Clinical Queries	19.2%	16.2%	26.9%	37.7%
Google	60.8%	18.5%	16.2%	4.6%
Google Scholar	21.5%	11.5%	24.6%	42.3%
Wikipedia	20.8%	13.8%	37.7%	27.7%
Other EBM-resources:	*19.7%*	*16.7%*	*19.7%*	*43.9%*

- *Summaries (MD consult, eMedicine–Medscape, Essential Evidence Plus, AccessMedicine);*
- *Engines (The FOAM Search Engine – GoogleFOAM);*
- *Drug resources (CADTH, Canada Medication updates, e-Therapeutics)*
- *Institutions' Websites (NICE, Ministry of Health-immunization schedule, Public Health Agency of Canada, Center for Disease Control and Prevention, Canadian Thoracic Society, Canadian Peadiatric Society, Canadian Diabetes Association, Hypertension Canada, Toward Optimized Practice (Alberta), American Family Physician)*
- *Calculators (QxMD)*

Other alert services to new evidence:

Journal Watch, ACP JournalWise / Internist, InfoPOEMs, Trip on Twitter, Dynamed / UpToDate Practice Changing, Highlights from e-Therapeutics, Medscape topic alert, Clinical Key Neurology Alert, Alberta family practice evidence updates, Epocrates, Pubmed (RSS feeds for specific authors), Specific Journals – table of content, search (NEJM, Lancet, JAMA, BMJ, Annals, Circulation, CMAJ, Canadian Family Physician).

CHAPTER 4

Third manuscript

Enhancing the Searching for Current Best Evidence to Answer Clinical Questions by Postgraduate Medical Trainees: Results from the MacPLUS FS Factorial Randomized Controlled Trials

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Tables: 4 / Figures: 3 / Appendices: 6

4.1 ABSTRACT

Background:

Although residents have almost 1 clinical question for each patient they see, they search evidence-based resources in only 20% of the time. No single resource provides all answers or is sufficiently updated. McMaster PLUS – Federated Search addresses this issue by looking in multiple high quality resources simultaneously and displaying results in 1 page, starting with the most clinically relevant.

Objective:

This trial tested 3 web-based interventions addressing logistical and educational barriers through MacPLUS FS, to increase the quantity and quality of searching for current best evidence among postgraduate medical trainees.

Methods:

We conducted a randomized-controlled trial among 431 postgraduate medical trainees currently registered to MacPLUS FS at the hospitals affiliated to the McMaster University Faculty of Health Sciences. Physicians were randomized to each of the 3 following interventions in a factorial design (AxBxC): (A) a web-based Clinical Questions Recorder & Reminder; (B) an Evidence Retrieval Coach composed of 8 short videos embedded in MacPLUS; (C) a Gamified Audit & Feedback based on the allocation of “badges” and “reputation scores”. We

recorded utilization continuously through individual accounts that track logins and use. The primary outcome was the rate of searches/user over 6 months. Secondary outcomes included frequency of access to pre-appraised evidence and to new evidence alerts.

Results:

There was no statistically significant increase of search rates with the Clinical Question Recorder (Relative Ratio [RR] 0.63, 95% Confidence Interval [CI] 0.29–1.25), the Evidence Retrieval Coach (RR 1.25, 95% CI 0.62–2.98), and the Audit, Feedback and Gamification (RR 1.25, 95% CI 0.62–2.98). In contrast, all 3 interventions resulted in a significant increase of accesses to new evidence e-mail alerts, by 14% relative increase for the Recorder (RR 1.14, 95% CI 1.06–1.22), by 20% for Coach (RR 1.20, 95% CI 1.12–1.29), and 48% for the Audit and Feedback (RR 1.48, 95% CI 1.36–1.58).

Conclusion:

Among a large sample of postgraduate medical trainees, 3 web-based interventions failed to increase the quantity and quality of searching for current best evidence to answer clinical questions, but increased access to new evidence alerts.

Trial Registration: ClinicalTrials.Gov NCT02038439

4.2 INTRODUCTION

Postgraduate medical training offers unique opportunities for physicians to learn and practice skills for evidence based practice. Undergraduate learning is often dominated by 'background' questions, as students try to grasp key elements of physiology, pathology, epidemiology, and general management (e.g., "Why does this patient have dyspnea?"; "What treatment options are available?").[1] In contrast, postgraduate trainees gradually turn to more and more 'foreground' questions, related to problem solving and decision-making (i.e., targeted questions of therapy, harm, diagnosis, or prognosis) and raised in caring for specific patients. To answer these questions in particular, physicians must learn how to efficiently find current best evidence.[2]

But this task remains challenging in daily practice.[3] Several Evidence-Based Medicine (EBM) resources identify, appraise, and synthesize current best evidence to help physicians find answers among the very large and ever-growing body of evidence.[3,4] However, each resource offers a scattered and fragmented view of the evidence, and none provides consistent updating[5-7] or comprehensive topic coverage.[8,9] Although residents have almost 1 clinical question for each patient they see, only 20% of their questions are searched in electronic resources.[10] Physicians practicing on their own after finishing their postgraduate training will remain with about 60% of their questions unanswered, and many

answers will not be based on current best evidence.[11-15] As a consequence about 40 to 45% of clinical encounters do not provide appropriate care.[16]

In an attempt to address the structural limitations of evidence retrieval, McMaster University's Health Information Research Unit has developed the MacPLUS Federated Search (MacPLUS FS), which combines the advantages of several EBM resources.[2,3] This online platform combines unique features that help busy clinicians efficiently navigate across multiple top resources in a simultaneous search to rapidly get the best available answers. Results are organized according to the *pyramid of EBM resources*[17], displaying a 1-page output with the most clinically useful results at the top (see Figure 4.8.1). Thus, MacPLUS FS simultaneously retrieves evidence from online *summaries* in the top layers (e.g., DynaMed, UpToDate, Best Practice).[3] If no satisfactory answer is found, clinicians have then access to *pre-appraised research* in the middle layers (i.e., Systematic reviews, Studies and their Synopses when available, selected in McMaster PLUS database for methodological rigor and clinical relevance[18]). Such evidence from PLUS provides new and different conclusions than existing summaries for about 25-50% of clinical topics.[6] Finally, *non-pre-appraised research* from PubMed complements the search at the bottom layers, both with and without the validated "Clinical Queries" filters.[19,20] In addition to the federated search, MacPLUS FS provides users with alerts to new research in their chosen disciplines[21], as well as numerous clinical and EBM practical links.[3]

However, beyond the structural advantages of MacPLUS FS for optimal evidence retrieval, more work is needed to address additional challenges for physicians in training. These include logistical barriers (e.g., time constraints, forgotten questions), as well as educational barriers (e.g., limited searching skills, lack of knowledge and experience of what federated searches can offer, and lack of reference standards for evidence retrieval among peers).[3,22-27]

This randomized trial tested 3 innovative web-based interventions among postgraduate medical trainees registered to MacPLUS FS to help overcome these logistical and educational barriers and thus increase the quantity and quality of searching for current best evidence to answer clinical questions.[3]

4.3 METHODS

4.3.1 STUDY DESIGN

The MacPLUS FS Factorial Randomized Controlled Trials consist of 3 trials, conducted separately in 3 different populations of health care providers registered in MacPLUS FS: (i) medical faculty members, (ii) postgraduates medical trainees (i.e., residents and fellows), (iii) nursing and medical students. Each trial tested the same 3 web-based interventions in a factorial design (AxBxC). We report here the results of the second trial among postgraduate medical trainees.

The study was registered at ClinicalTrials.gov before randomization (NCT02038439), and approved by the Hamilton Integrated Research Ethics Board. Details of the trial objectives, design, and methods were previously published in an open-access protocol [also available in Chapter 2], along with the development and full description of the 3 web-based interventions.[3] We summarize the methods and interventions briefly here.

4.3.2 THE WEB-BASED INTERVENTIONS

In a user-centered approach, we designed 3 interventions based on effective models for the teaching of clinical skills at the point of care, to facilitate using the

search engine as a clinical tool, and to present evidence retrieval skills as true clinical skills:

- Intervention A – Clinical Question Recorder and Reminder
- Intervention B – Evidence Retrieval Coach
- Intervention C – Audit, Feedback and Gamification on searching behaviors

These interventions, embedded in MacPLUS FS, are web-based adaptations of the "One-minute preceptor model" (also known as the "5-step Microskills" [28-32]), tailored to enhance evidence retrieval by identifying searching opportunities, prompting searches to answer clinical questions, providing general knowledge, skills and feedback, and inviting reflective practice. More details on our rationale, theoretical framework and user-centered development are described in our published protocol [3] [see also Chapter 2].

4.3.2.1 Intervention A – Clinical Question Recorder and Reminder

We designed an online platform directly linked to each participant's individual MacPLUS FS account and accessible across a wide range of devices, including smartphones, tablets and computer desktops (see Figure 4.8.2-A). This platform allows participants to: i) record their clinical questions on the fly, at the point of care; ii) easily answer them by triggering full searches in MacPLUS FS, iii) receive periodic reminders of unanswered questions along with evidence alerts, thus providing asynchronous opportunity for evidence retrieval[33]; iv) and keep track of their questions and short evidence-based answers along with

bookmarked citations, in a virtual logbook for reflective practice (see Appendix 4.11.1).

4.3.2.2 Intervention B – Evidence Retrieval Coach

This intervention provides physicians with guidance for evidence retrieval, through 8 short videos (< 90 seconds each), which are both embedded in MacPLUS FS as well as sent via weekly e-mails according to each physician's specific patterns of utilization and search (see Figure 4.8.2-B). The videos provide "small bites" of knowledge and skills on evidence-based practice (e.g., to translate clinical questions to answerable questions), on the "architecture" of evidence (i.e., pyramid of EBM resources), advantages and limits of individual resources, and how MacPLUS FS can help overcome them (see Appendix 4.11.1).

4.3.2.3 Intervention C – Audit, Feedback and Gamification

The purpose of this third intervention is to provide clinicians with timely feedback on their current search utilization compared to their peers. We used a *gamification* approach[34], based on allocation of *badges* (50 in total) popping-up online immediately after a desired searching behavior (e.g., frequency of searches, or access to pre-appraised resources). These badges result in *reputation scores,* which are based on the desirability of the behavior they reinforce, and can be compared to peers on an interactive and playful interface within MacPLUS FS (see Figure 4.8.2-C, & Appendix 4.11.1).

4.3.3 SETTING AND STUDY PARTICIPANTS

We conducted the present trial from January 2014 to June 2014 (6 months duration) in the teaching hospitals and clinics affiliated with McMaster University, Ontario, Canada, which comprises 2 major academic hospital systems, operating 10 hospitals in the Hamilton area, as well as 2 regional campuses in St Catherine and Waterloo, Ontario.

Eligible participants were all postgraduate medical trainees (i.e., residents and clinical fellows) who had registered in MacPLUS FS prior to the trial. Registration and use of MacPLUS FS are free on all campus areas. Physicians were invited to register through e-mail and flyer advertisement on campus, presentations at clinical rounds, and by word of mouth. They provided consent for MacPLUS FS' evaluation upon registration. Of the 678 postgraduate trainees registered by January 2014, 431 were deemed eligible for the trial (see Figure 4.8.3), after exclusion of 53 who were no longer working in the institutions and 194 who never interacted with MacPLUS FS during the prior year (either by logging in to read e-mail evidence alerts or to perform a search) and thus had almost no chance of being exposed to the web-based interventions.

4.3.4 RANDOMIZATION, CONCEALMENT & BLINDING

The trial was coordinated from the Health Information Research Unit at McMaster University, which designed and hosts MacPLUS FS. At the start of the trial, the independent programmer, in charge of MacPLUS FS administration, randomized

all the 431 eligible postgraduate trainees to the 3 web-based interventions through their individual account, using a computer-based random number generator (thus ensuring concealment of randomization). In a factorial design (AxBxC), half of the participants were randomly allocated to each intervention, with all possible permutations resulting in 8 factorial groups (2^3=8 groups – see Figure 4.8.3). Randomization was balanced on blocks of 16 within each stratum (=2 x 8) and further stratified according to time since last search in MacPLUS FS (<= 365 days vs. >365 days, the latter only logged in to read e-mail evidence alerts). The programmer maintained a secure master list of the randomization codes; the analyst was blind to allocation.

Although participants could not be blinded to the interventions, they were not informed of the different interventions being offered, and all participants, including the no intervention group, were exposed to new minor features in MacPLUS FS presentation and navigation 1 month prior to the beginning of the trial.[3]

4.3.5 OUTCOME MEASURES

The primary outcome of interest was *utilization* of MacPLUS FS to search for evidence over the 6 months duration of the trial (i.e., not counting logins via e-mail new evidence alerts or to access other resources). We also assessed 2 secondary *utilization* outcomes to capture the quality of the searches and MacPLUS FS use. First, we measured frequency of access to higher levels of evidence – i.e., summing the accesses to online summaries (e.g., DynaMed,

UpToDate, Best Practice), as well as individual pre-appraised research articles (systematic reviews, synopses of studies or reviews). Second, we recorded the frequency of accesses to new evidence email alerts, independently of searching. All utilization outcomes were automatically and continuously recorded over the duration of the trial, as participants were signed on through their individual user account that tracked down to individual keystrokes.

The trial included 2 additional surveys. The first survey was an adapted version of the Impact Assessment Method (IAM)[35-38], which assesses the *utility* of the evidence retrieved (meeting users' information needs), its *use* (application in practice), and its perceived *usefulness* for a specific patient's care and outcomes. We sent periodic online IAM questionnaires by e-mail according to an automatic algorithm built into MacPLUS FS. The first invitation was sent out 1 month after the participant's first online exposure the intervention(s), with 1 reminder after 24 hours. The next invitation was sent following the next search, but after a 2 weeks delay, repeating this process until the return of 1 filled questionnaire for a clinical question or the trial's end. We sent the second post hoc survey by e-mail after the end of the trial (with up to 3 reminders), to inquire about the resources users typically search outside MacPLUS FS in their practice.

4.3.6 STATISTICAL ANALYSIS

Following our protocol[3], we tested 3 primary hypotheses: whether the Clinical Question Recorder (A) is more effective than the control; whether the Evidence

Retrieval Coach (B) is more effective than the control; and whether Audit, Feedback and Gamification (C) is more effective than the control. We powered the trial to test each of these hypotheses separately at the margins (half of the sample compared to the other half).

After ensuring there was no statistically significant interaction, we regressed the number of searches over the trial's 6-month time period for each participant onto dummy variables for each intervention, controlling for time since last search at baseline (i.e., the stratifying variable). We used marginal models, applying generalized estimating equations (GEE) with Poisson distribution and a log link function. These analyses provided relative ratio estimates, which can be interpreted as the multiplicative factor of search rates with each intervention compared to rates without that intervention. We repeated the same analysis with the 2 secondary utilization outcomes: frequency of access to pre-appraised resources, and access to new evidence alerts.

For the primary outcome, we also conducted our 2 predefined subgroup analyses[3], to explore whether the interventions' effects on searching would differ according to baseline frequency (i.e., 6 months prior to the trial), and to specialty type (internal medicine vs. family medicine vs. other specialties). In a longitudinal analysis, we explored whether each intervention's effect varied across time during the course of the trial.[3] Finally, we analyzed the 2 surveys, comparing the distribution of answers using chi-squared tests. We performed all analyses using SPSS 22.0.0.1 software.

4.4 RESULTS

4.4.1 PARTICIPANTS FLOW AND CHARACTERISTICS

In January 2014, 431 postgraduate medical trainees were randomized to the 8 allocation groups (53-55 participants per group), with half the sample allocated to each intervention in a factorial design (see Figure 4.8.3). All were followed-up for primary and secondary utilization outcomes over the 6 months of the trial. The sample included a wide array of specialties, with about 25% training in family medicine, 19% in internal medicine and 18% in internal medicine subspecialties, (see Table 4.7.1). During the 6 months prior to the trial, about 67% of eligible users interacted with MacPLUS FS only through e-mail alerts, while 21% were occasional-searchers (average < 1/month) and 12% were regular or 'super-' searchers (average >= 1/month). This corresponded to a time since last search of more than 1 year for 62% of participants. All baseline variables showed similar distributions across the 8 allocation groups (see Appendix 4.11.2).

4.4.2 PRIMARY OUTCOME: SEARCH UTILIZATION

Postgraduate trainees performed in total 681 searches. The frequency of searches per user remained low during the course of the trial, and none of the 3 web-based interventions resulted in significant changes (see Table 4.7.2). With the Clinical Question Recorder (Intervention A), individual participants searched

on average 1.07 times, compared to 1.71 without the intervention. This corresponded to a non-significant Relative Ratio (RR) of 0.63, 95% Confidence Interval (CI) from 0.29 to 1.25. With the Evidence Retrieval Coach (Intervention B), physicians searched on average 1.51 times, compared to 1.21 without the intervention – RR 1.25 (95% CI 0.62 to 2.98). Finally with the Audit, Feedback and Gamification (Intervention C), the mean number of searches per user was 1.00, compared to 1.83 without the intervention – RR 0.55 (95% CI 0.25 to 1.09). The effect of each intervention did not significantly vary according to baseline frequency of search or specialty types, which were our 2 pre-specified subgroup analyses (see Appendix 4.11.3).

In longitudinal analysis, searches were higher in month 1 than in other months, across all allocation groups. However, there was a statistically significant interaction between time and the intervention of Audit, Feedback and Gamification (month 1 vs. months 2-6, p=0.005), such that there was a non-significant positive effect of this intervention in the first month, which became a statistically significant negative effect in subsequent months (61% decrease in rate of searching, 95% CI 12% to 83%).

4.4.2 SECONDARY UTILIZATION OUTCOMES

As for search rates, there were no statistically significant changes in the frequency of access for pre-appraised resources across interventions (see Table 4.7.3). However, postgraduate medical trainees accessed 569 resources and

individual citations during the course of the trial. They used the whole range offered in the federated search engine (see Appendix 4.11.4). About 36% of accessed resources were *Summaries* (UpToDate in 11% and DynaMed in 12%), 28% where individual *Pre-appraised research* (e.g., 6% of Synopsis of systematic reviews, and 14% of Synopsis of individual studies), while *Non Pre-appraised research* was accessed in 36% of the times (most of the times using clinical queries filters automatically added to PubMed search queries).

In contrast to searching, all 3 interventions resulted in a statistically significant increase in access to new evidence alerts (see Table 4.7.4). With the Clinical Question Recorder (Intervention A), trainees accessed on average 8.14 evidence alerts, compared to 7.15 without the intervention, corresponding to at 14% relative increase (RR 1.14, 95% CI 1.06 to 1.22). With the Evidence Retrieval Coach (Intervention B), the mean number of alerts access was 8.37, compared to 6.95 without the intervention – corresponding to a 20% relative increase (RR 1.20, 95% CI 1.12 to 1.29). Finally with the Audit, Feedback and Gamification (Intervention C), trainees accessed on average 9.27 alerts, compared to 6.28 without the intervention, corresponding to at 48% relative increase (RR 1.48, 95% CI 1.36 to 1.58).

4.4.3 RESULTS FROM THE SURVEYS

Due to the overall frequency of searches, our automatic algorithm sent only 48 IAM-questionnaires to 34 participants during the trial. Despite a 91% (31/34)

response rate, only 7% of all participants ended up being surveyed, which was insufficient to assess the interventions' effects. Among 10 participants reporting on a clinical question for an actual patient, the answer retrieved was associated with a 70% utility, 86% use in practice, and 100% perceived usefulness on patient outcomes (see Appendix 4.11.5).

Seventy-four participants (17.2%) answered the post-trial survey. There was a statistically significant difference in search rates between respondents and non-respondents (respectively 3.18 vs. 1.26). Among those who responded, 97% reported having searched for answers outside of MacPLUS FS more than 5 times in the last 3 months. This was largely dominated by Google-related searches in 89%, followed by summaries (e.g., UpToDate or DynaMed) accessed outside of MacPLUS by 82% of respondents, as well as PubMed by 57% of respondents (see Appendix 4.11.6).

4.5 DISCUSSION

Among a large sample of postgraduate medical trainees, 3 web-based interventions, based on effective models for the teaching of clinical skills at the point of care, failed to increase the quantity and quality of searching for current best evidence to answer clinical questions. One of the interventions – Audit, Feedback and Gamification – showed evidence of a transitory non-significant positive effect during the first month but a 61% decrease in searching rates during the subsequent 5 months of the trial. In contrast, all 3 interventions resulted in a significant increase of accesses to new evidence e-mail alerts, by 14% relative increase for the Clinical Question Recorder, 20% for the Evidence Retrieval Coach, and 48% for the Audit, Feedback and Gamification. Finally, there was evidence that postgraduate trainees often sought answers using Google, Wikipedia, and also summary resources and PubMed outside of MacPLUS FS.

These findings contrast sharply with the results from the separate trial we conducted among medical faculty[3], for whom the same interventions resulted in a significant 2 to 4-fold increase in search frequency and increase access to pre-appraised resources (see Chapter 3). Why did postgraduate medical trainees differ in their responsiveness to our interventions? First, residents may find it more convenient to ask their question to clinical supervisors and colleagues, and thus remain insensitive to the interventions. A cohort study among urban family

medicine teaching clinics showed that residents sought answers using colleagues for 66% of their questions – of whom 94% were preceptors – while accessing electronic resources only 21% of the time.[10] An EBM workshop training did not influence their behavior, but those working in semi-independent clinics (i.e., with less supervision from preceptors) used electronic resources more often, searching 51% of their questions.[10] More generally, their self-perceived identity as a medical trainee could also play a role in seeking behaviors. Residents may feel that it is not their direct role to check the evidence firsthand, but rather their role is keeping up with clinical workflow while their attending staff would be ultimately in charge of important clinical decision-making.

Alternatively, our interventions could simply have failed to convey the structural advantages of evidence retrieval using MacPLUS FS. Considerable effort was made to optimize the trial interfaces before their launch through iterative user-testing, in-house usability and beta testing.[3] However, this may not have been enough to accommodate the constraints of residents' busy clinical activity. The initial increase, yet followed by a decrease in searching rates with the Audit, Feedback and Gamification, suggests that some participants could have even been annoyed by the regular allocations of badges and online prompts to search more and better. Our post-hoc survey also suggests that participants accessed many resources outside of MacPLUS FS. This concurs with previous findings showing that, compared to practicing physicians, those in training had a more

frequent use of background resources like Wikipedia or other websites suggested by colleagues.[39]

Contrasting with the lack of effectiveness in searching, the web-based intervention did increase the access to evidence alerts, which also started at higher baseline rates (ranging from 6.28 to 7.15 per user) than searching rates (ranging from 1.21 to 1.83 per user). Staying alert to new evidence may be a more dominant way to interact with evidence at this stage of physicians' training. Rather than answering specific questions with available evidence, they pursue the questions: "What important new evidence should I know to optimally treat patients?" Clinicians traditionally addressed this question by attending conferences and rounds, or browsing the content of target journals.[1] However, the new evidence e-mail alerts, selected in McMaster PLUS pre-appraised database for methodological rigor and clinical relevance, offer an efficient alternative for staying up-to-date.[18,21] Indeed, more than 65,000 clinicians currently use this service worldwide, as the same content is disseminated by the widely accessed BMJ EvidenceUpdates.[40]

Several limitations of our investigation should be borne in mind. Although this is 1 of the largest trials to date on evidence retrieval among medical postgraduate trainees, and although it was sufficiently powered to detect meaningful differences (see Chapter 2)[3], our findings are not necessarily generalizable to other contexts, with different clinical constraints, degree of supervision, or educational incentives.[10] Similarly, results may not directly translate to other

federated search engines.[2] Second, although participants used the whole range or EBM resources offered in the federated search engine (see Appendix 4.11.4), they frequently sought answers outside of MacPLUS FS too (see Appendix 4.11.6) and we could not know whether the interventions had any impact on these searches. Third, despite a response rate of 91% to the Impact Assessment Method survey[36-38], few participants actually provided data on the utility, use and perceived usefulness of the evidence retrieved. This is in part due to the low absolute frequency of searches and the automatic algorithm designed not to overload participants with a questionnaire after each search. The implications to the present trial are limited, given the absence of effect observed on utilization rates, but it highlights the challenges for future studies assessing similar outcome measurements at the level of each participant.

4.6 CONCLUSION AND FUTURE PROSPECTS

Several avenues for research remain in order to enhance searching for postgraduate trainees. First, the intensity and modalities of the interventions could be further tailored to their information needs and context. Focus groups among practicing clinicians have identified features that influence the selection and use of knowledge resources and that could be optimized through the federated search engine.[27,41] These include, for example: more help with formulating a clinical question[2], better integration with the workflow and baseline

patterns of searching[3], or tools to support patient education and shared decision making.[42] Second, features of social media could be built into the search engine to increase physicians awareness of peer standards for evidence retrieval.[43] In a systematic review of Audit and Feedback, the impact on compliance with a desired practice was stronger when the source was a supervisor or a colleague.[44] Social media through MacPLUS FS could build communities of trainees – in a given care unit, department, or institution – and provide innovative ways for clinical preceptors to give feedback and act as role models in evidence retrieval. Furthermore, educational prescriptions, sent through federated searching platforms, could mobilize self-directing learning and work as continuous medical education incentives.[4,45]

It is essential to keep exploring such educational innovations, in order to enhance physicians' skills and ease with efficient evidence retrieval, and thus increase the likelihood that their subsequent clinical encounters are informed by current best evidence, rather than commonly used but less trustworthy sources.[15,16]

4.7 TABLES

Table 4.7.1 Characteristics of participating postgraduate medical trainees registered in MacPLUS FS

	Any Intervention (n = 378*)	No Intervention (n = 53**)	Total (n = 431)
Specialty type			
Family Medicine	98 (25.9%)	9 (17.0%)	107 (24.8%)
Internal Medicine	69 (18.3%)	13 (24.5%)	82 (19.0%)
Internal Medicine specialities	70 (18.5%)	6 (11.3%)	76 (17.6%)
Pediatrics	36 (9.5%)	8 (15.1%)	44 (10.2%)
Psychiatry	19 (5.0%)	5 (9.4%)	24 (5.6%)
Surgery	44 (11.6%)	7 (13.2%)	51 (11.8%)
Anaesthesiology	13 (3.4%)	1 (1.9%)	14 (3.2%)
Diagnostic services	4 (1.1%)	1 (1.9%)	5 (1.2%)
Other specialties	25 (6.6%)	3 (5.7%)	28 (6.5%)
Baseline average search frequency[§]			
>=1/month (Regular & Super-searchers)	46 (12.2%)	8 (15.1%)	54 (12.5%)
< 1/month (Occasional-searchers)	77 (20.4%)	12 (22.6%)	89 (20.6%)
0 (Alert-only-users)	255 (67.5%)	33 (62.3%)	288 (66.8%)
Time since last search			
<= 365 days	145 (38.4%)	20 (37.7%)	165 (38.3%)
> 365 days	233 (61.6%)	33 (62.3%)	266 (61.7%)

* Combining physicians randomized to at least 1 of the 3 interventions, i.e., group 1 to 7 (see Figure 1)
** Physicians randomized to none of the 3 interventions, i.e., group 8 (see Figure 1)
[§] Average rates during the 6 months prior to the trial

Table 4.7.2 Frequency of searches by postgraduate trainees (primary outcome): estimated mean and relative ratio compared to the no intervention group

Interventions		Estimated mean*	Relative Ratio	(95% CI)**
A. Clinical Question Recorder	Yes	1.07	0.63	(0.29 – 1.25)
	No	1.71	*Reference*	
B. Evidence Retrieval Coach	Yes	1.51	1.25	(0.62 – 2.98)
	No	1.21	*Reference*	
C. Audit,Feedback & Gamification	Yes	1.00	0.55	(0.25 – 1.09)
	No	1.83	*Reference*	

* Mean frequency of searches/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

Table 4.7.3 Frequency of access to pre-appraised resources by postgraduate trainees (secondary outcome): estimate mean and relative ratio of access compared to the no intervention group

Interventions		Estimated mean*	Relative Ratio	(95% CI)**
A. Clinical Question Recorder	Yes	0.57	0.68	(0.35 – 1.31)
	No	0.84	*Reference*	
B. Evidence Retrieval Coach	Yes	0.68	0.97	(0.47 – 1.89)
	No	0.70	*Reference*	
C. Audit,Feedback & Gamification	Yes	0.55	0.64	(0.33 – 1.25)
	No	0.86	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

Table 4.7.4 Frequency of access to e-mail alerts to new evidence by postgraduate trainees (secondary outcome): estimated mean and relative ratio compared to the no intervention group

Interventions		Estimated mean*	Relative Ratio	(95% CI)**
A. Clinical Question Recorder	Yes	8.14	1.14	(1.06 – 1.22)
	No	7.15	*Reference*	
B. Evidence Retrieval Coach	Yes	8.37	1.20	(1.12 – 1.29)
	No	6.95	*Reference*	
C. Audit,Feedback & Gamification	Yes	9.27	1.48	(1.38 – 1.58)
	No	6.28	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

4.8 FIGURES

Figure 4.8.1 Summary of EBM resources provided in the federated search output of MacPLUS FS

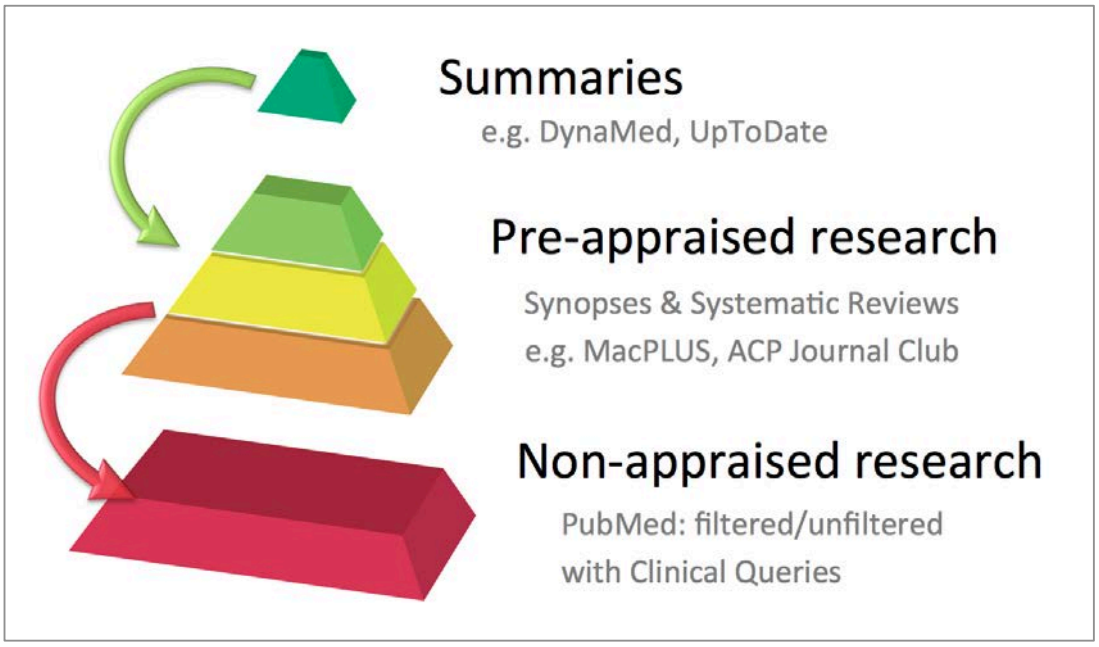
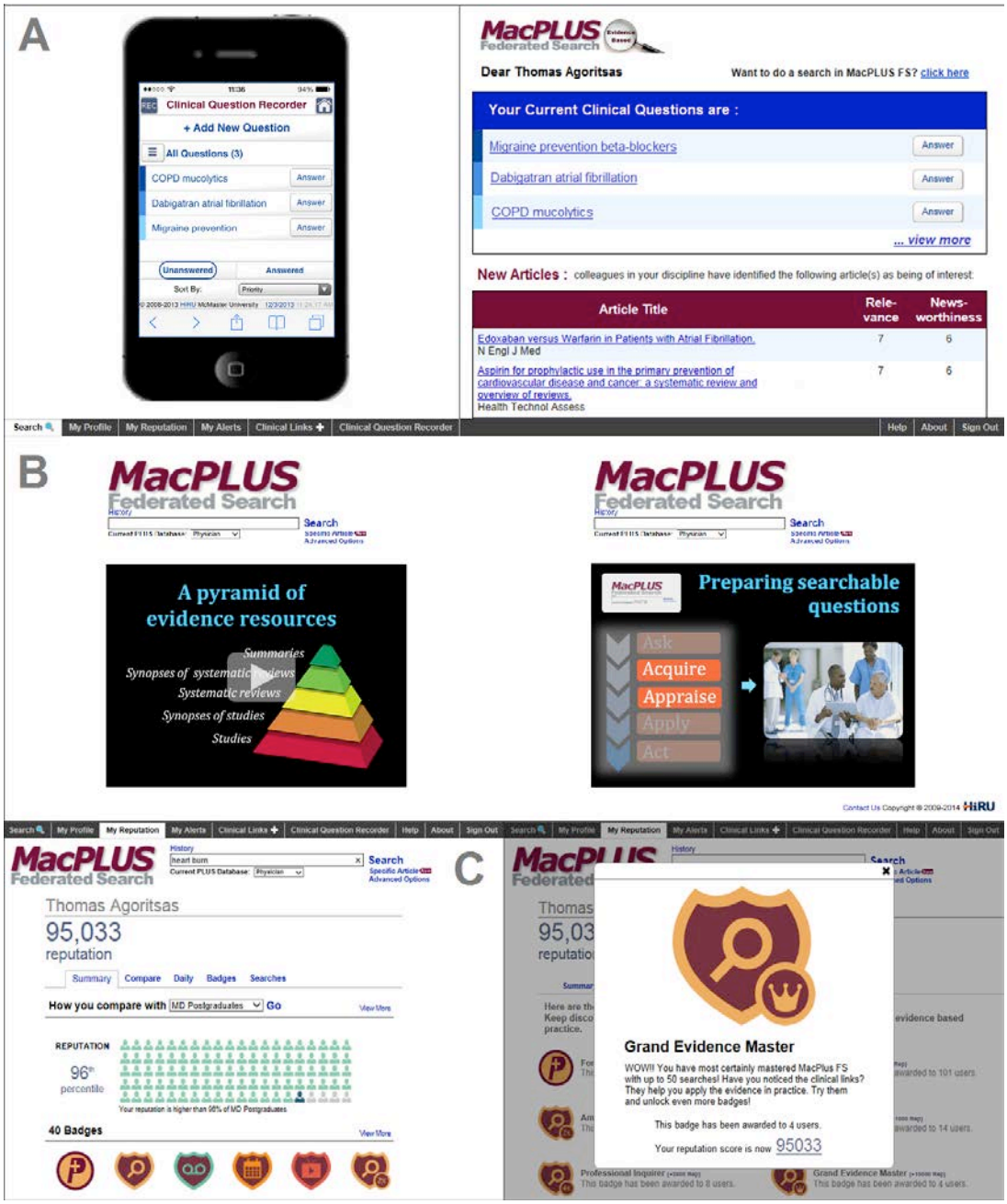
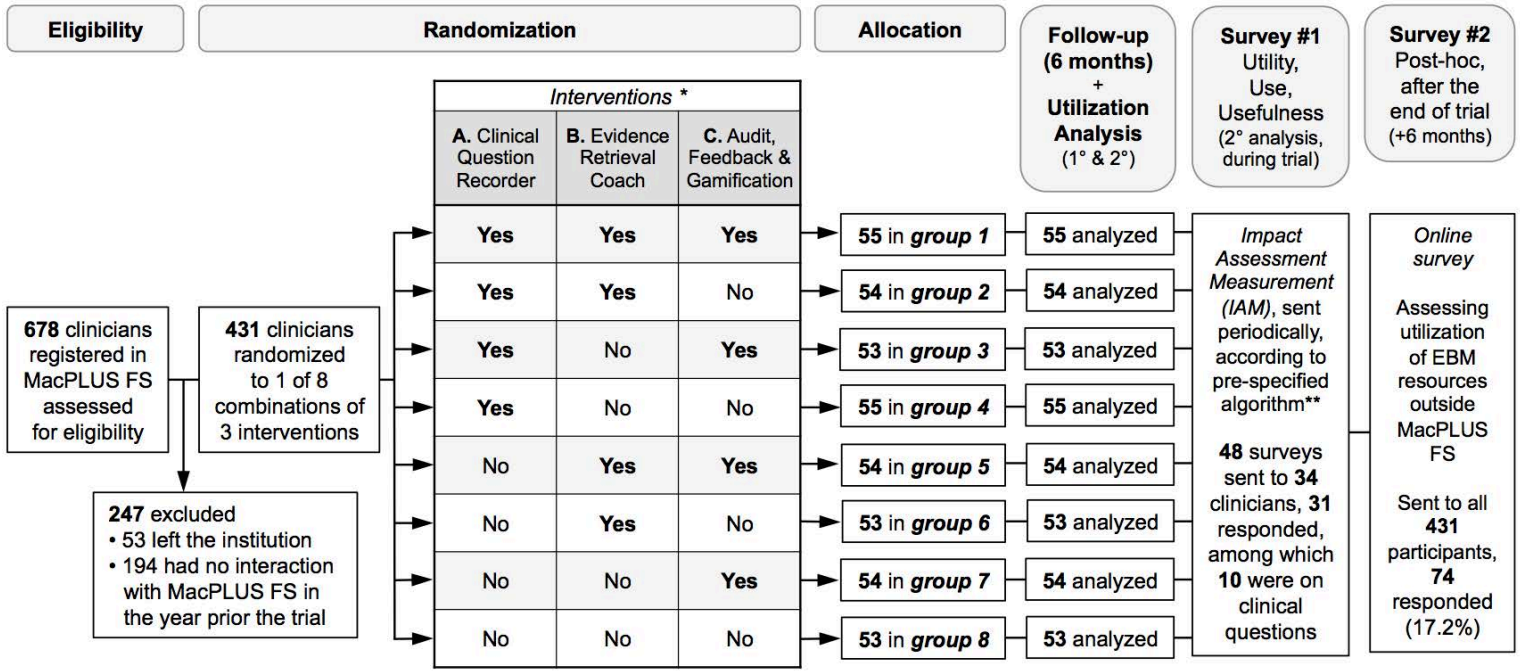


Figure 4.8.2 Illustrations of the 3 web-based interventions embedded in MacPLUS FS



Legend: (A) Clinical Question Recorder & Reminder; (B) Evidence Retrieval Coach; (C) Audit, Feedback and Gamification.

Figure 4.8.3 Participants flow



* For each intervention, half of the sample is randomized to receiving the intervention [Yes] and the other half to not receiving it [No]. All factorial combinations of the intervention result in 8 allocation groups (2^3=8).

** First invitation sent one month after the participants first online exposure to one or more interventions, with one reminder after 24 hours. Iterative invitations (but always after a two-weeks delay), until one filled questionnaire for clinical question is returned or trial end.

4.9 AUTHORS' CONTRIBUTIONS, ACKNOWLEDGMENTS & COMPETING INTERESTS

Authors' contribution

Conception of the interventions and study design: TA, with significant contributions from BH, and AI. Specific design of intervention A (*Clinical Question Recorder*): TA and NH. Specific design of intervention B (*Evidence Retrieval Coach*): TA, EI and PR. Specific design of intervention C (*Audit, Feedback & Gamification*): TA, NC. Programming: NH, RP, CC. Data management and monitoring: TA and EI. Statistical analysis: TA and EP. Result interpretation: TA, BH. Draft of the manuscript: TA. Critical revision of the manuscript for important intellectual content: EI, NH, PR, CC, NC, RP, EP, AI and BH. Overall supervision: BH. All authors read and approved the final manuscript. TA had full access to all the data presented in the manuscript and takes responsibility for its integrity and accuracy.

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Competing Interests

The Health Information Research Unit (HiRU), McMaster University, to which many authors are affiliated (TA, EI, NH, CC, RP, AI, and BH), has developed and implemented the MacPLUS Federated Search. The intellectual property belongs to McMaster University, a non-profit publicly funded institution. One of the main missions of HiRU is the development of new information resources to support evidence-based health care, and the evaluation of various innovations in overcoming health care information problems. Its McMaster Premium LiteratUre Service (PLUS) contributes to many other EBM resources worldwide, including: BMJ EvidenceUpdates, ACP Journal Club, ACP Smart Medicine, Best Practice, Clinical Access, Clinical Evidence, DynaMed, e-Therapeutics, Evidence-Based Medicine Reviews (Duodecim), First Consult (Elsevier), Helsebiblioteket (Norway), National Board of Medical Examiners, Stat!Ref (Teton Data Systems), all under contract with McMaster University.

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4.11 APPENDICES

Appendix 4.11.1 Description of the features available in the 3 interventions

A	**Clinical Question Recorder**	Web-based interface, linked to MacPLUS FS account, and accessible on any smartphone, tablet and desktop computer Easy recording and listing of clinical questions Clicking the "Answer" button next to each question triggers a comprehensive search in MacPLUS FS Browsing of citations retrieved according to the pyramid of EBP resources Bookmarking of links to relevant citations, saved along with the question Recording of short answer to the question Organizing of questions: setting priorities, sorting and classifying into folders Reminders and links to unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence Answered questions and bookmarked evidence are saved and accessible in a virtual logbook of EBP
B	**Evidence Retrieval Coach**)	Composed of 8 short videos, embedded in MacPLUS FS Display is tailored to clinician's patterns of behaviors, according to predefined triggers or sent on a weekly basis as the trial unfolds The title of each video [and gist of their content] are the following: 1. MacPLUS FS - Why use it? [Answering questions with information overload] 2. Enhancing Evidence-Based Clinical Practice [Using a parallel search in pre-appraised resources] 3. A pyramid of resources [Overview of the architecture of evidence] 4. Is one summary enough? [Top layers: Summaries] 5. New and critically appraised evidence [Middle layers: Pre-appraised research] 6. PubMed & the Clinical Queries [Bottom layers: Non-pre-appraised research] 7. Preparing searchable questions [Using the PICO framework] 8. Academic work [Using a federated search for presentations, grants and research]

C	***Audit, Feedback & Gamification***	Allocation of badges, popping up online after a specific desired behavior, and also sent by e-mail (about 50 badges available) Each badge is associated with an increase in reputation score, depending on the desirability of the behavior It also provides a short positively-framed feedback on the behavior, the number of time it was allocated to peers, and an upgraded reputation score Clicking on the badges lead to a Reputation tab in MacPLUS FS providing the following features: Comparison of reputation with peers using pictographs (percentiles) List of badges obtained, clicking on them displays the full badge again Graphical representation of daily reputation Frequency of access to each EBP resources and mapping according to the pyramid

Appendix 4.11.2 Characteristics of participants across the 8 allocation groups

	Group 1 A+B+C* (n = 55)	Group 2 A+B* (n = 54)	Group 3 A+C* (n = 53)	Group 4 A* (n = 55)	Group 5 B+C* (n = 54)	Group 6 B* (n = 53)	Group 7 C* (n = 54)	Group 8 No interv. (n = 53)
Specialty type								
Family Medicine	17 (30.9%)	15 (27.8%)	16 (30.2%)	9 (16.4%)	18 (33.3%)	15 (28.3%)	8 (14.8%)	9 (17.0%)
Internal Medicine	16 (29.1%)	10 (18.5%)	10 (18.9%)	11 (20.0%)	7 (13.0%)	7 (13.2%)	8 (14.8%)	13 (24.5%)
Internal Medicine specialities	4 (7.3%)	14 (25.9%)	7 (18.9%)	14 (25.5%)	8 (14.8%)	10 (18.9%)	13 (24.1%)	6 (11.3%)
Pediatrics	6 (10.9%)	2 (3.7%)	6 (11.3%)	5 (9.1%)	6 (11.1%)	6 (11.3%)	5 (9.3%)	8 (15.1%)
Psychiatry	3 (5.5%)	2 (3.7%)	3 (5.7%)	3 (5.5%)	3 (5.6%)	4 (7.5%)	1 (1.9%)	5 (9.4%)
Surgery	3 (5.5%)	4 (7.4%)	5 (5.7%)	7 (12.7%)	7 (13.0%)	8 (15.1%)	10 (18.5%)	7 (13.2%)
Anaesthesiology	3 (5.5%)	2 (3.7%)	1 (1.9%)	2 (3.6%)	1 (1.9%)	3 (5.7%)	1 (1.9%)	1 (1.9%)
Diagnostic services	0 (0%)	0 (0%)	0 (0%)	1 (1.8%)	1 (1.9%)	0 (0%)	2 (3.7%)	1 (1.9%)
Other specialties	3 (5.5%)	5 (9.3%)	5 (9.4%)	3 (5.5%)	3 (5.6%)	0 (0%)	6 (11.1%)	3 (5.7%)
Baseline search frequency**								
>=1(Regular & Super-searchers)	6 (10.9%)	7 (13.0%)	6 (11.3%)	6 (10.9%)	7 (13.0%)	4 (7.5%)	10 (18.5%)	8 (15.1%)
< 1 (Occasional-searchers)	10 (18.2%)	11 (20.4%)	13 (24.5%)	11 (20.0%)	10 (18.5%)	14 (26.4%)	8 (14.8%)	12 (22.6%)
0 (Alert-only-users)	39 (70.9%)	36 (66.7%)	34 (64.2%)	38 (69.1%)	37 (68.5%)	35 (66.0%)	36 (66.7%)	33 (62.3%)
Time since last search								
<= 365 days	21 (38.2%)	20 (37.0%)	20 (37.7%)	21 (38.2%)	22 (40.7%)	19 (35.8%)	22 (40.7%)	20 (37.7%)
> 365 days	34 (61.8%)	34 (63.0%)	33 (62.3%)	34 (61.8%)	32 (59.3%)	34 (64.2%)	32 (59.3%)	33 (62.3%)

* A - Clinical Question Recorder; B - Evidence Retrieval Coach; C - Audit, Feedback & Gamification.
** During the 6 month prior to the trial

Appendix 4.11.3 Subgroup analyses on the frequency of searches per Postgraduate Trainee (primary outcome)

Interventions		Super+Regular Searchers (>=1/month) RR	(95% CI)*	Occasional Searchers (<1/month) RR	(95% CI)*	Alerts-only Users (0/month) RR	(95% CI)*
A. Clinical Question Recorder **	Yes	1.00	(0.36-2.43)	0.81	(0.23-2.80)	0.31	(0.09-3.03)
	No	*Reference*		*Reference*		*Reference*	
B. Evidence Retrieval Coach§	Yes	1.01	(0.31-2.65)	0.80	(0.15-1.99)	3.13	(0.63-8.96)
	No	*Reference*		*Reference*		*Reference*	
C. Audit, Feedback & Gamification¶	Yes	0.77	(0.23-1.77)	0.48	(0.19-1.81)	0.36	(0.10-3.44)
	No	*Reference*		*Reference*		*Reference*	

* RR - Relative Ratio; CI - Confidence Interval

** Tests of interaction with Baseline search: p=0.213

§ Tests of interaction with Baseline search: p=0.219

¶ Tests of interaction with Baseline search: p=0.449

Interventions		Internal Medicine RR	(95% CI)*	Family Medicine RR	(95% CI)*	Other Speciatlites RR	(95% CI)*
A. Clinical Question Recorder **	Yes	0.46	(0.11-1.87)	1.81	(0.40-38.05)	0.32	(0.08-1.37)
	No	*Reference*		*Reference*		*Reference*	
B. Evidence Retrieval Coach§	Yes	1.07	(0.23-3.49)	1.05	(0.26-3.26)	1.70	(0.48-3.87)
	No	*Reference*		*Reference*		*Reference*	
C. Audit, Feedback & Gamification¶	Yes	0.26	(0.01-0.85)	1.51	(0.42-7.13)	0.33	(0.12-1.32)
	No	*Reference*		*Reference*		*Reference*	

* RR - Relative Ratio; CI - Confidence Interval

** Tests of interaction with Clinical specialty: p=0.645

§ Tests of interaction with Clinical specialty: p=0.654

¶ Tests of interaction with Clinical specialty: p=0.721

Appendix 4.11.4 Distribution of all accesses to EBM resources for all Postgraduate Trainees in the course of the trial

	681 searches
Summaries	**207 (36.4%)**
DynaMed	66 (11.6%)
UpToDate	64 (11.2%)
Best Practice	58 (10.2%)
ACP PIER	19 (3.3%)
Pre-appraised research	**157 (27.6%)**
Synopses of systematic reviews	35 (6.2%)
Systematic reviews	36 (6.3%)
Synopses of studies	4 (0.7%)
Studies	82 (14.4%)
Non-pre-appraised research	**205 (36.0%)**
Filtered studies	132 (23.2%)
Unfiltered studies	73 (12.8%)
Total number of accesses	**569 (100%)**

Appendix 4.11.5 Results from the Impact Assessment Measurement (IAM), for all Postgraduate Trainees participating in the trial

		Total n (%)	Clinical Question Recorder			Evidence Retrieval Coach			Audit, Feedback, Gamification		
			Yes	No	*p-value**	Yes	No	*p-value**	Yes	No	*p-value**
UTILITY *Did you find relevant information that partially or completely met your objective?*	Yes	**7 (70%)**	4 (67%)	3 (75%)	*p=0.667*	3 (75%)	4 (67%)	*p=0.667*	4 (80%)	3 (60%)	*p=0.500*
	No	**3 (30%)**	2 (33%)	1 (25%)		1 (25%)	2 (33%)		1 (20%)	2 (40%)	
USE *Did you (will you) use this information for a specific patient?*	Yes, or possibly	**6 (86%)**	4 (100%)	2 (67%)	*p=0.429*	3 (100%)	3 (75%)	*p=0.571*	4 (100%)	2 (67%)	*p=0.429*
	No	**1 (14%)**	0 (0%)	1 (33%)		0 (0%)	1 (25%)		0 (0%)	1 (33%)	
USEFULNESS *For this patient, did you observe (or do you expect) any health benefits as a result of applying this information?*	Yes, or possibly	**2 (100%)**	1 (100%)	1 (100%)	**	2 (100%)	0 (0%)	**	2 (100%)	0 (0%)	**
	No	**0 (0%)**	0 (0%)	0 (0%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	

**=Fischer's exact test (one-sided); ** Cannot be estimated*

Appendix 4.11.6 Results from Survey#2 for Postgraduates

"During the **last 3 months**, how many times have you searched the following resources **outside MacPLUS FS** for evidence to answer your **clinical questions**?"

EBM Resources (n=74 Postgrads)	**> 10 times**	**6-10 times**	**1-5 times**	**Never**
UpToDate	63.5%	16.2%	13.5%	6.8%
DynaMed	9.5%	2.7%	16.2%	71.6%
Best Practice	0%	1.4%	12.2%	86.5%
ACP PIER	1.4%	1.4%	6.8%	90.5%
Clinical Evidence	1.4%	2.7%	12.2%	83.8%
Micromedex	6.8%	2.7%	12.2%	78.4%
OVID	18.9%	9.5%	25.7%	45.9%
TRIP	0%	0%	6.8%	93.2%
Epistemonikos	0%	0%	0%	100.0%
SumSearch	0%	0%	0%	100.0%
ACP Journal Club	1.4%	1.4%	23.0%	74.3%
Cochrane Library	10.8%	10.8%	54.1%	24.3%
DARE	0%	0%	5.4%	94.6%
PubMed–using Clinical Queries filters	24.3%	10.8%	24.3%	40.5%
PubMed–without Clinical Queries	28.4%	13.5%	27.0%	31.1%
Google	74.3%	13.5%	6.8%	5.4%
Google Scholar	31.1%	12.2%	29.7%	27.0%
Wikipedia	56.8%	10.8%	12.2%	20.3%
Other EBM-resources:	*35.5%*	*9.7%*	*3.2%*	*51.6%*

- *Summaries (eMedicine–Medscape, BestBETs, Essential Evidence Plus –InfoPOEMS);*
- *Engines (Web of Science);*
- *Drug resources (E-pocrates)*
- *Institutions' Websites (Canadian Paediatric Society, American Academy of Pediatrics);*
- *Calculators (QxMD)*

Other alert services to new evidence:

ACP JournalWise, InfoPOEMS, Medscape topic alert, Psychiatric times, AAP Grand Rounds, PubMed (email feeds for specific authors), Specific Journals – table of content, search (e.g., JAMA, JAAOS, JBJS, Arthroscopy).

CHAPTER 5

Fourth manuscript

Enhancing the Searching for Current Best Evidence by Nursing Students and Medical Students: Results from the MacPLUS FS Factorial Randomized Controlled Trials

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Tables: 3 / Figures: 3 / Appendices: 6

5.1 ABSTRACT

Background:

Nurses, like other health care professionals, are expected to engage in evidence-based practice, but finding current best evidence remains one of the weakest links in implementation. Evidence access and use remain low, and no single evidence-based resource provides all answers or is sufficiently updated. McMaster PLUS – Federated Search (MacPLUS FS) addresses this issue by looking in multiple high quality resources simultaneously and displaying results in 1 page, starting with the most clinically relevant.

Objective:

This trial tested 3 web-based interventions, embedded in MacPLUS FS, and addressing logistical and educational barriers to increase the quantity and quality of searching for current best evidence.

Methods:

We conducted a randomized-controlled trial among 725 nursing students and 235 medical students currently registered to MacPLUS FS at the McMaster University Faculty of Health Sciences. Nursing students were randomized to each of the 3 following interventions in a factorial design (AxBxC): (A) a web-based Clinical Questions Recorder and Reminder; (B) an Evidence Retrieval Coach composed of 8 short videos embedded in MacPLUS; (C) Gamified Audit & Feedback based on the allocation of “badges” and “reputation scores”.

Medical students were randomized in 2-arms only (all 3 combined interventions vs. none). We recorded utilization continuously through individual accounts that track logins and use. The primary outcome was the rate of searches/user over 6 months. Secondary outcomes included frequency of access to pre-appraised evidence and to new evidence alerts.

Results:

Among nursing students, searching rates increased progressively with the number of interventions in a "dose-dependent" manner, ranging from a 9–12% relative increase with either intervention, to a 36% relative increase with all 3 interventions combined (RR 1.36, 95% confidence interval [CI] 1.27–1.44). There was a similar 32% increase in access to pre-appraised resources with all 3 interventions (RR 1.32, 95% CI 1.22–1.44), but no impact on access to new evidence alerts. Among medical students, the combined interventions showed no impact on either searching of pre-appraised resources or evidence alerts.

Conclusion:

Three web-based interventions successfully increased the quantity and quality evidence retrieval among nursing students, in contrast with medical students. Future research should follow students to determine if such interventions influence their searching and evidence-based practice after graduation.

Trial Registration: ClinicalTrials.Gov NCT02240095

5.2 INTRODUCTION

Nurses, like other health care professionals, are expected to engage in Evidence Based Practice (EBP), integrating current best evidence with patients' values and preferences, clinical context and resource considerations to inform clinical decision-making.[1,2] This involves searching, critically appraising and summarizing the best available evidence and subsequently applying, implementing, and evaluating its impact.[3-5] To achieve this goal, many nursing programs are now engaging in curricula that prepare nurses to engage in EBP upon entering the professional practice environment.[6-13]

However, finding current best evidence remains one of the weakest links in evidence-based nursing. A systematic review showed that nurses' self-reports of their evidence use remains almost unchanged over the last 15 years.[14] Although the reasons are multifactorial – at individual, organizational and environmental levels[15] – specific barriers arise from the volume, expansion and organization of evidence itself, as well as its accessibility to practicing nurses.[16-20] As many as 3000 new articles are published in Medline every day[3], including 75 randomized trials and 11 systematic reviews[21], with potentially important implications for clinical practice.[22-25] Numerous EBP resources identify, appraise, and synthesize best available evidence to help nurses find answers and keep up-to-date.[26,27] However, each resource offers a fragmented and scattered view of the evidence, and none provides consistent updating[23-25] or comprehensive topic coverage.[28,29]

Although several interventions for knowledge translation have been implemented in nursing, recent systematic reviews identified no specific interventions to address these challenges and improve nurses searching or use of research evidence.[30,31]

To address these issues, McMaster's University Health Information Research Unit has developed a novel online tool: the *MacPLUS Federated Search (MacPLUS FS).*[26,32] This knowledge translation platform combines the advantages of several EBP resources, and helps busy clinicians rapidly get the best available answers by navigating across multiple top resources in a simultaneous search. Results are organized according to the *pyramid of EBP resources*[33], displaying a 1 page output with the most clinically useful results at the top (see Figure 5.8.1). MacPLUS FS thus simultaneously retrieves evidence from online *summaries* in the top layers (e.g., UpToDate, DynaMed, Best Practice).[32] If they do not find a satisfactory answer, users have then access to individual *pre-appraised research* in the middle layers (i.e., Systematic reviews, Studies and their Synopses when available, selected in McMaster PLUS database for methodological rigor and clinical relevance by nurses and physicians[34]). Finally *non-pre-appraised research* from PubMed complements the search at the bottom layers, both with and without the validated "Clinical Queries" filters.[35,36] In addition to the federated search, MacPLUS FS provides users with alerts to new research tailored to clinical disciplines[37] (the same content is also disseminated to EvidenceUpdates, widely accessed worldwide[38]).

In addition to helping nurses navigate across EBP resources more optimally, MacPLUS FS offers an opportunity to address additional barriers to evidence retrieval, both logistical, such as time constraints at the point of care, and educational barriers, such nurses' limited knowledge and skills for evidence retrieval.[16-20,32] We previously described the development of 3 innovative web-based interventions linked to MacPLUS FS aimed at overcoming these barriers and increasing the quantity and quality of searching for current best evidence to answer clinical questions.[32]

The MacPLUS FS Randomized Controlled Trials consist of several trials testing these 3 web-based interventions in different populations registered in MacPLUS FS. Results of 2 trials among medical faculty members and postgraduates medical trainees are reported elsewhere (see Chapter 3 & 4). We report here the findings of 2 trials on (i) a large sample of nursing students (n=725); (ii) as well as a smaller sample of medical students (n=235), included in this paper for a direct comparison of the findings among students in health care.

5.3 METHODS

5.3.1 STUDY DESIGN

This randomized controlled trial tested the 3 web-based interventions in a factorial design among nursing students (AxBxC), and parallel 2-arm design among medical student (all interventions versus none). The study was registered at ClinicalTrials.gov before randomization (NCT02240095), and approved by the Hamilton Integrated Research Ethics Board. Details of the trial objectives, design, and methods were previously published in an open-access protocol [also available in Chapter 2], along with the development and full description of the 3 web-based interventions.[32] We summarize the methods and interventions briefly here.

5.3.2 THE WEB-BASED INTERVENTIONS

In a user-centered approach, we designed 3 interventions based on effective models for the teaching of clinical skills at the point of care, to facilitate using the search engine as a clinical tool, and to present evidence retrieval skills as true clinical skills:

- Intervention A – Clinical Question Recorder and Reminder
- Intervention B – Evidence Retrieval Coach
- Intervention C – Audit, Feedback and Gamification of searching behaviors

These interventions, embedded in MacPLUS FS are web-based adaptations of the "One-minute preceptor model" (also known as the "5-step Microskills" [39-43]), tailored to enhance evidence retrieval by identifying searching opportunities, prompting searches to answer clinical questions, providing general knowledge, skills and feedback, and inviting reflective practice. More details on our rationale, theoretical framework and user-centered development are described in our published protocol [32] [see also Chapter 2].

5.3.2.1 Intervention A – Clinical Question Recorder and Reminder

We designed an online platform directly linked to users' individual MacPLUS FS account and accessible across a wide range of devices, including smartphones, tablets and computer desktops (see Figure 5.8.2-A). This platform allows clinicians and students to: i) record their clinical questions on the fly; ii) easily answer them by triggering full searches in MacPLUS FS, iii) receive periodic reminders of unanswered questions along with evidence alerts, thus providing asynchronous opportunity for evidence retrieval[44]; iv) and keep track of their questions and short evidence-based answers along with bookmarked citations, in a virtual logbook for reflective practice (see Appendix 5.11.1).

5.3.2.2 Intervention B – Evidence Retrieval Coach

This intervention provides students with guidance with evidence retrieval, through 8 short videos (< 90 seconds each), which are embedded in MacPLUS FS as

well as sent via weekly e-mails according to each of the student's specific patterns of utilization and search (see Figure 5.8.2-B). The videos provide "small bites" of knowledge and skills on evidence-based practice (e.g., to translate clinical questions to answerable questions), on the "architecture" of evidence (i.e., pyramid of EBP resources), advantages and limits of individual resources, and how MacPLUS FS can help overcome them (see Appendix 5.11.1).

5.3.2.3 Intervention C – Audit, Feedback and Gamification

The purpose of this third intervention is to provide students with timely feedback on their current search utilization compared to their peers. We used a *gamification* approach[45], based on allocation of *badges* (about 50 in total) popping-up online immediately after a desired searching behavior (e.g., frequency of searches, or accessing pre-appraised resources). These badges result in *reputation scores,* which are based on the desirability of the behavior they reinforce and can be compared to peers on an interactive and playful interface within MacPLUS FS (see Figure 5.8.2-C, & Appendix 5.11.1).

5.3.3 SETTING AND STUDY PARTICIPANTS

We conducted the present trial from September 2014 to March 2015 (6 months duration) at McMaster University, its partner sites (Conestoga College and Mohawk College), and its affiliated teaching hospitals and clinics, which

comprises 2 major academic hospital systems, operating 10 hospitals in the Hamilton area, as well as 2 regional campuses in Niagara and Waterloo, Ontario.

Eligible participants were (i) undergraduate nursing students enrolled in 1 of 3 programs (traditional 4-year BScN, RN-BScN, or accelerated), and (ii) undergraduate medical students enrolled in Michael DeGroote School of Medicine, who had registered in MacPLUS FS prior to the trial. Registration and use of MacPLUS FS are free on all campus areas.

Of all 1,996 students registered by September 2014, 725 nursing students and 235 medical students were deemed eligible for the trial (see Figure 5.8.3). We excluded 859 students who had graduated since their registration and 177 who never interacted with MacPLUS FS during the last year (either by logging in to read e-mail evidence alerts or to perform a search) and thus had almost no chance of being exposed to the web-based interventions.

5.3.4 RANDOMIZATION, CONCEALMENT & BLINDING

The trial was coordinated from the Health Information Research Unit, at McMaster University, which designed and hosts MacPLUS FS. Nursing students and medical students were randomized separately. At the start of the trial, the independent programmer, in charge of MacPLUS FS administration, randomized all the 725 eligible nursing students to the 3 web-based interventions, using a computer-based random number generator (thus ensuring concealment of

randomization). In a factorial design (AxBxC), half of the nursing students were randomly allocated to each intervention, with all possible permutations resulting in 8 factorial groups (2^3=8 groups – see Figure 5.8.3). Randomization was balanced on blocks of 16 within each stratum (=2 x 8) and further stratified according to time since last search in MacPLUS FS (<= 365 days vs. >365 days, the latter only logged in to read e-mail evidence alerts). Given their smaller sample, all 235 eligible medical students were randomized in 2 arms only, allocating them to either all 3 combined interventions or no intervention, stratifying again for time since last search.

The programmer maintained a secure master list of the randomization codes; the analyst was blind to allocation. Although participants could not be blinded to the interventions, they were not informed of the different interventions being offered, and all participants, including the no intervention group, were exposed to new minor features in MacPLUS FS presentation and navigation in the months prior to the beginning of the trial.[32]

5.3.5 OUTCOME MEASURES

The primary outcome of interest was *utilization* of MacPLUS FS to search for evidence over the 6 months duration of the trial (i.e., not counting logins to e-mail new evidence alerts or to access other resources). We also assessed 2 secondary *utilization* outcomes to capture the quality of the searches and

MacPLUS FS use. First, we measured frequency of access to higher levels of evidence – i.e., summing the accesses to online summaries (e.g., DynaMed, UpToDate, Best Practice), as well as individual pre-appraised research (systematic reviews, synopses of reviews or studies). Second, we recorded the frequency of accesses to new evidence email alerts, independently of searching. All utilization outcomes were automatically and continuously recorded over the duration of the trial, as participating students were signed on through their individual user account that tracked down to individual keystrokes.

The trial included 2 additional surveys. The first survey was an adapted version of the Impact Assessment Method (IAM)[46-48], which assesses the *utility* of the evidence retrieved (meeting users' information needs), its *use* (application of in practice), and its perceived *usefulness* for a specific patient's care and outcomes. We periodically sent the online IAM questionnaire by e-mail according to an automatic algorithm built into MacPLUS FS. The first invitation was sent out 1 month after the participant's first online exposure the intervention(s), with 1 reminder after 24 hours. The next invitation was sent following the next search, but after a 2 weeks delay, repeating this process until the return of 1 filled questionnaire for a clinical question or the trial's end. We sent the second post hoc survey by e-mail after the end of the trial (with up to 3 reminders), to inquire about the resources users typically search outside MacPLUS FS in their practice.

5.3.6 STATISTICAL ANALYSIS

Although we anticipated the primary analysis to be at the margins, that is, looking at the effect of each intervention independently[32], actual analysis revealed 3-way statistically significant interactions among the nursing students. Consequently, we regressed the number of searches over the trial's 6-month time period for each participant onto all combinations of interventions (i.e., 8 allocation groups) controlling for time since last search at baseline (i.e., the stratifying variable). We used marginal models, applying generalized estimating equations (GEE) with Poisson distribution and a log link function. These analyses provided relative ratio estimates, which can be interpreted as the multiplicative factor of search rates with each combination of intervention (groups 1 to 7 – see Figure 5.8.3) compared to no intervention (group 8). We used a similar model for medical students, with the exception that no interaction was possible between the interventions, as they were either randomized to all versus no interventions.

We repeated the same analysis with the 2 secondary utilization outcomes: frequency of access to pre-appraised resources, and access to new evidence alerts. Finally, we analyzed the 2 surveys, comparing the distribution of answers using chi-squared tests. We performed all analyses using SPSS 22.0.0.1 software.

5.4 RESULTS

5.4.1 PARTICIPANTS FLOW AND CHARACTERISTICS

In September 2014, 725 nursing students were randomized to the 8 allocation groups (89-91 participants per group), with half the sample allocated to each intervention in a factorial design (see Figure 5.8.3). All were followed-up for primary and secondary utilization outcomes, over the 6 months of the trial. Time since last search was evenly stratified across the 8 allocation groups (see Appendix 5.11.2), being more than 1 year for 68% of participants. In parallel to nursing students, the 235 medical students were randomized to the 3 combined interventions (n=117) or no intervention (n=118)

5.4.2 PRIMARY OUTCOME: SEARCH UTILIZATION

5.4.2.1 Nursing Students

Nursing students performed 15,583 searches over the course of the trial. All 3-way interactions between the Clinical Question Recorder (Intervention A), the Evidence Retrieval Coach (Intervention B), and the Audit, Feedback and Gamification (Intervention C) were statistically significant, so that the effect of each varied depending on whether it was presented on its own or in combination. Nursing students who were allocated to no interventions (group 8: 0-0-0)

conducted on average 18.4 searches over the course of the trial. Compared to this group, all interventions resulted a statistically significant increase in frequency of searches (see Table 5.7.1). Rates increased gradually with the number of interventions in a "dose-dependent" manner, ranging from a 9–12% relative increase with either intervention, to a 36% relative increase with all 3 interventions combined (RR 1.36, 95% confidence interval [CI] 1.27 to 1.44).

5.4.2.2 Medical Students

In contrast, medical students conducted many fewer searches than nurses, 404 in total during the trial, with 3.7 searches on average in the no-intervention arm. There was no statistically significant increase in search rates with the 3 interventions combined (RR 0.73, 95% CI 0.38 to 1.49).

5.4.3 SECONDARY UTILIZATION OUTCOMES

5.4.3.1 Nursing Students

Results followed a similar pattern for the frequency of access to pre-appraised resources. Compared to the no-intervention group, there was again a "dose-dependent" increase in accesses with the number of interventions, compared to no intervention, although the effect of some combinations did not reach statistical significance (see Table 5.7.2). The significant increases ranged up to a 32% relative increase with all 3 interventions combined (RR 1.32, 95% confidence

interval [CI] 1.22 to 1.44). Nursing students accessed individual resources 10,382 times during the course of the trial, using the whole range offered in the federated search engine (see Appendix 5.11.3). About 73% of accessed resources were *Summaries* (UpToDate in 20% and DynaMed in 27%), 13% where individual *Pre-appraised research*), while *Non Pre-appraised research* were accessed in 14% of the times (mainly using clinical queries filters).

Nursing students accessed new evidence alerts infrequently, with an average frequency during the whole trial ranging from 0.01 to 0.06 accesses. Only 2 combinations of interventions significantly increased the rates to 0.22 and 0.29, but with very imprecise estimates of effect (see Table 5.7.3)

5.4.3.2 Medical Students

As for searches, the 3 interventions combined had no effect on either the frequency of access to pre-appraised research (RR 0.78, 95% CI 0.39 to 1.56) or accesses to new evidence alerts (RR 1.41, 95% CI 0.50 to 3.85). However medical students also used the whole range offered in the federated search engine (see Appendix 5.11.3).

5.4.4 RESULTS FROM THE SURVEYS

Following the frequency of searches, our automatic algorithm sent 1,094 IAM-questionnaires to 335 participating students during the trial (both nursing and medical). Despite a response rate of 89% (297/335), only 36 students reported

searches on questions regarding actual clinical practice. This was insufficient to assess the interventions' effect on utility, use and usefulness. For those reporting on clinical questions, the answer retrieved was associated with a 61% utility, 72% use in practice, and 75% perceived usefulness on patient outcomes (see Appendix 5.11.4).

Only 68 students answered the post-trial survey. About 85% reported having searched for answers outside of MacPLUS FS more than 5 times in the last 3 months. This was dominated by far by Google searches, but also included summaries (e.g., UpToDate or DynaMed) accessed outside of MacPLUS by 79% of respondents, as well as PubMed by 57% of respondents (see Appendix 5.11.5).

5.5 DISCUSSION

Among a large sample of nursing students (n=725), 3 web-based interventions, developed to reflect effective models for the teaching of clinical skills at the point of care, increased the quantity and quality of searching for current best evidence using a federated search engine. Searching rates increased progressively with the number of interventions in a "dose-dependent" manner, ranging from a 9–12% relative increase with either intervention, to a 36% relative increase with all 3 interventions combined. Increased access to pre-appraised resources followed a similar pattern, with up to 32% relative increase with all 3 interventions.

To our knowledge, this is the first large scale trial of web-based interventions to enhance the searching for current best research evidence among nursing students.[49] The use of such interventions hold promise in other settings given that previous studies have reported electronic sources being the most reported information source among nursing students.[50] Furthermore, we designed the interventions so as to map the steps of the "One-minute preceptor model", validated and widely used for clinical teaching at the point care.[39-43] These steps are intended to complement each other by identifying searching opportunities, prompting searches to answer clinical questions, providing general knowledge, skills and feedback, and inviting reflective practice.[32] We hypothesized that this approach may help teach and enhance evidence retrieval as for other clinical

skills. The positive results, and the observed "dose-dependent" effect in particular, provide some proof of concept of our approach.

The unique setting in which the study was conducted is also helpful for interpreting the results. This trial was conducted among undergraduate nursing students at McMaster University, who traditionally have been exposed to a stand-alone course in EBP towards the end of their studies for over the past 20 years. In 2010, a revision of the undergraduate nursing curriculum was undertaken to integrate EBP content from this course throughout the major theory and clinical courses. Now the students are introduced to information seeking and searching skills, as well as the pyramid of EBP resources and how to access them through MacPLUS FS, in their first term, with further reinforcement throughout the remainder of the curriculum.[33] This integration and reinforcement may explain the high frequency with which nursing students in this study searched, and their receptivity to the interventions. For example, library sessions are conducted by health sciences librarians both during and outside of class time, students work through in-class exercises with faculty in regard to development of clinical questions, and formal evaluation methods include assignments in which students are required to document their search for best evidence to address a clinical question.

Nursing students' access to pre-appraised resources also increased with the interventions. Although this may be related to the early introduction and

reinforcement of approaching evidence according the 6S pyramid or EBP resources[33], this is likely also a direct result of using MacPLUS FS, as it structurally organizes search outputs across the pyramid's layers, with the most clinical relevant and methodologically sound resources at the top.[26,32] Our experience is that students are using summaries (e.g., evidence-based textbooks such as UpToDate, DynaMed) primarily as a source of information related to background questions (e.g., what is gestational diabetes mellitus?), but also sometimes for more foreground clinical questions (e.g., effectiveness of physical activity interventions for preventing gestational diabetes mellitus).[26]

However, nursing students accessed alerts to new evidence infrequently, and the intervention did not increase their frequency of access to alerts. These findings differ with results from similar trials that we conduced among medical faculty members and postgraduate trainees (see Chapter 3). Although the difference might be partly explained by differences in self-perceived professional culture, the structure of the undergraduate nursing curriculum may also have hindered the usefulness of alerts. Similar to other nursing curricula, during a 12-week term, nursing students are enrolled in a clinical placement and take nursing theory courses. As such, for the alerts to meet the student's clinical learning needs, the alert setting in their profile would need to be changed each term. Theory courses engage students in problem-based learning in which they are exposed to several patient scenarios covering a range of content areas over the course of one 12-week term. Thus, the frequency with which alert settings would need to be

changed to meet learning needs associated with their theory courses may render the alerts not as useful as they are for other students and health care professionals.

In sharp contrast with nursing students, the same interventions combined tested on a smaller sample of medical students (n=235) had no impact on their frequency of searches, accesses of pre-appraised research, or accesses to new evidence alerts. This surprising finding probably emphasizes the importance of embedding the interventions within the curriculum. Despite the strong EBP culture in McMaster University's medical training, the teaching in evidence retrieval is currently not as stressed and well organized as for nursing students. As a consequence, medical students' baseline searching rates were 5 to 10 times lower than nurses, although they likely also conduct searches outside of MacPLUS FS, particularly in Google and Wikipedia, as the post-hoc survey suggests.

This trial has several limitations. First, the sample consists of students at McMaster University who were registered with MacPLUS FS at the beginning of the trial. As we have discussed, this may limit the generalizability of the findings given possible unique features of the curriculum that the students were exposed to before and during the trial. Embedded coursework within the undergraduate nursing curriculum prompts searching which, in turn, could suggest that the students who participated in this study may differ in the quantity and quality of

searching compared with nursing students in other academic settings. Second, the interventions' effects may be intimately linked with MacPLUS FS architecture, which complements top summary resources with the unique properties of PLUS that ensures selected evidence is methodologically sound and clinically relevant.[29,34,37] Results may not directly translate to other federated search engines.[26] Third, although both nursing students and medical students used the whole range or EPB resources offered in the federated search engine, they frequently sought answers outside of MacPLUS FS and we could not know whether the interventions had any impact on these searches. Similarly, we do not know the long-term effect of the interventions, beyond the 6-month follow-up of the trial. Finally, despite a response rate of 89%, few participants provided data on the Impact Assessment Method survey. This is in part due to the low absolute frequency of searches and the automatic algorithm designed not to overload participants with a questionnaire after each search. But this probably also means that students felt that their questions were not directly relevant to clinical practice and they could therefore not answer items on the utility, use and perceived usefulness of the evidence retrieved.

5.6 CONCLUSION

This large randomized trial provides a proof of concept that 3 web-based interventions, embedded in an online federated search engine, can enhance evidence retrieval by nursing students, but the same intervention showed no

equivalent effect among medical students. The MacPLUS FS interface – and its twin version available internationally – the ACCESSSS FS (http://plus.mcmaster.ca/ACCESSSS) – allow a broad implementation of such interventions. Future research should determine how specific attributes of undergraduate curricula could support these interventions across various academic settings, as well as among medical students. Students should also be followed after graduation to determine if access to the features incorporated in MacPLUS FS influence their searching and, in turn, their use of evidence in decision making in their subsequent practice.

5.7 TABLES

Table 5.7.1 Frequency of searches by nursing students (primary outcome): estimated mean and relative ratio compared to the no intervention group

	Interventions			Overall Frequency of Searches		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ***	**Relative Ratio**	**(95% CI)****
Group 1	**Yes**	**Yes**	**Yes**	25.01	1.36	(1.27 – 1.44)
Group 2	**Yes**	**Yes**	No	24.38	1.32	(1.24 – 1.41)
Group 3	**Yes**	No	**Yes**	22.09	1.20	(1.12 – 1.28)
Group 4	**Yes**	No	No	20.11	1.09	(1.02 – 1.17)
Group 5	No	**Yes**	**Yes**	20.28	1.10	(1.03 – 1.17)
Group 6	No	**Yes**	No	20.58	1.12	(1.05 – 1.19)
Group 7	No	No	**Yes**	20.18	1.09	(1.02 – 1.17)
Group 8	No	No	No	18.44	*Reference*	

* Mean frequency of searches/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

Table 5.7.2 Frequency of access to pre-appraised resources by nursing students (secondary outcome): estimate mean and relative ratio of access compared to the no intervention group

	Interventions			Overall Access to Pre-appraised Resources		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ****	**Relative Ratio**	**(95% CI)***
Group 1	**Yes**	**Yes**	**Yes**	13.60	1.32	(1.22 – 1.44)
Group 2	**Yes**	**Yes**	No	15.48	1.51	(1.39 – 1.63)
Group 3	**Yes**	No	**Yes**	11.92	1.16	(1.06 – 1.26)
Group 4	**Yes**	No	No	11.05	1.07	(0.98 – 1.17)
Group 5	No	**Yes**	**Yes**	11.00	1.07	(0.98 – 1.17)
Group 6	No	**Yes**	No	10.52	1.02	(0.94 – 1.12)
Group 7	No	No	**Yes**	11.29	1.10	(1.01 – 1.20)
Group 8	No	No	No	10.29	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

Table 5.7.3 Frequency of access to e-mail alerts to new evidence by nursing students (secondary outcome): estimated mean and relative ratio compared to the no intervention group

	Interventions			**Overall Access to E-mail Alerts**		
	A. Clinical Question Recorder	**B.** Evidence Retrieval Coach	**C.** Audit, Feedback & Gamification	**Estimated mean ***	**Relative Ratio**	**(95% CI)****
Group 1	**Yes**	**Yes**	**Yes**	0.03	1.50	(0.25 – 8.98)
Group 2	**Yes**	**Yes**	No	0.22	9.73	(2.27 – 41.76)
Group 3	**Yes**	No	**Yes**	0.01	0.50	(0.05 – 5.51)
Group 4	**Yes**	No	No	0.01	0.50	(0.05 – 5.51)
Group 5	No	**Yes**	**Yes**	0.29	12.50	(2.96 – 52.77)
Group 6	No	**Yes**	No	0.06	2.50	(0.48 – 12.88)
Group 7	No	No	**Yes**	0.06	2.53	(0.49 – 13.70)
Group 8	No	No	No	0.02	*Reference*	

* Mean frequency of access/user during the 6-month trial, estimated from a model adjusted for each intervention and baseline frequency of search

** CI - Confidence Interval

5.8 FIGURES

Figure 5.8.1 Summary of EBP resources provided in the federated search output of MacPLUS FS

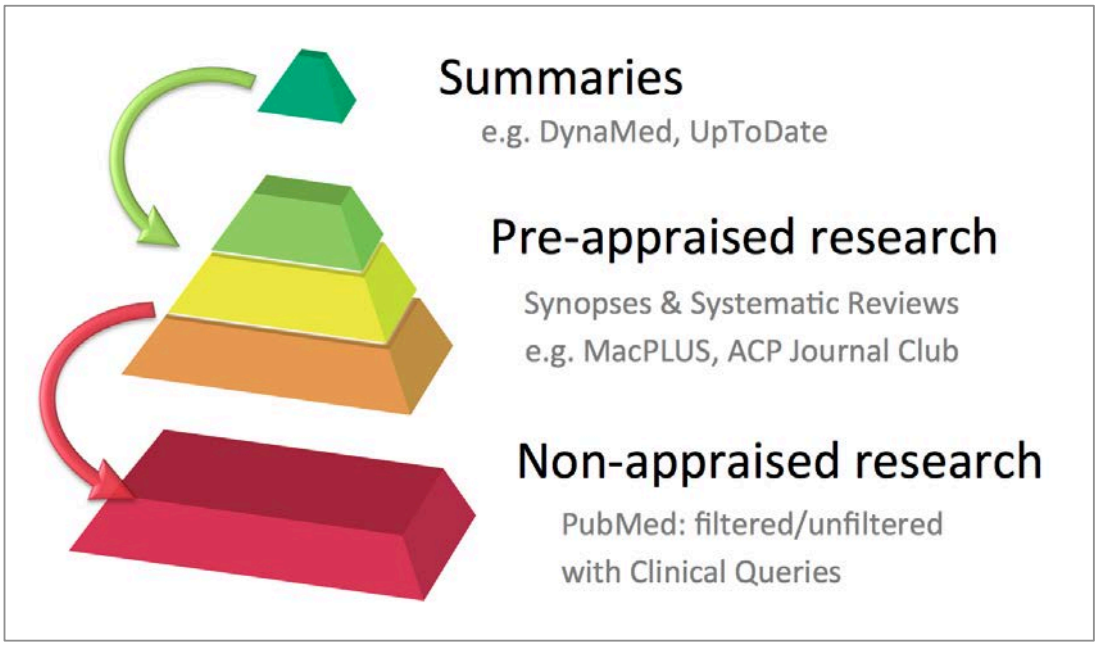
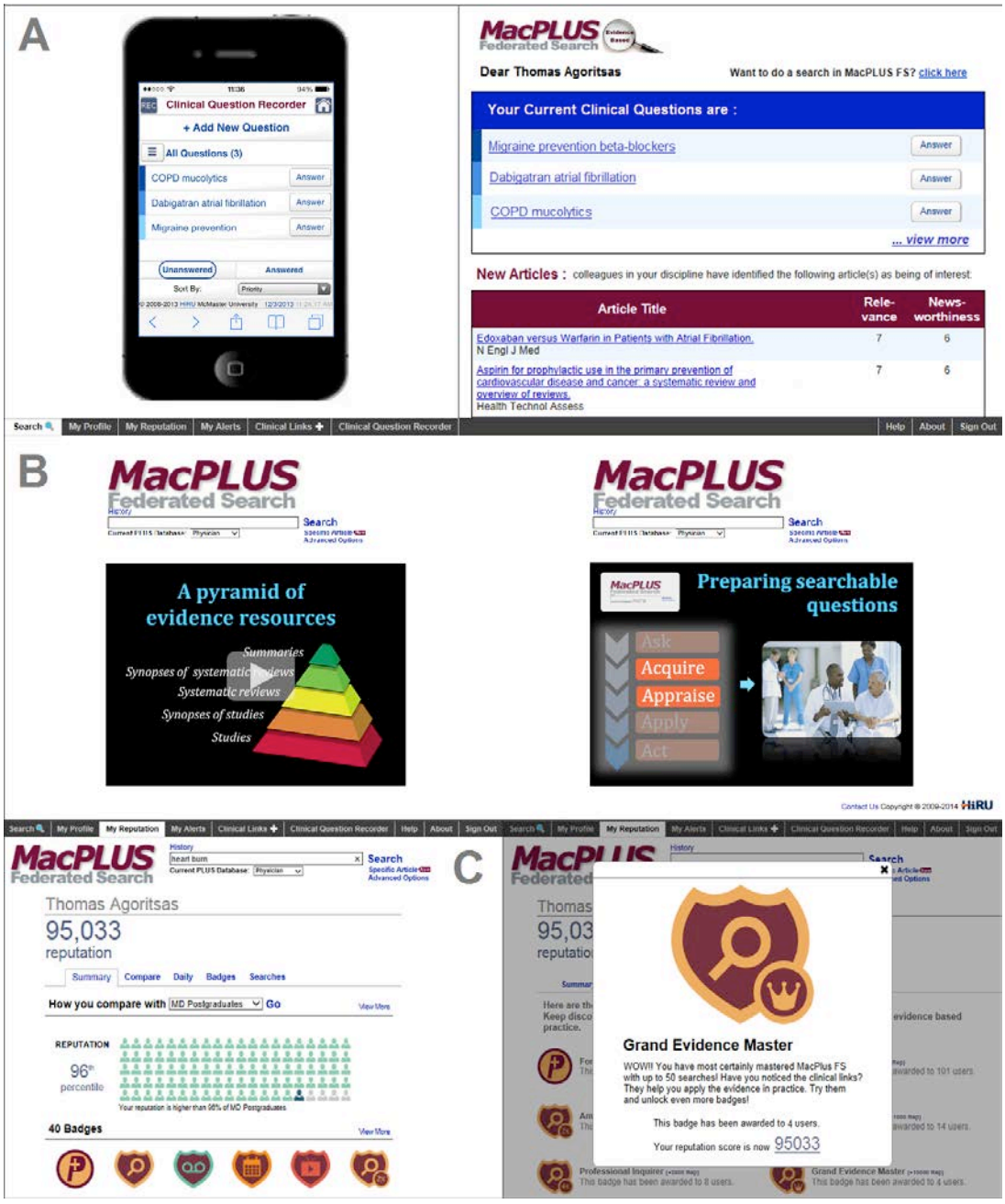
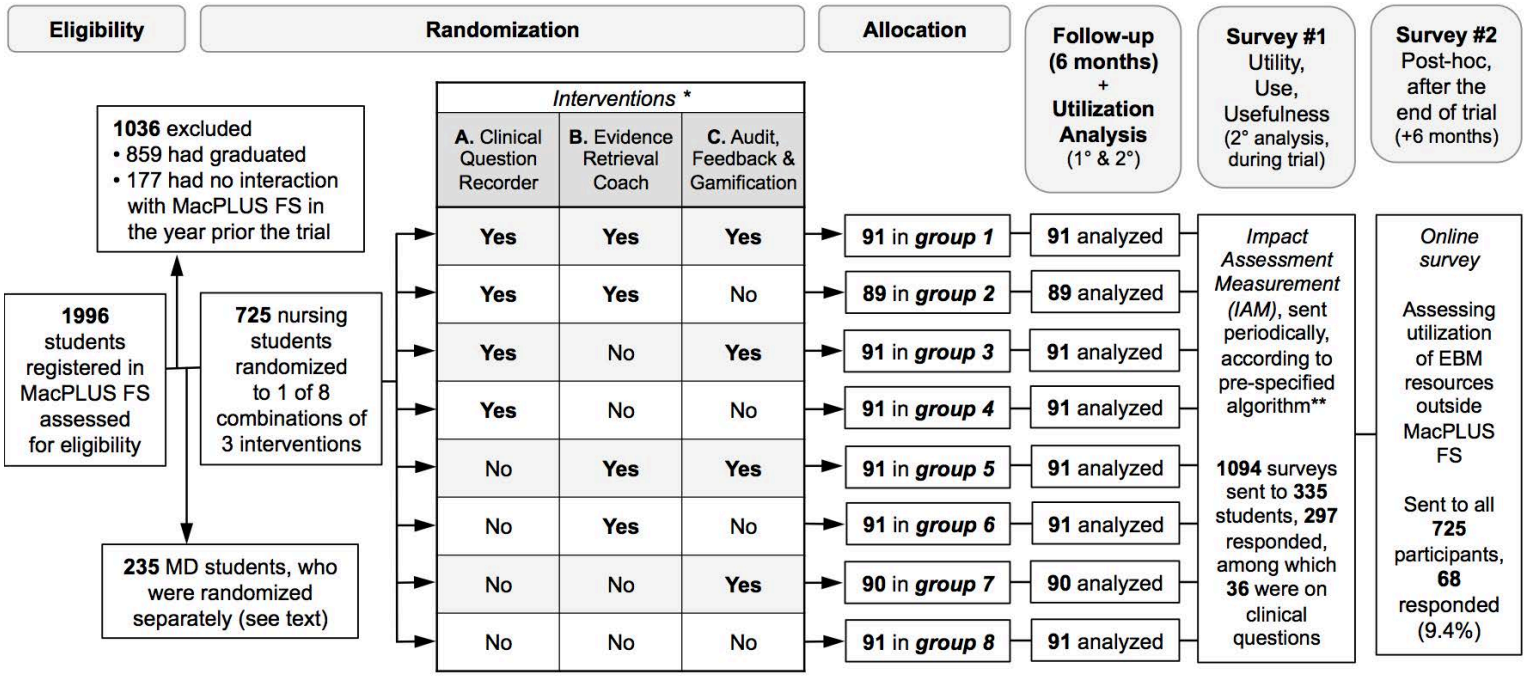


Figure 5.8.2 Illustrations of the 3 web-based interventions embedded in MacPLUS FS



Legend: (A) Clinical Question Recorder & Reminder; (B) Evidence Retrieval Coach; (C) Audit, Feedback and Gamification.

Figure 5.8.3 Participants flow



* For each intervention, half of the sample is randomized to receiving the intervention [Yes] and the other half to not receiving it [No]. All factorial combinations of the intervention result in 8 allocation groups (2^3=8).

** First invitation sent one month after the participants first online exposure to one or more interventions, with one reminder after 24 hours. Iterative invitation (but always after a two-weeks delay), until one filled questionnaire for clinical question is returned or trial end.

5.9 AUTHORS' CONTRIBUTIONS, ACKNOWLEDGMENTS & COMPETING INTERESTS

Authors' contribution

Conception of the interventions and study design: TA, with significant contributions from BH and AI. Specific design of intervention A (*Clinical Question Recorder*): TA and NH. Specific design of intervention B (*Evidence Retrieval Coach*): TA and EI. Specific design of intervention C (*Audit, Feedback & Gamification*): TA. Programming: NH, RP and CC. Data management and monitoring: TA and EI. Statistical analysis: TA and EP. Result interpretation: TA, JY, BH. Draft of the manuscript: TA and JY. Critical revision of the manuscript for important intellectual content: EI, NH, RP, CC, EP, DC, BH. Overall supervision: BH and DC. All authors read and approved the final manuscript. TA had full access to all the data presented in the manuscript and takes responsibility for its integrity and accuracy.

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Competing Interests

The Health Information Research Unit (HiRU), McMaster University, to which many authors are affiliated (TA, EI, NH, CC, AI, and BH), has developed and implemented the MacPLUS Federated Search. The intellectual property belongs to McMaster University, a non-profit publicly funded institution. One of the main missions of HiRU is the development of new information resources to support evidence-based health care, and the evaluation of various innovations in overcoming health care information problems. Its McMaster Premium LiteratUre Service (PLUS) contributes to many other EBP resources worldwide, including: BMJ EvidenceUpdates, ACP Journal Club, ACP Smart Medicine, Best Practice, Clinical Access, Clinical Evidence, DynaMed, e-Therapeutics, Evidence-Based Medicine Reviews (Duodecim), First Consult (Elsevier), Helsebiblioteket (Norway), National Board of Medical Examiners, Stat!Ref (Teton Data Systems), all under contract with McMaster University.

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5.11 APPENDICES

Appendix 5.11.1 Description of the features available in the 3 interventions

A	**Clinical Question Recorder**	Web-based interface, linked to MacPLUS FS account, and accessible on any smartphone, tablet and desktop computer Easy recording and listing of clinical questions Clicking the "Answer" button next to each question triggers a comprehensive search in MacPLUS FS Browsing of citations retrieved according to the pyramid of EBP resources Bookmarking of links to relevant citations, saved along with the question Recording of short answer to the question Organizing of questions: setting priorities, sorting and classifying into folders Reminders and links to unanswered questions are sent on top of regular MacPLUS FS alerts to new evidence Answered questions and bookmarked evidence are saved and accessible in a virtual logbook of EBP
B	**Evidence Retrieval Coach**)	Composed of 8 short videos, embedded in MacPLUS FS Display is tailored to clinician's patterns of behaviors, according to predefined triggers or sent on a weekly basis as the trial unfolds The title of each video [and gist of their content] are the following: 1. MacPLUS FS - Why use it? [Answering questions with information overload] 2. Enhancing Evidence-Based Clinical Practice [Using a parallel search in pre-appraised resources] 3. A pyramid of resources [Overview of the architecture of evidence] 4. Is one summary enough? [Top layers: Summaries] 5. New and critically appraised evidence [Middle layers: Pre-appraised research] 6. PubMed & the Clinical Queries [Bottom layers: Non-pre-appraised research] 7. Preparing searchable questions [Using the PICO framework] 8. Academic work [Using a federated search for presentations, grants and research]

C	***Audit, Feedback & Gamification***	Allocation of badges, popping up online after a specific desired behavior, and also sent by e-mail (about 50 badges available) Each badge is associated with an increase in reputation score, depending on the desirability of the behavior It also provides a short positively-framed feedback on the behavior, the number of time it was allocated to peers, and an upgraded reputation score Clicking on the badges lead to a Reputation tab in MacPLUS FS providing the following features: Comparison of reputation with peers using pictographs (percentiles) List of badges obtained, clicking on them displays the full badge again Graphical representation of daily reputation Frequency of access to each EBP resources and mapping according to the pyramid

Appendix 5.11.2 Distribution of time since last search for Nursing Students, across the 8 allocation groups

		Time since last search	
		<= 365 days	**> 365 days**
Group 1 (A+B+C*)	**n = 91**	29 (31.9%)	62 (68.1%)
Group 2 (A+B*)	**n = 89**	28 (31.5%)	61 (68.5%)
Group 3 (A+C*)	**n = 91**	29 (31.9%)	62 (68.1%)
Group 4 (A*)	**n = 91**	29 (31.9%)	62 (68.1%)
Group 5 (B+C*)	**n = 91**	29 (31.9%)	62 (68.1%)
Group 6 (B*)	**n = 91**	29 (31.9%)	62 (68.1%)
Group 7 (C*)	**n = 90**	28 (31.1%)	62 (68.9%)
Group 8 (No interv.)	**n = 91**	29 (31.9%)	62 (68.1%)
	n = 725	230 (31.7%)	495 (68.3%)

* A - Clinical Question Recorder; B - Evidence Retrieval Coach; C - Audit, Feedback & Gamification.

Appendix 5.11.3 Distribution of all accesses to EBP resources for all (a) Nursing students and (b) Medical Students in the course of the trial

(a) Nursing Students (n=725)	15583 searches
Summaries	**7554 (72.8%)**
DynaMed	2098 (20.2%)
UpToDate	2748 (26.5%)
Best Practice	2101 (20.2%)
ACP PIER	607 (5.8%)
Pre-appraised research	**1349 (13.0%)**
Synopses of systematic reviews	499 (4.8%)
Systematic reviews	652 (6.3%)
Synopses of studies	18 (0.2%)
Studies	180 (1.7%)
Non-pre-appraised research	**1479 (14.2%)**
Filtered studies	947 (9.1%)
Unfiltered studies	532 (5.1%)
Total number of accesses	**10382 (100%)**

(b) Medical Students (n=235)	**691 searches**
Summaries	**542 (77.1%)**
DynaMed	189 (26.9%)
UpToDate	177 (25.2%)
Best Practice	143 (20.3%)
ACP PIER	33 (4.7%)
Pre-appraised research	**97 (13.8%)**
Synopses of systematic reviews	33 (4.7%)
Systematic reviews	41 (5.8%)
Synopses of studies	9 (1.3%)
Studies	14 (2.0%)
Non-pre-appraised research	**64 (9.1%)**
Filtered studies	56 (8.0%)
Unfiltered studies	8 (1.1%)
Total number of accesses	**703 (100%)**

Appendix 5.11.4 Results from the Impact Assessment Measurement (IAM), aggregated for all students (nursing & medical) participating in the trial

		Total n (%)	Clinical Question Recorder			Evidence Retrieval Coach			Audit, Feedback, Gamification		
			Yes	No	*p-value**	Yes	No	*p-value**	Yes	No	*p-value**
UTILITY *Did you find relevant information that partially or completely met your objective?*	Yes	**22 (61%)**	9 (82%)	13 (52%)	*p=0.092*	3 (21%)	3 (33%)	*p=0.435*	2 (100%)	4 (67%)	*p=0.536*
	No	**14 (39%)**	2 (18%)	12 (48%)		11 (79%)	6 (67%)		0 (0%)	2 (33%)	
USE *Did you (will you) use this information for a specific patient?*	Yes, or possibly	**17 (74%)**	9 (53%)	13 (68%)	*p=0.272*	8 (80%)	9 (69%)	*p=0.463*	4 (100%)	2 (50%)	*p=0.214*
	No	**6 (26%)**	8 (47%)	6 (32%)		2 (20%)	4 (31%)		0 (0%)	2 (50%)	
USEFULNESS *For this patient, did you observe (or do you expect) any health benefits as a result of applying this information?*	Yes, or possibly	**6 (75%)**	9 (56%)	13 (65%)	*0.423*	5 (56%)	12 (86%)	*p=0.132*	3 (100%)	3 (60%)	*p=0.357*
	No	**2 (25%)**	7 (44%)	7 (35%)		4 (44%)	2 (14%)		0 (0%)	2 (40%)	

**=Fischer's exact test (one-sided)*

Appendix 5.11.5 Results from follow-up Survey#2 among Students (Nursing & Medical)

"During the **last 3 months**, how many times have you searched the following resources **outside MacPLUS FS** for evidence to answer your **clinical questions**?"

EBM Resources (n=68 Students)	**> 10 times**	**6-10 times**	**1-5 times**	**Never**
UpToDate	39.7%	17.6%	35.3%	7.4%
DynaMed	27.1%	27.1%	45.8%	0%
Best Practice	19.1%	11.8%	26.5%	42.6%
ACP PIER	0%	2.9%	7.4%	89.7%
Clinical Evidence	4.4%	11.8%	22.1%	61.8%
Micromedex	5.9%	4.4%	5.9%	83.8%
OVID	10.3%	16.2%	33.8%	39.7%
TRIP	2.9%	2.9%	22.1%	72.1%
Epistemonikos	0%	0%	1.5%	98.5%
SumSearch	0%	0%	1.5%	98.5%
ACP Journal Club	2.9%	1.5%	19.1%	76.5%
Cochrane Library	17.6%	11.8%	42.6%	27.9%
DARE	4.4%	5.9%	16.2%	73.5%
PubMed–using Clinical Queries filters	19.1%	17.6%	26.5%	36.8%
PubMed–without Clinical Queries	39.7%	8.8%	30.9%	20.6%
Google	82.4%	5.9%	8.8%	2.9%
Google Scholar	50.0%	11.8%	27.9%	10.3%
Wikipedia	58.8%	10.3%	13.2%	17.6%
Other EBM-resources:	*34.4%*	*6.3%*	*15.6%*	*43.8%*

Summaries (Merck Manual, eMedicine–Medscape, Essential Evidence Plus –InfoPOEMS, National Guideline Clearinghouse); Engines (Cinhal, Web of Science, ClinicalKey); Drug resources (Epocrates; Calculators (QxMD, theNNT)

Other alert services to new evidence: *BMJ EvidenceUpdates, ACP JournalWise, InfoPOEMS.*

CHAPTER 6

Fifth manuscript

SHARE-IT project – Decision aids that really promote shared decision making: the pace quickens

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Agoritsas et al.: **Decision aids that really promote shared decision making: the pace quickens**.

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6.1 ABSTRACT & KEY MESSAGES

Decision aids can help shared decision making, but most have been hard to produce, onerous to update, and are not being used widely. Thomas Agoritsas and colleagues explore why and describe a new electronic model that holds promise of being more useful for clinicians and patients to use together at the point of care.

Key messages

1. Traditional decision aids are time consuming to produce, often not based on current best evidence, and have not had the desired uptake in clinical practice. Whether they facilitate collaborative deliberation remains unknown, as they are usually designed for patients to use outside the clinical encounter.
2. Recent developments can overcome these limitations:
   - Decision aids designed for use in the clinical consultation effectively facilitate shared decision making and have great appeal to clinicians and patients.
   - GRADE produces structured evidence summaries that are ideally suited for shared decision making.
   - New authoring and publication platforms can automate the production of decision aids with electronic presentations ideal for efficient use in clinical consultations.
3. Building on these developments, we have produced and successfully tested prototypes that promise of being more useful at the point of care: interactive, adaptive to local circumstances, and continuously updated with new evidence.

6.2 BACKGROUND

Many, perhaps most, important decisions in medicine are not clear-cut.[2,3] Patients and clinicians, need to discuss the options using the best available evidence and make informed joint decisions that take account of patients' context, values, and preferences.[4,5] But implementing shared decision making is not easy. Doctors need the skills and tools to do it and to build trust; patients need information and support. Patients also need to have a greater role in developing strategies to improve the process.[6,7]

Access to best evidence is another key ingredient. Until now the production and dissemination of clinical practice guidelines and summaries of evidence has largely been generated and tailored to meet the educational needs of clinicians. They are seldom provided in a format that supports shared decision making.[8] Patients meanwhile, struggle to find reliable and accessible summaries of evidence, although plain language summaries and patient versions of guidelines are being developed.[9] Most efforts have thus so far focused on the development of patient decision aids.

In this article we highlight the limitations of current decision aids, and discuss how the generic production of electronic decision aids, linked directly to trustworthy evidence summaries from systematic reviews and guidelines, may help in the long march to realising effective shared decision making.

6.3 CHALLENGE OF SHARED DECISION MAKING

Shared decision making depends on a good conversation[10] in which clinicians share information about the benefits, harms and burden of alternative diagnostic and therapeutic options, and patients explain what matters to them and their views on the options and choices they face.[5,11] It should follow the principles of patient-centred care, promote informed choice, and result in care that patients value.[2,4,12] Many clinicians think they practice shared decision making, but evidence suggest a perception-reality gap[4], due to misconceptions about the nature of shared decision making, the skills it requires, the time it takes, and the degree to which patients, families, and carers wish to share in decision-making.[13-15]

Each clinical encounter is influenced by many factors. These include patients' circumstances and medical needs as well as their beliefs, stemming from what they have read, personal experience, advice from family and friends, and the media. It is therefore important to provide patients with accurate, up to date evidence on the benefits and harms of alternative management strategies, and likely effect on outcomes that matter to them, although evidence may not always reflect the complexity and multimorbidity of individual patients and patients may choose to ignore the evidence. Good shared decision making requires clinicians to have access to detailed knowledge and ideally summaries of the latest

evidence and the means to share it in a way that is supports thoughtful deliberation – something that cannot be done on the fly.

6.4 LIMITATIONS OF TRADITIONAL DECISION AIDS

For the past two decades, enthusiasts have advocated decision aids to facilitate shared decision making, and over 500 have been developed.[16] [17] A systematic review of 115 randomized trials showed that their use was associated with a 13% absolute increase in patients' knowledge scores, and an 82% relative increase in accurate expectations of possible benefits and harms. Effects on clinical outcomes, adherence to treatment, and use of services have not, however, been consistent.[16,18]

Most decision aids have been designed for patients to use independently outside the consultation, either in waiting rooms or at home.[11] Although these decision aids promote understanding of the issues, they cannot guarantee that decisions in the consultation are shared[4,19], and there is insufficient evidence to determine how their use influences the consultation.[19] Another problem is that use of decision aids in routine care is low[14], mainly because of poor design and lack of ready access to them. Furthermore clinicians may find the format impractical to use in consultations and may be as unfamiliar as their patients with risk estimates and the inherent uncertainty associated with probabilities.[20]

Traditional decision aids are often not based on current based evidence or rapidly outdated, at least in part because of limitations in funding after tool development – and may thus do more harm than good.[21] A rigorous systematic review is needed for each important outcome, and such reviews are often unavailable. A recent assessment found that, although approximately two thirds of decision aids are based on systematic reviews or guidelines, many of these sources are of questionable quality, and only 5% of aids included an "expiry date" or a stated policy about updating.[21]

Ensuring the quality and timeliness of decision aids is a daunting challenge. The work required to summarize evidence for a trustworthy decision aid is similar to that of producing a systematic review or a guideline, suggesting the potential for synergy between the worlds of evidence-based practice and shared decision making.[21,22 23]

6.5 HARNESSING THE POTENTIAL OF RECENT DEVELOPMENTS

6.5.1 NEW DECISION AIDS

Some newer decision aids have been designed to facilitate collaborative deliberation in the course of the clinical encounter.[4,11] Montori and colleagues pioneered a user centred approach to producing decision aids through iterative observations of discussions between doctors and patients.[10,24] Their approach

resulted in succinct easy to use tools that provide graphic displays of the benefits and harms of different options organized around concerns that are important to patients (http://shareddecisions.mayoclinic.org). In contrast to traditional aids which patients' use independently, they are not designed to be comprehensive and do not include explicit exercises to help patients clarify theirs values (e.g. relative value of avoiding a stroke versus a gastro-intestinal bleed)[25] Instead they rely on the unique conversations that take place between patients and clinicians, with clinicians providing just in time, tailored explanations and information.[11] Direct observations in randomized trials have shown that these short tools (so far available for diabetes, statins, and anti-depressants) promote shared decision making and increase joint deliberation.[26] They also shift the "body language" as patients and clinicians sit together to review the same data.[24,27]

Other short point-of-care decision aids include the Option Grids®.[28,29] (www.optiongrid.co.uk) These are one-page summaries that provide answers to patients' frequently asked questions, covering clinical outcomes and practical concerns faced in daily life. Their value in routine care is being evaluated.[28]

6.5.2 DEVELOPMENTS IN APPRAISAL AND PRESENTATION OF CURRECT BEST EVIDENCE

The *GRADE* approach (*Grading of Recommendations Assessment, Development and Evaluation)*[30] provides systematic, transparent and explicit guidance for

processing evidence from the medical literature, and has been widely adopted.[8,30] Use of the GRADE approach results in standardized and succinct "evidence profiles" or "summary of findings" tables, which specify the absolute effects of an intervention on outcomes important to patients rather than surrogate outcomes, and provide a rating of the certainty in these estimates (high, moderate, low and very low).[31] The recent *International Patient Decision Aids Standards (IPDAS)* have emphasised the potential of GRADE for the production of decision aids[21], and it has been adopted by over 80 organisations (www.gradeworkinggroup.org).

Further more, clinical practice guideline using GRADE now issue weak recommendations (in contrast to strong) when there is a close balance between desirable and undesirable outcomes among alternatives, low certainty in estimates of effect, or when there is large variability in patients' values and preferences. Weak recommendations, which dominate in recent high-quality guidelines, thus identify decisions where shared decision making is particularly important.[3,21,23]

6.5.3 USE OF NEW TECHNOLOGIES

The not-for-profit MAGIC organization, (*Making GRADE the Irresistible Choice*" – www.magicproject.org) has developed an online "app" with potential to produce electronic decision aids for use in the clinical encounter.[8] This MAGICapp (www.magicapp.org) allows authors of guidelines or systematic reviewers to write

evidence summaries into a structured database and appraise them using GRADE criteria.[30,31] The content can then be published on a web-platform and presented in numerous interactive formats on tablets, web portals or electronic medical record systems.[32]

In the SHARE-IT project, we use this authoring and publication platform for the generic and semi-automated production of a large number of decision aids.[8] The aids can be used with the corresponding systematic review or clinical practice guidelines and the format modified and tailored to specific context – for example, published in different languages or adapted to national guidelines).[33,34] The electronic format facilitates continuous updating because the data in the decision aids will change automatically each time the underlying review is modified.[8]

Figure 6.8.1 summarises the methods of the SHARE-IT project.[8] In collaboration with DECIDE, a European funded project of GRADE (www.decide-collaboration.eu)[35], we gathered an international team of experts in evidence-based medicine and shared decision making, clinicians, guideline developers, and designers. Through evidence review and iterative brainstorming, we developed an initial framework and electronic prototype for the translation of GRADE evidence summaries into decision aids that follow both international standards[36] and practical models for shared decision making.[5] We then applied an iterative and user-centred design (see Figure 6.8.1) directly involving patients and clinicians facing real decisions. As summarised in Box 6.7.1, we built 10 decision aids on antithrombotic drugs and modified the generic prototype in light

of observations of their use in practice and individual feedback from patients and clinicians.

Figures 6.8.2 to 6.8.5 illustrates how the prototype uses interactive formats to present evidence summaries at varying levels of detail. [Video 6.8.6 also demonstrates its use in a clinical encounter and is embedded within the online version of the published article: http://www.bmj.com/content/350/bmj.g7624.full]. The prototype shows that the approach is feasible, and preliminary experience suggests that both patients and clinicians appreciate it. Across 16 clinical encounters, patients consistently reported high levels of satisfaction with the prototype in understanding risks and benefits and in enhancing their confidence in decisions as assessed by COMRADE[37] (See Box 6.7.1 and 6.7.2).

6.6 CONCLUSION

No decision aid is sufficient to guarantee that clinical decision making is shared. Undergraduate, post-graduate, and continuing education programmes must teach health professionals about the importance of creating and fostering a culture of shared decision making and the skills needed to communicate evidence, and its limitations, in a way people can understand. Furthermore, the challenge of producing evidence summaries that deal optimally with complexity, multimorbidity, and potentially limited applicability to the patient at hand remains.[38]

We are, however, now in a position to construct, test, and refine electronic evidence summaries for use in the clinical encounter for a wide variety of patient groups and clinical settings. Our prototype, built within the MAGICapp, demonstrates the feasibility of semi-automated production of decision aids from a large number of electronically published evidence summaries. We also plan to implement these formats in another similar platform, the *GRADEpro Guideline Development Tool* (www.guidelinedevelopment.org). We invite patient organizations, research groups, guideline developers, individual patients and clinicians, to partner with us (www.magicproject.org) and help us advance the science and art of truly shared and well informed decision making.

6.7 BOXES

Box 6.7.1 Refining the prototype for generic decision aids in patient-clinician real-life decision-making: Results from user-testing

- We applied the early prototype to build 10 decision aids addressing various anti-thrombotic therapies, based on GRADE evidence summaries we created from systematic reviews.
- We then conducted direct observations of how patients and clinicians used the decision aids in real clinical encounters, followed by individual interviews with patients and clinicians. This user-centred approach helps us continuously refine the prototype as we develop new formats and features (see Figure 1).
- The analysis of 16 clinical encounters, including patients from 18 to 90 years old, has identified issues that have led to over 30 modifications of the prototype, across 4 major iterations. Figures 2 to 5 show an example of a decision aid from the latest iteration.
- Patients have consistently reported high levels of satisfaction with the decision aid prototype in understanding risks and benefits and in enhancing their confidence in decisions (mean scores of respectively 88.7 and 90.9 on a maximum of 100, as assessed by the *COMRADE* instrument[37]).
- Similarly clinicians have found the tool useful and appealing, some expressing pleased surprise in how it shifted the conversation towards SDM (see real-life example in Box 2).

Box 6.7.2 Reaction to the decision aid

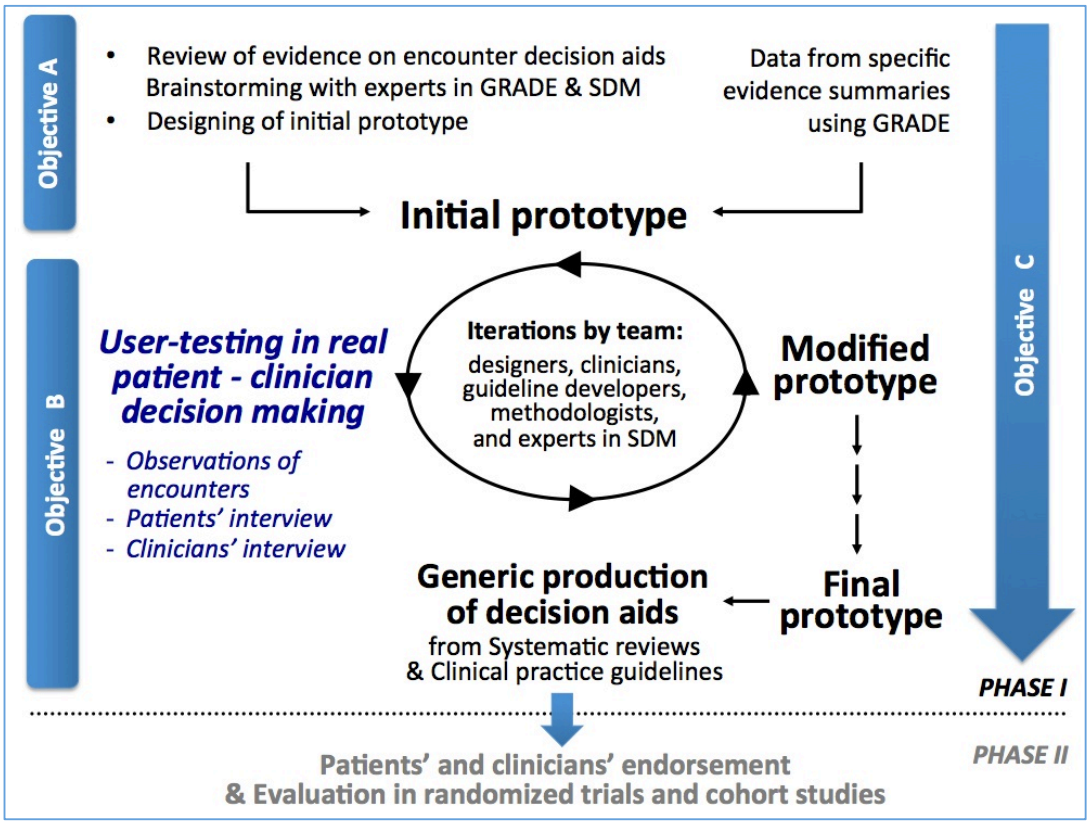
A haematologist expressed surprise that one decision aid regarding long term anticoagulation treatment for patients with unprovoked venous thromboembolism begins by inviting patients to choose which outcome to discuss first (Figure 2). She usually started by discussing the risk of recurrence, then bleeding before inviting patients' questions, omitting mortality.

After we clarified she could use the tool as she wanted, she began with the six month follow-up of a 47 year old man taking rivaroxaban for an unprovoked pulmonary embolism. She explained that, although the treatment was indicated after the acute event, the decision to continue rivaroxaban depended on his preferences. She accessed the decision aid and moved to sit next to the patient. Revising her prior plan to use her accustomed order, she used the trigger sentence offered: "What aspect of your medication would you like to discuss first?" The patient chose "practical consequences" (Figure 5). In the conversation that followed, they further discussed risk of bleeding, recurrence, and associated mortality (Figure 3 & 4). The patient decided to discontinue rivaroxaban.

After the encounter, the clinician pointed out that the patient focused on practical consequences first, and she reflected on how the tool resulted in positive changes to her usual communication strategy. The patient reported that the decision aid made it easier to "digest the information and get the bigger picture." He explained he was first interested by "day-to-day stuff" before exploring "more intimidating" but important issues.

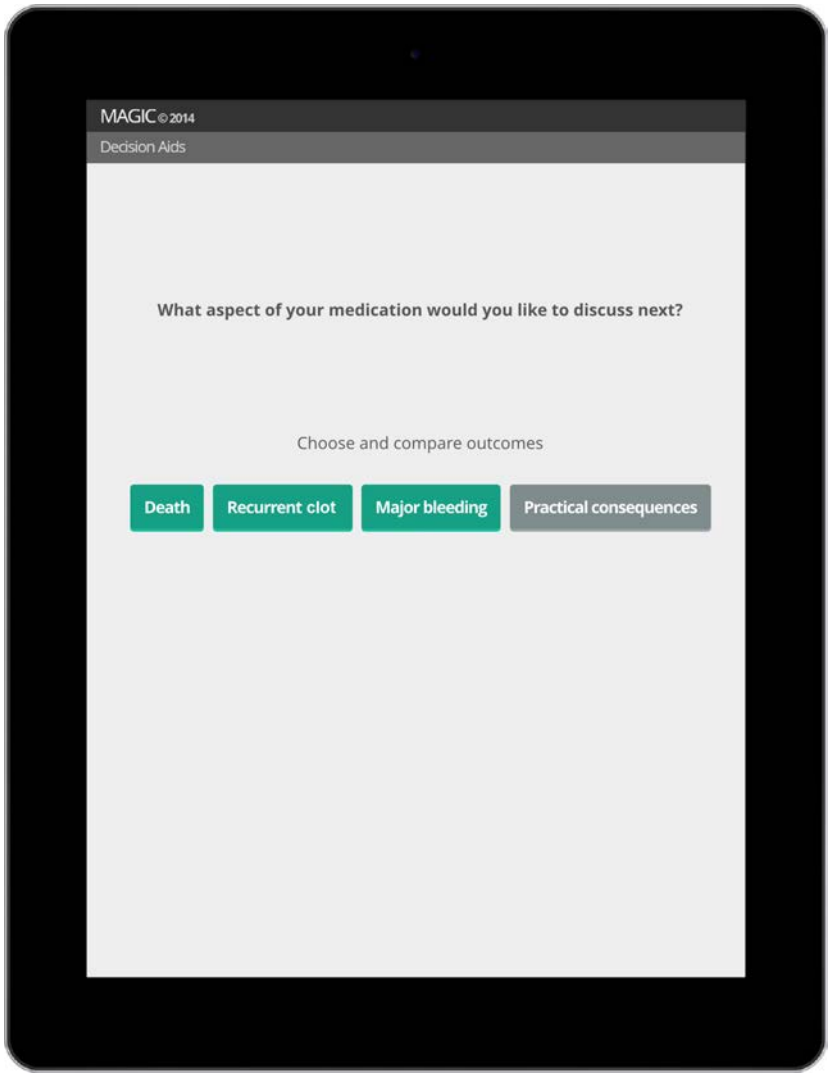
6.8 FIGURES (AND VIDEO)

Figure 6.8.1 Outline of the methods and user-centred approach in the SHARE-IT project



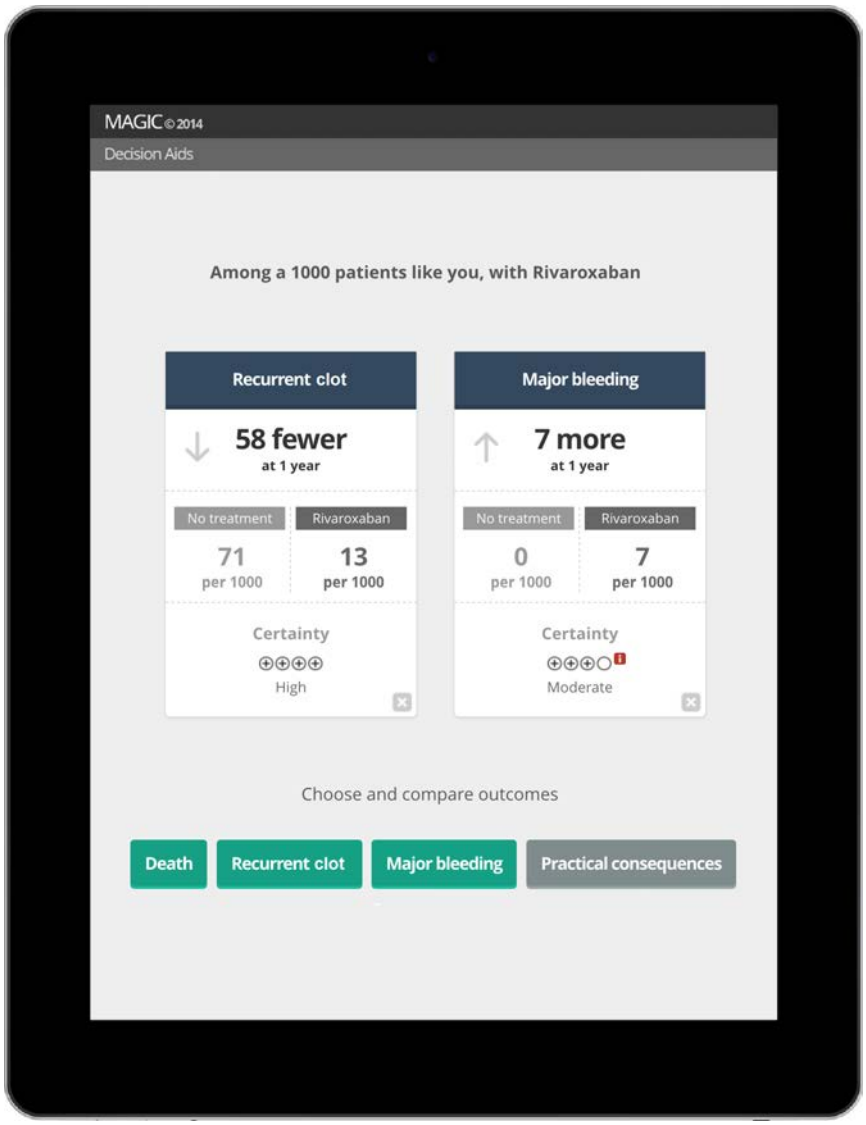
Legend. Outline of the methods and user-centred approach in the SHARE-IT project. Objective A=to develop a framework for the generic translation of GRADE evidence summaries into decision aids; Objective B=to design a set of interactive presentation formats for use in the clinical encounter; Objective C=to test the feasibility of an automated production of these decision aids from electronically published evidence summaries. Subsequent phases of the project involve the generic production of decision aids from real practice guidelines and their evaluation in randomised trials and cohort studies.

Figure 6.8.2 First layer of the decision aid: example for rivaroxaban vs. no treatment for extended anticoagulation for venous thrombo-embolism



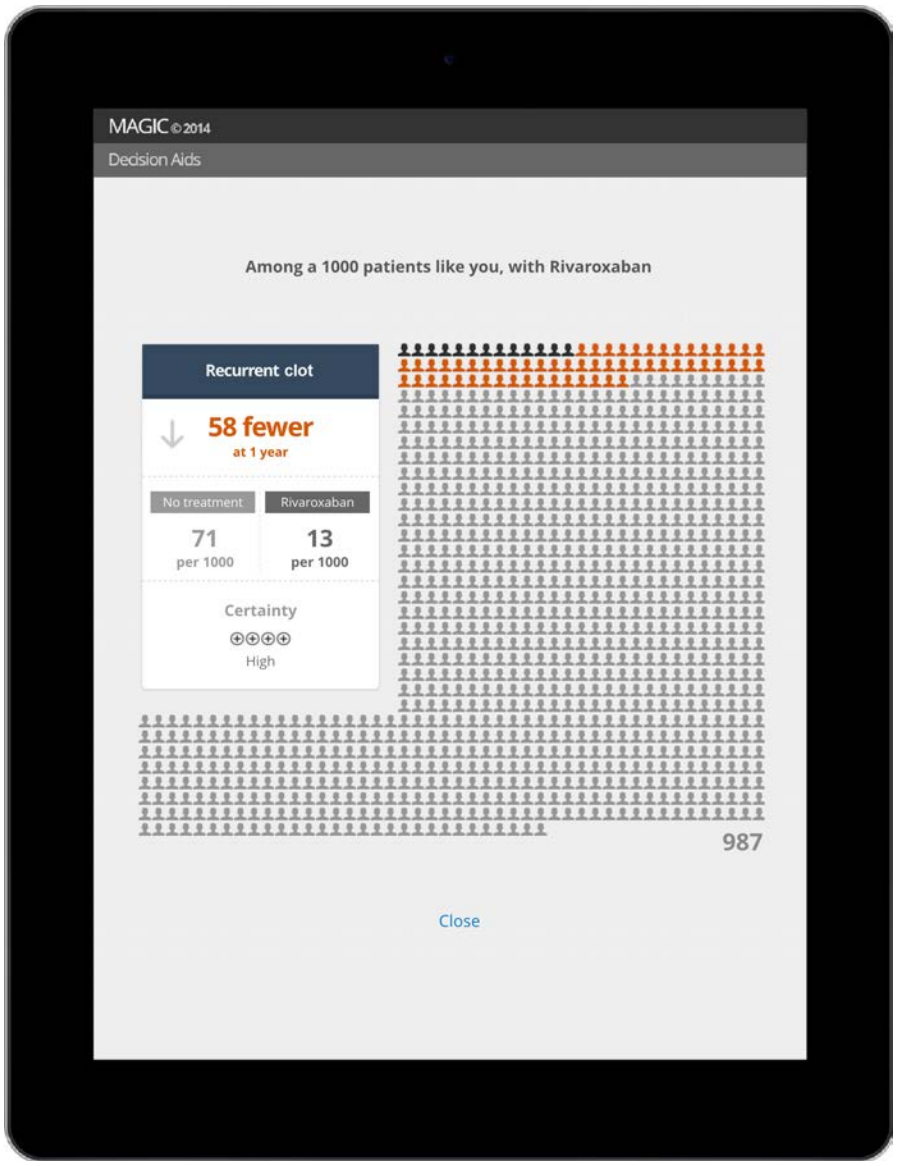
Legend. Accessed by clinicians from the detailed evidence summary or corresponding recommendation in a clinical practice guideline, this first layer of the decision aid displays only the list of patient important outcomes, including practical consequences. Clinicians are prompted to use the trigger sentence – *"What aspect of your medication would you like to discuss next?"* This invites patients to choose which outcome whey want to discuss and in which order, thus offering a first opportunity for a SDM conversation (see example in Box 2).

Figure 6.8.3 Second layer of the decision aid (for numerical outcomes)



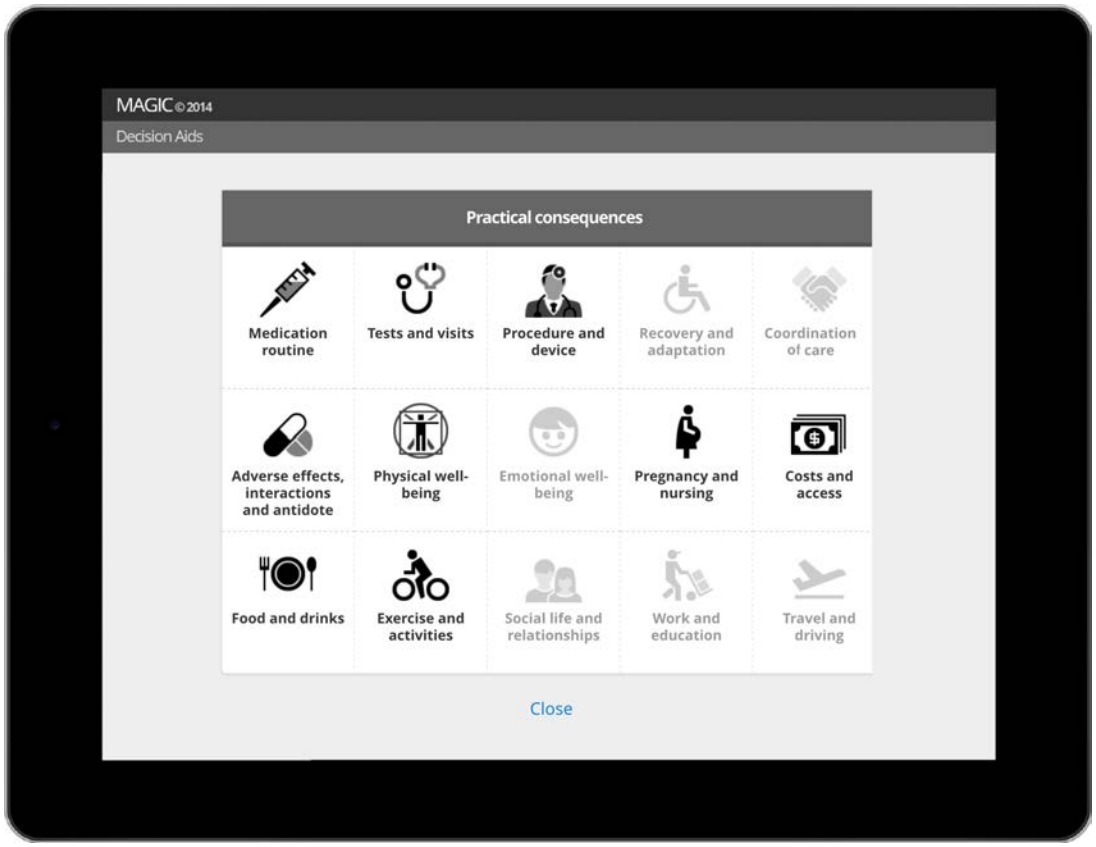
Legend. The second layer displays the gist of numerical outcomes on separate "cards" that allow interactive and direct comparison. The trigger sentence *"Among a 1000 patients like you"* facilitates clinicians in discussing absolute risks. GRADE certainty in estimates of effect is specified with words and symbols (high, moderate, low, or very low). Clicking on each number opens a graphical presentation in the third layer (Figure 4).

Figure 6.8.4 Third layer of the decision aid (for numerical outcomes)



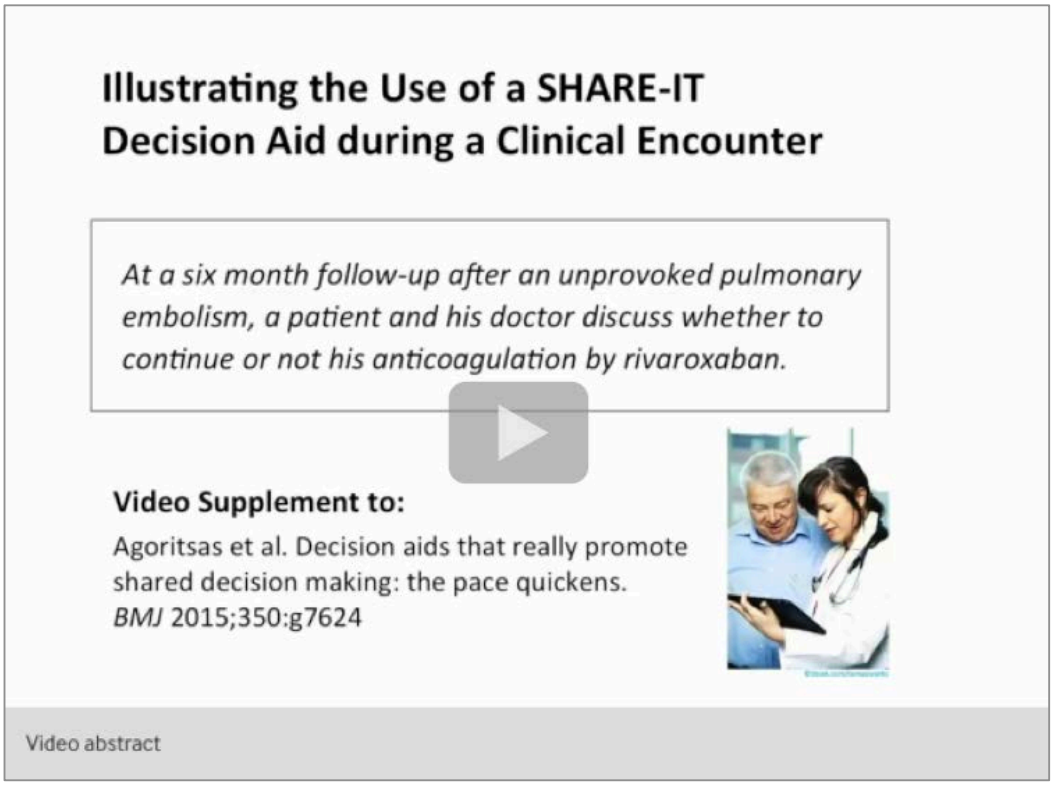
Legend. Clicking on each number of the outcome cards opens a corresponding set of pictographs – e.g., risk of recurrent clot with or without treatment. Both the number of events and the number of non-events are displayed. Clicking at the difference superimposes the pictographs from each option and highlights the absolute risk reduction (in red).

Figure 6.8.5: Discussing practical consequences



Legend. In complement to numerical outcomes from GRADE evidence summaries, the prototype can display practical issues of management options in various formats, from simple text to intuitive icons and labels for an open discussion about what matters most to patients. We show here the most current format, still being tested and refined, which can organize the evidence summary and display across 15 categories, mapped on existing decision aids and patient experience databases.

Video 6.8.6: Demonstration of SHARE-IT Decision Aid during a hypothetical clinical encounter



This video is also embedded within the online version of the published article on: http://www.bmj.com/content/350/bmj.g7624.full.

6.9. AUTHORS' CONTRIBUTIONS, ACKNOWLEDGMENTS & COMPETING INTERESTS

Authors' contribution and sources

The SHARE-IT project was conceived and is mainly funded by the MAGIC program, in close collaboration with the DECIDE project and GRADE working group, to which most contributors are affiliated. The team includes international experts in evidence-based medicine and shared decision making, clinician methodologists and guideline developers, which collaborated across iterations of our framework and prototypes. We also received numerous feedbacks from stakeholders at international meetings, including: the *International Shared Decision Making conference* (Peru, 2013), *Guidelines-International-Network conferences* (USA 2013, Australia 2014), *Cochrane Colloquia* (Canada 2013, India 2014), *GRADE and DECIDE consortium meetings* and conference (Italy 2013, Spain 2014, Scotland 2014).

TA led and coordinated the project, supervised by GHG and POV. TA, AFH, LB, POV developed and implemented the prototype, and all contributors provided feedback at different stages. TA, AFH, POV performed user-testing in clinical encounters. TA drafted the manuscript and all authors critically revised the manuscript. TA is guarantor.

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Competing Interests

The authors have read and understood BMJ policy on declaration of interests and declare the following interests: TA, AFH, LB, AK, PAC, EAA, IN, KAOT, VMM, GHG, POV are members of the GRADE working group (www.gradeworkinggroup.org), as well as co-investigators in the DECIDE project (www.decide-collaboration.eu). TA, AFH, LB, AK, GHG, POV are members of the MAGIC research and innovation program, which is a not-for-profit organization. GE leads the Option Grid® Collaborative, which publishes the tools using a Creative Commons Licence.VMM designs and tests shared decision making tools at the KER UNIT in Mayo Clinic. These tools are then made available for free with no income generated for him, his unit, or his institution.

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ANALYSIS

SPOTLIGHT: PATIENT CENTRED CARE

Decision aids that really promote shared decision making: the pace quickens

Decision aids can help shared decision making, but most have been hard to produce, onerous to update, and are not being used widely. **Thomas Agoritsas and colleagues** explore why and describe a new electronic model that holds promise of being more useful for clinicians and patients to use together at the point of care

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Many, perhaps most, important decisions in medicine are not clear cut.[1 2] Patients and clinicians need to discuss the options using the best available evidence and make informed joint decisions that take account of patients' context, values, and preferences.[3 4] But implementing shared decision making is not easy. Doctors need the skills and tools to do it and to build trust; patients need information and support. Patients also need to have a greater role in developing strategies to improve the process.[5 6]

Access to best evidence is another key ingredient. Until now the production and dissemination of clinical practice guidelines and summaries of evidence has largely been tailored to meet the educational needs of clinicians. They are seldom provided in a format that supports shared decision making.[7] Patients meanwhile, struggle to find reliable and accessible summaries of evidence, although plain language summaries and patient versions of guidelines are being developed.[8]

In this article we highlight the limitations of current decision aids and discuss how the generic production of electronic decision aids designed for use in the clinical encounter, linked directly to trustworthy summaries of evidence from systematic reviews and guidelines, may help in the long march to realising effective shared decision making.

Challenge of shared decision making

Shared decision making depends on a good conversation[9] in which clinicians share information about the benefits, harms, and burden of alternative diagnostic and therapeutic options and patients explain what matters to them and their views on the choices they face.[4 10] It should follow the principles of patient centred care, promote informed choice, and result in care that patients value.[1-11] Many clinicians think they practice shared decision making, but evidence suggest a perception-reality gap[3] because of misconceptions about the nature of shared decision making, the skills it requires, the time it takes, and the degree to which patients, families, and carers wish to share in decision making.[12-14]

Each clinical encounter is influenced by many factors. These include patients' circumstances and medical needs as well as

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their beliefs, stemming from what they have read, personal experience, advice from family and friends, and the media. It is therefore important to provide patients with accurate, up to date evidence on the benefits and harms of alternative management strategies and their likely effect on outcomes that matter to them, although evidence may not always reflect the complexity and multimorbidity of individual patients and patients may choose to ignore the evidence**.** Good shared decision making requires clinicians to have access to detailed knowledge and ideally summaries of the latest evidence and the means to share it in a way that supports thoughtful deliberation, something that cannot be done on the fly.

Limitations of traditional decision aids

For the past two decades enthusiasts have advocated decision aids to facilitate shared decision making, and over 500 have been developed.[15 16] A systematic review of 115 randomised trials showed that their use was associated with a 13% absolute increase in patients' knowledge scores and an 82% relative increase in accurate expectations of possible benefits and harms. Effects on clinical outcomes, adherence to treatment, and use of services have not, however, been consistent.[15 17]

Most decision aids have been designed for patients to use independently outside the consultation, either in the waiting room or at home.[10] Although these decision aids promote understanding of the issues, they cannot guarantee that decisions in the consultation are shared,[3 18] and there is insufficient evidence to determine how their use influences the consultation.[18] Another problem is that use of decision aids in routine care is low,[13] mainly because of poor design and lack of ready access to them. Furthermore clinicians may find the format impractical to use in consultations and may be as unfamiliar as their patients with risk estimates and the inherent uncertainty associated with probabilities.[19]

Traditional decision aids are often not based on current evidence or rapidly outdated, at least in part because of limitations in funding after tool development—and may thus do more harm than good.[20] A rigorous systematic review is needed for each important outcome, and such reviews are often unavailable. A recent assessment found that although around two thirds of decision aids are based on systematic reviews or guidelines, many of these sources are of questionable quality, and only 5% of aids included an "expiry date" or a stated policy about updating.[20]

Ensuring the quality and timeliness of decision aids is a daunting challenge. The work required to summarise evidence for a trustworthy decision aid is similar to that for producing a systematic review or a guideline, suggesting the potential for synergy between the worlds of evidence based practice and shared decision making.[20-22]

Harnessing the potential of recent developments

New decision aids

Some newer decision aids have been designed to facilitate collaborative deliberation in the course of the clinical encounter.[3 10] Montori and colleagues pioneered a user centred approach to producing decision aids through iterative observations of discussions between doctors and patients.[9 23] Their approach resulted in succinct, easy to use tools that provide graphic displays of the benefits and harms of different options organised around concerns that are important to patients (http://shareddecisions.mayoclinic.org). In contrast to traditional aids, which patients use independently, they are not designed to be comprehensive and do not include explicit exercises to help patients clarify their values (such as the relative values of avoiding a stroke versus a gastrointestinal bleed) [24] Instead they rely on the unique conversations that take place between patients and clinicians, with clinicians providing just in time, tailored explanations and information.[10] Direct observations in randomised trials have shown that these short tools (so far available for diabetes, statins, and antidepressants) promote dialogue and increase joint deliberation.[25] They also shift the "body language" as patients and clinicians sit together to review the data.[23 26]

Other short point of care decision aids include Option Grids (www.optiongrid.co.uk).[27 28] These are one page summaries that provide answers to patients' frequently asked questions, covering clinical outcomes and practical concerns faced in daily life. Their value in routine care is being evaluated.[27]

Developments in appraisal and presentation of best evidence

The GRADE approach (Grading of Recommendations Assessment, Development and Evaluation) provides systematic, transparent, and explicit guidance for processing evidence from the medical literature, and has been widely adopted.[7-30] Use of the GRADE approach results in standardised and succinct evidence profiles or summary of findings tables, which specify the absolute effects of an intervention on outcomes important to patients rather than surrogate outcomes and provide a rating of the certainty in these estimates (high, moderate, low, or very low).[30] The recent international patient decision aids standards have emphasised the potential of GRADE for the production of decision aids[20], and it has been adopted by over 80 organisations (www.gradeworkinggroup.org).

Furthermore, clinical practice guidelines using GRADE now issue weak recommendations (in contrast to strong) when there is a close balance between desirable and undesirable outcomes among alternatives, low certainty in estimates of effect, or when there is large variability in patients' values and preferences. Weak recommendations, which dominate in recent high quality guidelines,[2] thus identify decisions where shared decision making is particularly important.[20 22]

Use of new technologies

The not-for-profit MAGIC project (Making GRADE the Irresistible Choice www.magicproject.org) has developed an online "app" with potential to produce electronic decision aids for use in the clinical encounter.[7] This MAGICapp (www.magicapp.org) allows authors of guidelines or systematic reviewers to write evidence summaries into a structured database and appraise them using GRADE criteria. The content can then be published on a web platform and presented in interactive formats on tablets, web portals, or electronic medical record systems.[31]

In the SHARE-IT project, we use this authoring and publication platform for the generic and semi-automated production of a large number of decision aids.[7] The aids can be used with the corresponding systematic review or clinical practice guidelines and the format modified and tailored to specific contexts—for example, published in different languages or adapted to national guidelines.[32 33] The electronic format facilitates continuous updating because the data in the decision aids will change automatically each time the underlying review is modified.[7]

Figure 1⇓ summarises the methods of the SHARE-IT project. In collaboration with DECIDE (www.decide-collaboration.eu),[34]

we gathered an international team of experts in evidence based medicine and shared decision making, clinicians, guideline developers, and designers, and developed an initial framework and electronic prototype for the translation of GRADE summaries into decision aids. We then applied an iterative and user centred design, directly involving patients and clinicians facing real decisions. We built 10 decision aids on antithrombotic drugs and modified the generic prototype in light of observations of their use in practice and individual feedback from patients and clinicians.

The video illustrates how the prototype uses interactive formats to present evidence summaries at varying levels of detail. The prototype shows that the approach is feasible, and preliminary experience suggests it is appreciated by both patients and clinicians (box). Across 16 clinical encounters, patients consistently reported high levels of satisfaction with the prototype in understanding risks and benefits and in enhancing their confidence in decisions (mean scores of 88.7 and 90.9 respectively (maximum 100) as assessed by COMRADE.[35]

Conclusion

No decision aid is sufficient to guarantee that clinical decision making is shared. Undergraduate, postgraduate, and continuing education programmes must teach health professionals about the importance of creating and fostering a culture of shared decision making and the skills needed to communicate evidence, and its limitations, in a way people can understand. Furthermore, the challenge of producing evidence summaries that deal optimally with complexity, multimorbidity, and potentially limited applicability to the patient remains.[36]

We are, however, now in a position to construct, test, and refine electronic evidence summaries for use in the clinical encounter for a wide variety of patient groups and clinical settings. Our prototype, built in the MAGICapp, demonstrates the feasibility of semiautomated production of decision aids from a large number of electronically published evidence summaries. We also plan to implement these formats in another similar platform, the GRADEpro Guideline Development Tool (www.guidelinedevelopment.org). We invite patient organisations, research groups, guideline developers, patients, and clinicians to partner with us (www.magicproject.org) and help us advance the science and art of truly shared and well informed decision making.

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Competing interests: All authors have read and understood BMJ policy on declaration of interests and declare the following interests: TA, AFH, LB, AK, PAC, EAA, IN, KAOT, VMM, GHG, POV are members of the GRADE working group (www.gradeworkinggroup.org), as well as coinvestigators in the DECIDE project (www.decide-collaboration.eu). TA, AFH, LB, AK, GHG, POV are members of the MAGIC research and innovation program. GE leads the Option Grid collaborative. VMM designs and tests shared decision making tools at the KER UNIT in Mayo Clinic. These tools are then made available for free with no income generated for him, his unit, or his institution.

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Reaction to the decision aid

A haematologist expressed surprise that one decision aid regarding long term anticoagulation treatment for patients with unprovoked venous thromboembolism begins by inviting patients to choose which outcome to discuss first. She usually started by discussing the risk of recurrence, then bleeding before inviting patients' questions, omitting mortality.

After we clarified she could use the tool as she wanted, she began with the six month follow-up of a 47 year old man taking rivaroxaban for an unprovoked pulmonary embolism. She explained that, although the treatment was indicated after the acute event, the decision to continue rivaroxaban depended on his preferences. She accessed the decision aid and moved to sit next to the patient. Revising her prior plan to use her accustomed order, she used the trigger sentence offered: "What aspect of your medication would you like to discuss first?" The patient chose "practical consequences." In the conversation that followed, they further discussed risk of bleeding, recurrence, and associated mortality. The patient decided to discontinue rivaroxaban.

After the encounter, the clinician pointed out that the patient focused on practical consequences first, and she reflected on how the tool resulted in positive changes to her usual communication strategy. The patient reported that the decision aid made it easier to "digest the information and get the bigger picture." He explained he was first interested by "day-to-day stuff" before exploring "more intimidating" but important issues.

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Cite this as: *BMJ* 2015;350:g7624

Figure

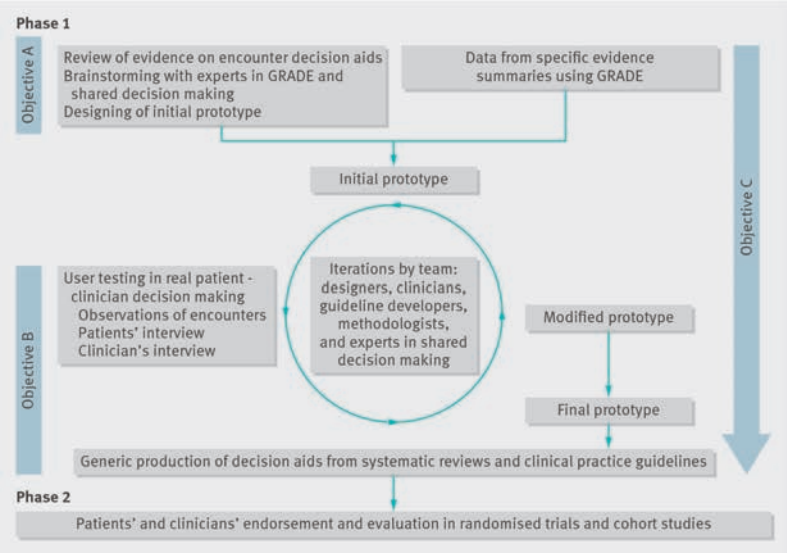


Fig 1 Outline of the methods and user-centred approach in the SHARE-IT project. Objective A=to develop a framework for the generic translation of GRADE evidence summaries into decision aids; Objective B=to design a set of interactive presentation formats for use in the clinical encounter; Objective C=to test the feasibility of an automated production of these decision aids from electronically published evidence summaries. Subsequent phases of the project involve the generic production of decision aids from real practice guidelines and their evaluation in randomised trials and cohort studies

CHAPTER 7

7.1 CONCLUSION

Designed to enhance evidence implementation, the tools presented in these projects are at various stages of development. MacPLUS FS builds on 20 years of experience in the filtering, appraisal and summarization of evidence across top EBM resources worldwide (and to many of which PLUS directly contributes).[1,2] Although we can thus be confident that they address the *structural limitations* of evidence retrieval, the key issue is therefore to enhance the actual *utilization* of the resources. Table 7.1.1 provides a qualitative summary of findings, which show that the different populations included in the MacPLUS FS randomized trials differed both in the baseline frequency of search and access to alerts, as in their responsiveness to the 3 web-based interventions. Future refinements of the interventions, as well as any new ones, would need to be further tailored to the specific needs of each target audience.

In contrast, the tools developed in SHARE-IT are still at an earlier phase of their development. Although early testing holds promise for the translation of evidence summaries into useful tools for shared decision making[3], the issue of their utilization in practice will also arise in the next steps of implementation. For example, once made available in existing guidelines published through online publication platforms such as MAGIC (www.magicapp.org)[4], they would still need

specific interventions to encourage clinicians to actually use them in their practice. These will again need to address educational and logistical barriers to shared decision making.[5,6] As for MacPLUS FS, it is unlikely that "one size fits all", and such interventions could need to be tailored to specific target clinicians (e.g., seasoned physicians vs. trainees vs. nurses) as well as clinical context and patient populations (e.g. chronic outpatients vs. acute care inpatients).

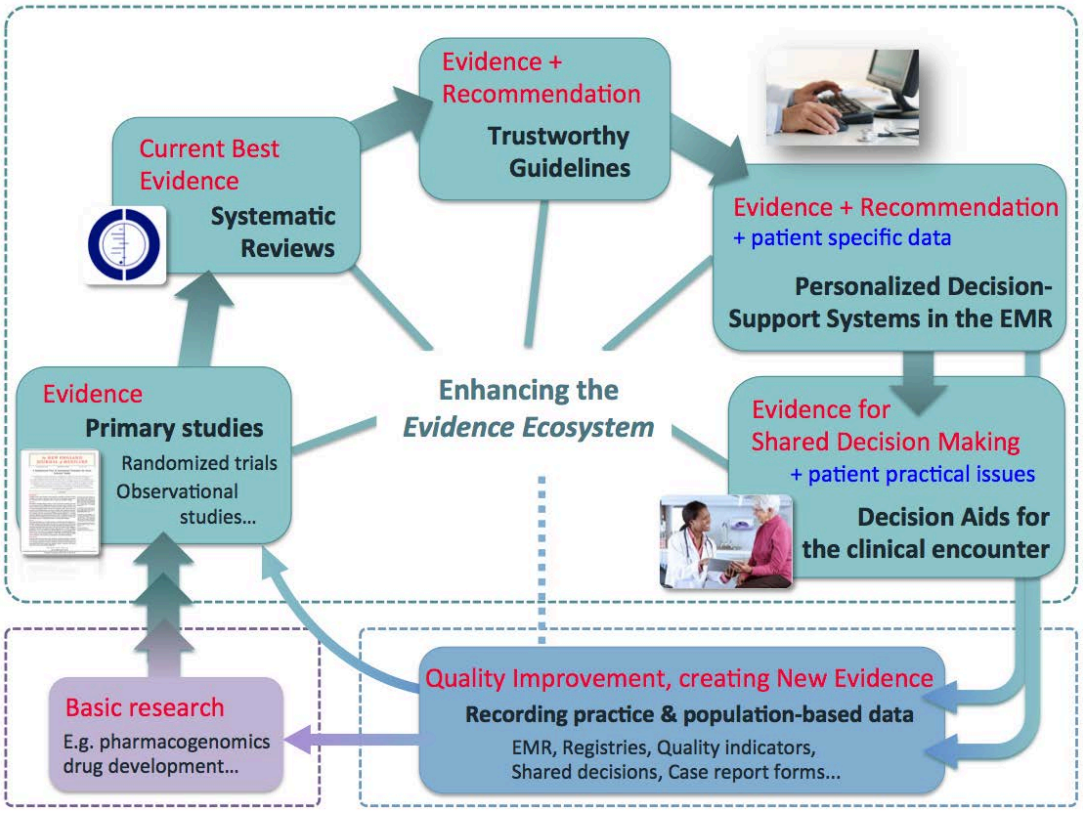
Table 7.1.1 Qualitative Summary of Findings of the MacPLUS FS randomized trials, across the 4 populations tested *

	Medical Faculty (n=477)	**Medical Postgraduate Trainees** (n=431)	**Nursing Students** (n=725)	**Medical Students** (n=235)
Effect of the 3 interventions				
Searching for Current Best Evidence	+++	No effect	++	No effect
Access to Pre-appraised Resources	+++	No effect	++	No effect
Access to New Evidence Alerts	+++	++	No effect	No effect
Additional observations				
Baseline Frequency of Searching	Low	Low	High	Moderate
Baseline Access to Evidence Alerts	Very high	High	Very low	Low
Use of Resources Across the Federated Search	All layers	All layers	All layers	All layers

* See detailed results in Chapter 2 to 5.

Beyond the development of individual tools, evidence implementation could further be enhanced by taking a broader perspective of the current *Evidence Ecosystem*[7].

Figure 7.1.1 The Evidence Ecosystem



As exemplified by the federated search in MacPLUS FS, primary research is continuously produced and processed into systematic reviews, and then into clinical practice guidelines or online summaries (e.g. UpToDate, DynaMed).[8] Furthermore, many groups work on integrating of evidence summaries and recommendations into Electronic Medical Records (EMR – e.g., often using

computerized decision support systems[9,10]), while others focus more on the development of tools for shared decision-making.[3,11] Finally, quality improvement efforts aim at monitoring current practice (e.g. adherence with recommended practice[12]). Each of these 'steps' involves numerous structures, institutions and teams, and each increasingly works with their own software tools (e.g. for evidence screening, abstraction, appraisal, dissemination, searching, etc.).[13] But most structures too often work in silos, often resulting in needless duplications of efforts[7], and most of their software tools are not designed for a seamless transfer of data.[14]

The future of evidence implementation should address these issues and try to harness the full potential of this digital Evidence Ecosystem, through more efficient shared data-models.[7,14] Many of the key ingredients already exist but need more coordination, and at a more global scale.[15] The tools presented in our work are only but one small step into this journey. The goal should be that practicing clinicians and their patients are at once able to continuously access and use current best evidence with minimal effort and for care decisions that patients value.

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