UNIVERSITÉ CLAUDE BERNARD LYON 1

ANNÉE 2022 N° 074

Obstacles et facilitateurs à l'utilisation de systèmes d'aide à la décision médicale en soins primaires: une revue systématique mixte

Barriers and Facilitators to the Use of Clinical Decision Support Systems in Primary Care: a Mixed-Methods Systematic Review

THESE D'EXERCICE EN MEDECINE

Présentée à l'Université Claude Bernard Lyon 1

Et soutenue publiquement le 3 mai 2022

En vue d'obtenir le titre de Docteur en Médecine

Par

Pierre-Yves Meunier

Né le 13 janvier 1992 au Plessis-Bouchard

Sous la direction du Pr Laurent Letrilliart

UNIVERSITE CLAUDE BERNARD LYON 1

Président	Pr Frédéric FLEURY
Présidente du Comité de Coordination des Etudes Médicales	Pr Carole BURILLON
Directeur Général des services	M. Pierre ROLLAND

Secteur Santé

Doyen de l'UFR de Médecine Lyon Est	Pr Gilles RODE
Doyenne de l'UFR de Médecine Lyon-Sud Charles Mérieux	Pr Carole BURILLON
Doyenne de l'Institut des Sciences Pharmaceutiques (ISPB)	Pr Christine VINCIGUERRA
Doyenne de l'UFR d'Odontologie	Pr Dominique SEUX
Directeur de l'Institut des Sciences et Techniques de Réadaptation (ISTR)	Dr Xavier PERROT

Secteur Sciences et Technologie

Administratrice Provisoire de l'UFR BioSciences	Pr Kathrin GIESELER
Administrateur Provisoire de l'UFR Faculté des Sciences et Technologies	Pr Bruno ANDRIOLETTI
Directeur de l'UFR Sciences et Techniques des Activités Physiques et Sportives (STAPS)	M. Yannick VANPOULLE
Directeur de Polytech	Pr Emmanuel PERRIN
Directeur de l'IUT	Pr Christophe VITON
Directeur de l'Institut des Sciences Financières Et Assurances (ISFA)	M. Nicolas LEBOISNE
Directrice de l'Observatoire de Lyon	Pr Isabelle DANIEL
Directeur de l'Institut National Supérieur du Professorat et de l'Education (INSPé)	M. Pierre CHAREYRON
Directrice du Département Composante Génie Electrique et Procédés (GEP)	Pr Rosaria FERRIGNO
Directeur du Département Composante Informatique	Pr Behzad SHARIAT TORBAGHAN
Directeur du Département Composante Mécanique	Pr Marc BUFFAT

Faculté de Médecine Lyon Est
Liste des enseignants 2021/2022

Professeurs des Universités – Praticiens Hospitaliers Classe exceptionnelle Echelon 2

BLAY	Jean-Yves	Cancérologie ; radiothérapie
BORSON-CHAZOT	Françoise	Endocrinologie, diabète et maladies métaboliques ; Gynécologie médicale
CHASSARD	Dominique	Anesthésiologie-réanimation ; médecine d'urgence
CLARIS	Olivier	Pédiatrie
DUCERF	Christian	Chirurgie viscérale et digestive
FINET	Gérard	Cardiologie
GUERIN	Claude	Réanimation ; médecine d'urgence
LACHAUX	Alain	Pédiatrie
LERMUSIAUX	Patrick	Chirurgie thoracique et cardiovasculaire
LINA	Bruno	Bactériologie-virologie ; hygiène hospitalière
MIOSSEC	Pierre	Immunologie
MORNEX	Jean-François	Pneumologie ; addictologie
MOULIN	Philippe	Nutrition
NEGRIER	Sylvie	Cancérologie ; radiothérapie
NIGHOGHOSSIAN	Norbert	Neurologie
OBADIA	Jean-François	Chirurgie thoracique et cardiovasculaire
OVIZE	Michel	Physiologie
PONCHON	Thierry	Gastroentérologie ; hépatologie ; addictologie
REVEL	Didier	Radiologie et imagerie médicale
RIVOIRE	Michel	Cancérologie ; radiothérapie
VANDENESCH	François	Bactériologie-virologie ; hygiène hospitalière
ZOULIM	Fabien	Gastroentérologie ; hépatologie ; addictologie

Professeurs des Universités – Praticiens Hospitaliers Classe exceptionnelle Echelon 1

ARGAUD	Laurent	Réanimation ; médecine d'urgence
BERTRAND	Yves	Pédiatrie
BOILLOT	Olivier	Chirurgie viscérale et digestive
CHEVALIER	Philippe	Cardiologie
COLIN	Cyrille	Epidémiologie, économie de la santé et prévention
COTTIN	Vincent	Pneumologie ; addictologie
D'AMATO	Thierry	Psychiatrie d'adultes ; addictologie
DELAHAYE	François	Cardiologie
DENIS	Philippe	Ophtalmologie
DOUEK	Charles-Philippe	Radiologie et imagerie médicale
DUMONTET	Charles	Hématologie ; transfusion
DURIEU	Isabelle	Médecine interne ; gériatrie et biologie du

		vieillissement ; médecine générale ; addictologie
EDERY	Charles Patrick	Génétique
FROMENT	Caroline	Physiologie
GAUCHERAND	Pascal	Gynécologie-obstétrique ; gynécologie médicale
GUEYFFIER	François	Pharmacologie fondamentale ; pharmacologie clinique ; addictologie
HONNORAT	Jérôme	Neurologie
KODJIKIAN	Laurent	Ophtalmologie
MABRUT	Jean-Yves	Chirurgie générale
MERTENS	Patrick	Anatomie
MORELON	Emmanuel	Néphrologie
RODE	Gilles	Médecine physique et de réadaptation
SCHOTT-PETHELAZ	Anne-Marie	Epidémiologie, économie de la santé et prévention
TRUY	Eric	Oto-rhino-laryngologie
TURJMAN	Francis	Radiologie et imagerie médicale

Professeurs des Universités – Praticiens Hospitaliers
Première classe

ADER	Florence	Maladies infectieuses ; maladies tropicales
AUBRUN	Frédéric	Anesthésiologie-réanimation ; médecine d'urgence
BADET	Lionel	Urologie
BERTHEZENE	Yves	Radiologie et imagerie médicale
BESSEREAU	Jean-Louis	Biologie cellulaire
BRAYE	Fabienne	Chirurgie plastique, reconstructrice et esthétique ; Brûlologie
BUZLUCA DARGAUD	Yesim	Hématologie ; transfusion
CALENDER	Alain	Génétique
CHAPURLAT	Roland	Rhumatologie
CHARBOTEL	Barbara	Médecine et santé au travail
COLOMBEL	Marc	Urologie
COTTON	François	Radiologie et imagerie médicale
DAVID	Jean-Stéphane	Anesthésiologie-réanimation ; médecine d'urgence
DEVOUASSOUX	Mojgan	Anatomie et cytologie pathologiques
DI FILLIPO	Sylvie	Cardiologie
DUBERNARD	Gil	Gynécologie-obstétrique ; gynécologie médicale
DUBOURG	Laurence	Physiologie
DUCLOS	Antoine	Epidémiologie, économie de la santé et prévention
DUMORTIER	Jérome	Gastroentérologie ; hépatologie ; addictologie
FANTON	Laurent	Médecine légale
FAUVEL	Jean-Pierre	Thérapeutique
FELLAHI	Jean-Luc	Anesthésiologie-réanimation ; médecine d'urgence
FERRY	Tristan	Maladies infectieuses ; maladies tropicales
FOURNERET	Pierre	Pédopsychiatrie ; addictologie
GUENOT	Marc	Neurochirurgie
GUIBAUD	Laurent	Radiologie et imagerie médicale
HOT	Arnaud	Médecine interne
JACQUIN-COURTOIS	Sophie	Médecine physique et de réadaptation
JAVOUHEY	Etienne	Pédiatrie
JUILLARD	Laurent	Néphrologie
JULLIEN	Denis	Dermato-vénéréologie
KROLAK SALMON	Pierre	Médecine interne ; gériatrie et biologie du vieillissement ; médecine générale ; addictologie
LEJEUNE	Hervé	Biologie et médecine du développement et de la

		reproduction ;
MERLE	Philippe	Gastroentérologie ; hépatologie ; addictologie
MICHEL	Philippe	Epidémiologie, économie de la santé et prévention
MURE	Pierre-Yves	Chirurgie infantile
NICOLINO	Marc	Pédiatrie
PERETTI	Noël	Nutrition
PICOT	Stéphane	Parasitologie et mycologie
PONCET	Gilles	Chirurgie viscérale et digestive
POULET	Emmanuel	Psychiatrie d'adultes ; addictologie
RAVEROT	Gérald	Endocrinologie, diabète et maladies métaboliques ; gynécologie médicale
RAY-COQUARD	Isabelle	Cancérologie ; radiothérapie
RICHARD	Jean-Christophe	Réanimation ; médecine d'urgence
ROBERT	Maud	Chirurgie digestive
ROMAN	Sabine	Physiologie
ROSSETTI	Yves	Physiologie
ROUVIERE	Olivier	Radiologie et imagerie médicale
ROY	Pascal	Biostatistiques, informatique médicale et technologies de communication
SAOUD	Mohamed	Psychiatrie d'adultes et addictologie
SCHAEFFER	Laurent	Biologie cellulaire
THAUNAT	Olivier	Néphrologie
VANHEMS	Philippe	Epidémiologie, économie de la santé et prévention
VUKUSIC	Sandra	Neurologie
WATTEL	Éric	Hématologie ; transfusion

Professeurs des Universités – Praticiens Hospitaliers
Seconde Classe

BACCHETTA	Justine	Pédiatrie
BOUSSEL	Loïc	Radiologie et imagerie médicale
CHENE	Gautier	Gynécologie-obstétrique ; gynécologie médicale
COLLARDEAU FRACHON	Sophie	Anatomie et cytologie pathologiques
CONFAVREUX	Cyrille	Rhumatologie
COUR	Martin	Médecine intensive de réanimation
CROUZET	Sébastien	Urologie
CUCHERAT	Michel	Pharmacologie fondamentale ; pharmacologie clinique ; addictologie
DI ROCCO	Federico	Neurochirurgie
DUCRAY	François	Neurologie
EKER	Omer	Radiologie ; imagerie médicale
GILLET	Yves	Pédiatrie
GLEIZAL	Arnaud	Chirurgie maxillo-faciale et stomatologie
GUEBRE-EGZIABHER	Fitsum	Néphrologie
HENAINE	Roland	Chirurgie thoracique et cardiovasculaire
HUISSOUD	Cyril	Gynécologie-obstétrique ; gynécologie médicale
JANIER	Marc	Biophysique et médecine nucléaire
JARRAUD	Sophie	Bactériologie-virologie ; hygiène hospitalière
LESCA	Gaëtan	Génétique
LEVRERO	Massimo	Gastroentérologie ; hépatologie ; addictologie
LUKASZEWICZ	Anne-Claire	Anesthésiologie-réanimation ; médecine d'urgence
MEWTON	Nathan	Cardiologie
MEYRONET	David	Anatomie et cytologie pathologiques
MILLON	Antoine	Chirurgie vasculaire ; médecine vasculaire

MOKHAM	Kayvan	Chirurgie viscérale et digestive
MONNEUSE	Olivier	Chirurgie générale
NATAF	Serge	Cytologie et histologie
PIOCHE	Mathieu	Gastroentérologie
RHEIMS	Sylvain	Neurologie
RIMMELE	Thomas	Anesthésiologie-réanimation ; médecine d'urgence
SOUQUET	Jean-Christophe	Gastroentérologie ; hépatologie ; addictologie
THIBAULT	Hélène	Cardiologie
VENET	Fabienne	Immunologie
VOLPE-HAEGELEN	Claire	Neurochirurgie

Professeur des Universités - Classe exceptionnelle

PERRU	Olivier	Épistémologie, histoire des sciences et techniques

Professeur des Universités - Médecine Générale Première classe

FLORI	Marie
LETRILLIART	Laurent

Professeur des Universités - Médecine Générale Deuxième classe

ZERBIB	Yves

Professeurs associés de Médecine Générale

FARGE	Thierry
LAINÉ	Xavier

Professeurs associés autres disciplines

CHVETZOFF	Gisèle	Médecine palliative
GAZARIAN	Aram	Chirurgie Orthopédique

Professeurs émérites

BEZIAT	Jean-Luc	Chirurgie maxillo-faciale et stomatologie
COCHAT	Pierre	Pédiatrie *(en retraite à compter du 01/03/2021)*
CORDIER	Jean-François	Pneumologie ; addictologie
DALIGAND	Liliane	Médecine légale et droit de la santé
DROZ	Jean-Pierre	Cancérologie ; radiothérapie
ETIENNE	Jérôme	Bactériologie-virologie ; hygiène hospitalière
FLORET	Daniel	Pédiatrie
GHARIB	Claude	Physiologie
GUERIN	Jean-François	Biologie et médecine du développement et de la Reproduction ; gynécologie médicale
LEHOT	Jean-Jacques	Anesthésiologie-réanimation ; médecine d'urgence
MAUGUIERE	François	Neurologie
MELLIER	Georges	Gynécologie
MICHALLET	Mauricette	Hématologie ; transfusion
MOREAU	Alain	Médecine générale

NEGRIER	Claude	Hématologie ; transfusion
PUGEAT	Michel	Endocrinologie
RUDIGOZ	René-Charles	Gynécologie
SINDOU	Marc	Neurochirurgie
TOURAINE	Jean-Louis	Néphrologie
TREPO	Christian	Gastroentérologie ; hépatologie ; addictologie
TROUILLAS	Jacqueline	Cytologie et histologie

Maîtres de Conférence – Praticiens Hospitaliers
Hors classe

BENCHAIB	Mehdi	Biologie et médecine du développement et de la reproduction ; gynécologie médicale
BRINGUIER	Pierre-Paul	Cytologie et histologie
CHALABREYSSE	Lara	Anatomie et cytologie pathologiques
HERVIEU	Valérie	Anatomie et cytologie pathologiques
KOLOPP-SARDA	Marie Nathalie	Immunologie
LE BARS	Didier	Biophysique et médecine nucléaire
MENOTTI	Jean	Parasitologie et mycologie
PERSAT	Florence	Parasitologie et mycologie
PIATON	Éric	Cytologie et histologie
SAPPEY-MARINIER	Dominique	Biophysique et médecine nucléaire
STREICHENBERGER	Nathalie	Anatomie et cytologie pathologiques
TARDY GUIDOLLET	Véronique	Biochimie et biologie moléculaire
TRISTAN	Anne	Bactériologie-virologie ; hygiène hospitalière

Maîtres de Conférence – Praticiens Hospitaliers
Première classe

BONTEMPS	Laurence	Biophysique et médecine nucléaire
BUTIN	Marine	Pédiatrie
CASALEGNO	Jean-Sébastien	Bactériologie-virologie ; hygiène hospitalière
CHARRIERE	Sybil	Nutrition
COUTANT	Frédéric	Immunologie
COZON	Grégoire	Immunologie
CURIE	Aurore	Pédiatrie
DURUISSEAUX	Michaël	Pneumologie
ESCURET - PONCIN	Vanessa	Bactériologie-virologie ; hygiène hospitalière
HAESEBAERT	Julie	Médecin de santé publique
JOSSET	Laurence	Bactériologie-virologie ; hygiène hospitalière
LEMOINE	Sandrine	Physiologie
PLOTTON	Ingrid	Biochimie et biologie moléculaire
RABILLOUD	Muriel	Biostatistiques, informatique médicale et technologies de communication
SCHLUTH-BOLARD	Caroline	Génétique
VASILJEVIC	Alexandre	Anatomie et cytologie pathologiques
VLAEMINCK-GUILLEM	Virginie	Biochimie et biologie moléculaire

Maîtres de Conférences – Praticiens Hospitaliers
Seconde classe

BOUCHIAT SARABI	Coralie	Bactériologie-virologie ; hygiène hospitalière
BOUTY	Aurore	Chirurgie infantile
CORTET	Marion	Gynécologie-obstétrique ; gynécologie médicale
HAESEBAERT	Frédéric	Psychiatrie d'adultes ; addictologie
JACQUESSON	Timothée	Anatomie
LACOIN REYNAUD	Quitterie	Médecine interne ; gériatrie ; addictologie
LILOT	Marc	Anesthésiologie, Réanimation, Médecine d'urgence
NGUYEN CHU	Huu Kim An	Pédiatrie
ROUCHER BOULEZ	Florence	Biochimie et biologie moléculaire
SIMONET	Thomas	Biologie cellulaire
VILLANI	Axel	Dermatologie, vénéréologie

Maîtres de Conférence – Classe normale

DALIBERT	Lucie	Epistémologie, histoire des sciences et techniques
GOFFETTE	Jérôme	Epistémologie, histoire des sciences et techniques
LASSERRE	Evelyne	Ethnologie préhistoire anthropologie
LECHOPIER	Nicolas	Epistémologie, histoire des sciences et techniques
NAZARE	Julie-Anne	Physiologie
PANTHU	Baptiste	Biologie Cellulaire
VIALLON	Vivian	Mathématiques appliquées
VIGNERON	Arnaud	Biochimie, biologie
VINDRIEUX	David	Physiologie

Maitres de Conférence de Médecine Générale

CHANELIERE	Marc
LAMORT-BOUCHE	Marion

Maîtres de Conférences associés de Médecine Générale

BREST	Alexandre
DE FREMINVILLE	Humbert
PERROTIN	Sofia
PIGACHE	Christophe
ZORZI	Frédéric

COMPOSITION DU JURY

Président

Pr François GUEYFFIER

Professeur des Universités de Pharmacologie Clinique, Université Lyon 1, CNRS UMR5558, Hospices Civils de Lyon

Assesseurs

Pr Philippe MICHEL

Professeur des Universités de Santé Publique, Université Lyon 1, Inserm U1290, Directeur Qualité, Usagers et Santé Populationnelle, Hospices Civils de Lyon.

Pr Laurent LETRILLIART

Professeur des Universités de Médecine Générale, Université Lyon 1, Inserm U1290, Directeur du Collège Universitaire de Médecine Générale

Dr Emmanuel VIRY

Médecin généraliste libéral, Lyon 8, Maître de Stage des Universités, Université Lyon 1

SERMENT D'HIPPOCRATE

Je promets et je jure d'être fidèle aux lois de l'honneur et de la probité dans l'exercice de la Médecine.

Je respecterai toutes les personnes, leur autonomie et leur volonté, sans discrimination.

J'interviendrai pour les protéger si elles sont vulnérables ou menacées dans leur intégrité ou leur dignité. Même sous la contrainte, je ne ferai pas usage de mes connaissances contre les lois de l'humanité.

J'informerai les patients des décisions envisagées, de leurs raisons et de leurs conséquences. Je ne tromperai jamais leur confiance.

Je donnerai mes soins à l'indigent et je n'exigerai pas un salaire au-dessus de mon travail.

Admis dans l'intimité des personnes, je tairai les secrets qui me seront confiés et ma conduite ne servira pas à corrompre les mœurs.

Je ferai tout pour soulager les souffrances. Je ne prolongerai pas abusivement la vie ni ne provoquerai délibérément la mort.

Je préserverai l'indépendance nécessaire et je n'entreprendrai rien qui dépasse mes compétences. Je perfectionnerai mes connaissances pour assurer au mieux ma mission.

Que les Hommes m'accordent leur estime si je suis fidèle à mes promesses. Que je sois couvert d'opprobre et méprisé si j'y manque.

REMERCIEMENTS

Monsieur le Professeur Laurent LETRILLIART,
Je te remercie vivement d'avoir dirigé ma thèse avec autant de disponibilité et de bienveillance. Nos travaux en commun m'ont passionné et m'ont beaucoup appris.

Monsieur le Professeur François GUEYFFIER,
Merci d'avoir accepté de présider le jury de cette thèse. Je vous remercie d'avoir pris le temps de nos échanges, et de l'intérêt que vous portez à ce travail.

Monsieur le Professeur Philippe MICHEL,
Merci d'avoir accepté de juger ce travail.

Monsieur le Docteur Emmanuel VIRY,
Merci de ton accompagnement pendant mon stage d'internat et de ta confiance lors de mes remplacements. Je salue ta simplicité dans la transmission de ton art. Merci de ta participation au jury.

Monsieur le Docteur Maxime BONJOUR, Monsieur le Docteur Mathieu FAUVERNIER du service de Biostatistiques des Hospices Civils de Lyon,
Merci de nos échanges intéressants et de votre avis statistique sur ce travail.

Monsieur Bastien BLANCHON, Monsieur Colin SIDRE de la Bibliothèque Inter-Universitaire de Santé de Paris,
Merci de votre aide à la rédaction des équations de recherche pour chaque base de données.

Monsieur Philip ROBINSON, de la Direction de la Recherche Clinique des Hospices Civils de Lyon
Merci de vos précieux commentaires à la relecture du manuscrit en langue anglaise.

Camille RAYNAUD et Emmanuelle GUIMARAES,
Merci de vos contributions à ce travail, sans lesquelles il n'aurait pas pu voir le jour. Camille, merci de la qualité de ton travail. Merci aussi pour ta curiosité, ta bonne humeur et ta persévérance sans faille ! Emmanuelle, merci du temps consacré, de ton niveau d'exigence dans l'analyse des données et de ta patience lors de l'étape de recherche de consensus.

Merci aux **patients** rencontrés alors que j'étais en apprentissage ; il n'est sûrement pas évident d'accepter de se livrer et d'être examiné par un étudiant. J'ai également eu la chance de travailler avec plusieurs figures d'humanité et de compétence pendant ma formation médicale. Veuillez recevoir l'expression de ma gratitude et mes remerciements les plus vifs pour le temps que vous avez voulu me donner. Merci en particulier

- à **l'équipe paramédicale de soins palliatifs du centre Jeanne Garnier**
- à **l'équipe médicale et paramédicale des urgences de l'hôpital Lariboisière** où j'ai bénéficié pendant l'externat d'un compagnonnage lors de gardes volontaires
- au **Dr Yacine Tandjaoui-Lambiotte**, pneumologue
- au **Pr Dominique Valla,** hépatologue
- au **Dr Catherine Viezzi**, gériatre
- au **Dr Marianne Vasseur**, médecin généraliste
- au **Dr Etienne Deslandes, Dr Pierre Genot, Dr Olivier Beley**, médecins généralistes
- au **Dr Catherine Grosrey**, médecin généraliste
- au **Dr Céline Humbert-Gimeno**, médecin généraliste
- au **Dr Cédric Luyton**, **Dr Yves Roux** et **Dr Lucien Marchand**, endocrinologues
- aux **secrétaires** avec qui j'ai pu travailler, pour leur bienveillance et leur amitié
- à mes **co-internes**

Merci à la chouette **équipe de la maison médicale Beauvisage de Lyon 8** qui m'a accueilli d'abord comme interne puis comme remplaçant et bientôt comme collaborateur. Je mesure ma chance de travailler avec vous. Merci en particulier au **Dr France Bardonnet** pour ta confiance lors de mes remplacements.

Mes **amis** savent mon amitié sincère et fidèle, et ils me reconnaîtront sûrement dans cette sobre dédicace !

Merci à **mes parents** pour tout, et pour ce que vous avez su me transmettre. Merci à **ma famille** pour son soutien.

Emmanuelle, merci de partager ta vie avec moi !

TABLE DES MATIERES

INTRODUCTION GENERALE

1. Introduction

1.1. Les outils de la santé numérique

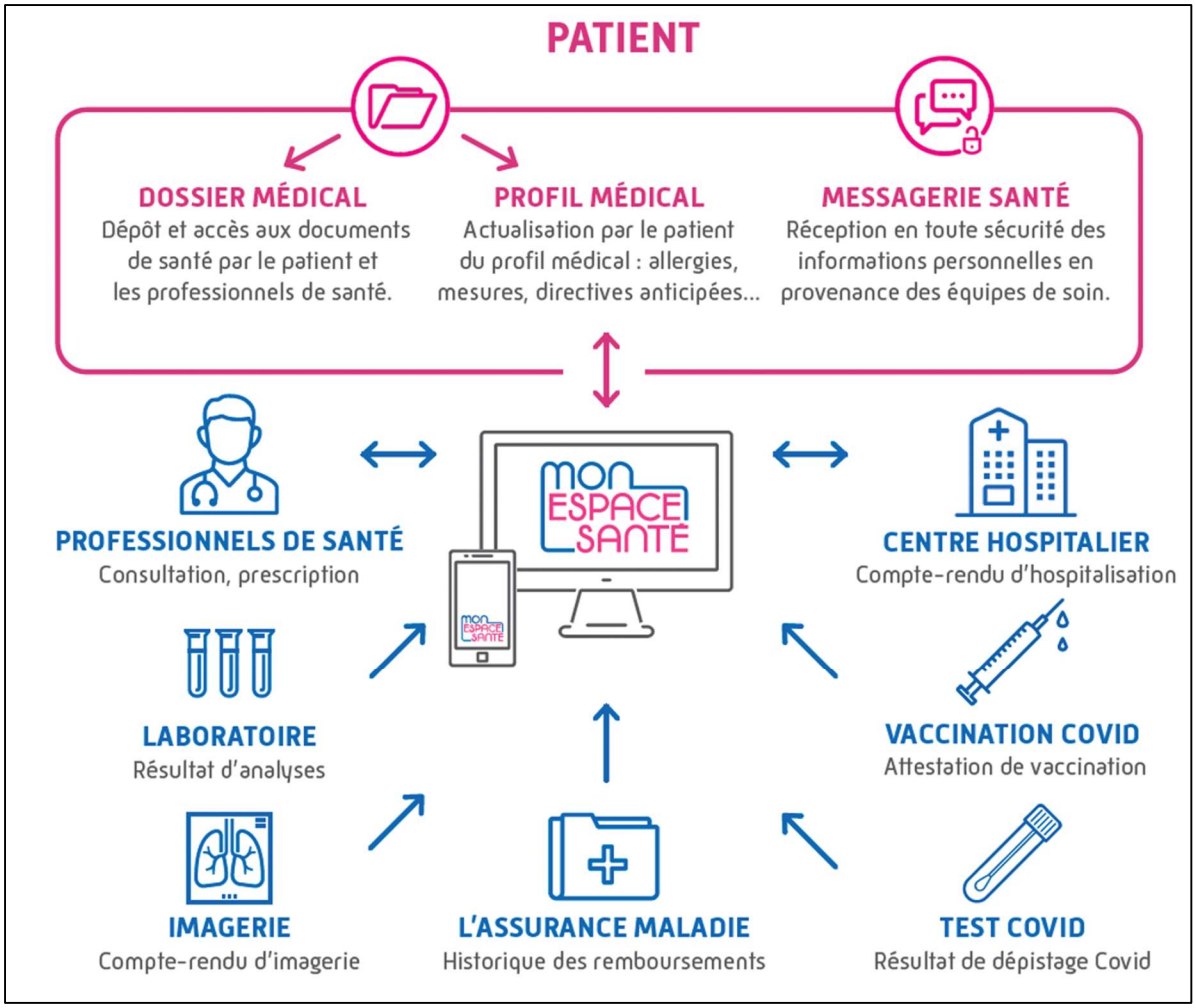
La santé numérique (ou e-santé) est l'application des technologies de l'information et de la communication[1] au domaine de la santé.(1) Elle contribue à trois objectifs : la facilitation de l'accès aux soins, l'amélioration de l'efficience, de la qualité et de la sécurité des soins, et la mise en valeur et la sécurisation des données de santé. Ces deux derniers objectifs servent l'idéal d'une médecine des « 5P » : personnalisée, préventive, prédictive, participative, et basée sur les preuves. A ce titre, la transformation numérique de la santé est considérée par l'Organisation Mondiale de la Santé comme une priorité stratégique.(2) Elle englobe une grande diversité d'outils :

- Facilitation de l'accès aux soins
  - Plateformes en ligne de prise de rendez-vous
  - Systèmes de télémédecine
- Amélioration de l'efficience, de la qualité et de la sécurité des soins
  - La « m-santé » (pour mobile-santé) : applications mobiles de santé à destination des patients (prévention et conseils personnalisés). En 2021, 23% des Français disposent d'un objet de m-santé. Ceux-ci sont parfois connectés à du matériel implanté ; par exemple des pompes à insuline connectées à des capteurs de glucose interstitiel et à des applications de suivi, permettant le partage de données avec les professionnels de santé, ou des défibrillateurs implantés connectés avec envoi de rapports automatiques au médecin référent.
  - Systèmes d'aide à la décision médicale, logiciels d'aide à la prescription
  - Applications d'intelligence artificielle et analyse des données massives de santé
  - Systèmes d'information de gestion logistique
  - Registres d'identification et annuaires
  - Systèmes de communication avec le patient ; par exemple, outils de rappels de rendez-vous ou rappels automatisés d'éligibilité à un dépistage organisé, etc.

[1] Les technologies de l'information et de la communication (TIC) sont les technologies qui concourent à la visualisation, au traitement, au stockage et à la transmission de l'information par des moyens électroniques.

- <u>Mise en valeur et sécurisation des données de santé</u>
  - Dossier médical électronique
  - Systèmes de gestion de l'information sanitaire ; par exemple en France, le portail AMELI de l'assurance maladie, la base de données SIDEP mise en place lors de l'épidémie de Covid-19, ou le très récent portail « Mon Espace Santé » déployé en France depuis avril 2022 et qui intègre le dossier médical partagé (cf. Figure 1)
  - Bases de données de santé
  - Normes d'interopérabilité

Figure 1: Schéma fonctionnel du portail de santé publique « Mon Espace Santé »



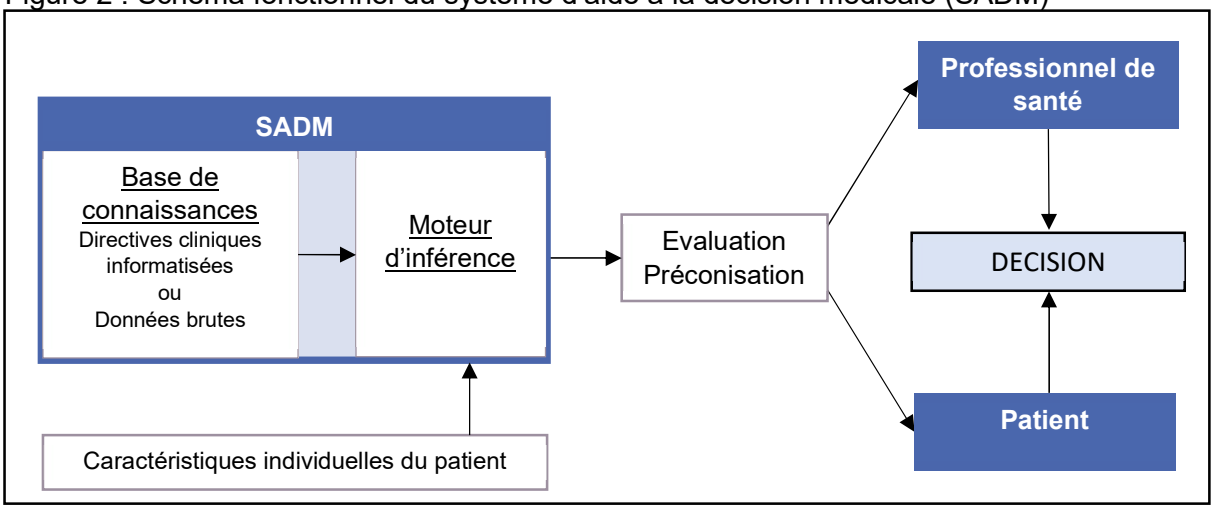
1.2. Les systèmes d'aide à la décision médicale et la médecine fondée sur les faits prouvés

Les multiples défis du système de santé ainsi que les outils de santé numérique susceptibles d'y répondre ont été récemment définis et classifiés par l'OMS, dans l'objectif de standardiser leur dénomination courante et de faciliter leur articulation et leur évaluation.(3) Parmi ces outils, les systèmes d'aide à la décision médicale (SADM) sont des logiciels conçus pour être une aide directe à la prise de décision clinique, dans lequel un moteur d'inférence met en correspondance les caractéristiques individuelles du patient avec une base de connaissances informatisée ou un algorithme d'apprentissage automatique pour proposer au professionnel de santé et/ou au patient une évaluation de risque ou des préconisations adaptées.(4,5) Ils sont développés depuis les années 1960-70, où la recherche sur les « systèmes experts » s'associe à une tentative de modélisation du raisonnement clinique.[2] Ils suscitent aujourd'hui un intérêt de santé publique dans l'objectif d'améliorer l'efficience, la qualité et la sécurité des soins. Cet intérêt s'est développé avec le constat de la variabilité des pratiques médicales qui a conduit au nouveau paradigme de la médecine fondée sur les faits prouvés. La médecine fondée sur les faits prouvés, ou médecine factuelle (Evidence-Based Medicine, EBM) est une méthode des méthodes de recherche clinique qui est l'aboutissement de mouvements débutés dès le 18e siècle et qui promeuvent la statistique expérimentale dans ce qu'elle peut donner un statut de science à la médecine. A partir des années 1970, la Food and Drug administration aux Etats-Unis impose aux laboratoires pharmaceutiques de prouver l'efficacité des médicaments avant leur mise sur le marché. Le constat par Sir Archibald Cochrane de la variabilité des pratiques médicales donne un argument supplémentaire de santé publique au contrôle de la validité des preuves médicales, dans l'idée de réduire les dépenses publiques liées aux traitements inutiles ou moins efficaces que d'autres et pour permettre au plus grand nombre d'accéder aux soins. C'est par une triple justification philosophique (conditions d'accès de la médecine au statut de science), médico-économique (nécessité de maîtriser les couts pour soigner le plus grand monde qui légitime le pouvoir normatif de la santé publique) et pratique (l'augmentation exponentielle du nombre de publication scientifiques est incompatible avec le temps médical et la synthèse méthodique des connaissances les plus fiables est nécessaire pour le soignant) que l'EBM s'impose comme une méta-méthode de recherche en médecine. Elle légitime les faits prouvés issus de la recherche clinique en fonction de la validité interne des études dont ils sont issus. Elle vise à assurer définitivement la supériorité épistémique des faits prouvés issus de la statistique expérimentale face au jugement clinique général des cliniciens. Ce jugement clinique général est un argument d'autorité fondé sur

[2] Feinstein a ainsi proposé une théorie du raisonnement physiopathologique dans une série d'articles publiés au début des années 1970.(6)

l'expérience personnelle des conséquences des décisions médicales. La médecine factuelle se définit par l'articulation de trois sphères de savoirs pour aboutir à une bonne décision : les faits prouvés, l'expertise du praticien, et les préférences du patient. Les SADM s'inscrivent dans la médecine factuelle par la production de préconisations ou d'évaluations individualisées qui assistent la décision médicale partagée. Un schéma fonctionnel de SADM est représenté dans la figure 2, et la figure 3 représente les défis du système de santé identifiés par l'OMS auxquels ils sont susceptibles de répondre.

Figure 2 : Schéma fonctionnel du système d'aide à la décision médicale (SADM)

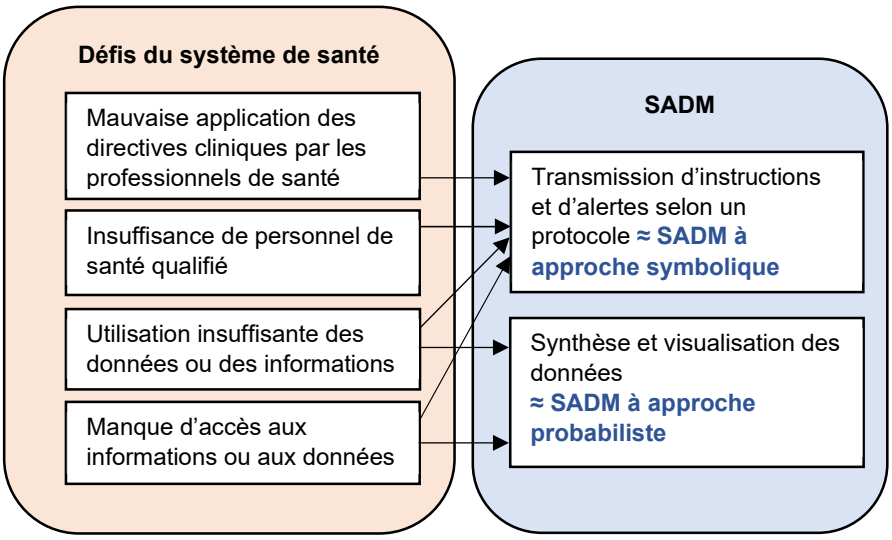


1.3. Enjeux épistémologiques liés à l'utilisation des SADM

Parmi ces défis du système de santé, la mauvaise application des directives cliniques par les professionnels de santé s'explique par une diversité de facteurs(7) : par exemple, la méconnaissance des directives ou leur difficulté d'accès dans le temps contraint de la consultation sont bien connus des praticiens de soins primaires qui font face à une grande diversité de problèmes de santé. Le SADM peut répondre à ce défi en présentant au médecin et/ou au patient une préconisation individualisée et basée sur les preuves au moment opportun. En retour, cette fonctionnalité soulève des enjeux liés à la justification du choix des directives cliniques implémentées, à l'explicabilité de la préconisation ainsi qu'à la présentation de son niveau de preuve. De plus, la réponse à ce défi n'est que partielle car le SADM ne résout pas certains de ses facteurs explicatifs comme le conflit entre la directive clinique et l'expertise ou les croyances du praticien. Certains SADM sont développés pour répondre au défi identifié par l'OMS de l'insuffisance de personnel de santé qualifié.(8–10) Leur utilisation permet de guider la prise en charge de patients par des professionnels de santé paramédicaux grâce au suivi de protocoles standardisés qui limitent le recours à un avis médical.

Ces deux derniers défis décrits par l'OMS font le plus souvent intervenir des SADM à approche symbolique[3], dont la base de connaissance est constituée de directives cliniques informatisées. On pourrait estimer que cette approche procédurale ou protocolaire de la décision médicale ne serait utile ou justifiable que dans des pays où l'accès à un médecin est très limité, ce qui fait de lui un intervenant de deuxième recours.

Figure 3 : Interventions de santé numérique du SADM face aux défis du système de santé : une conceptualisation selon la taxonomie de l'OMS (3)



Pourtant cet enjeu est moindre en France et dans d'autres pays au développement comparable, alors que les SADM qui y sont développés et utilisés sont le plus souvent à approche symbolique.(11) En France, certains SADM à approche symbolique simple[4] sont plébiscités par les médecins généralistes.(12,13) Ils permettent au praticien de résoudre d'une part un besoin d'information non satisfait(14) (« quelle posologie pour la pyélonéphrite de cet enfant ? ») qui correspond au défi identifié par l'OMS du manque d'accès aux informations ou aux données, et d'autre part de résoudre un besoin d'information non identifié (l'oubli par le praticien de la prise en compte de la fonction rénale du patient) qui correspond au défi identifié par l'OMS de l'utilisation insuffisante des données ou des informations. Par exemple, *Antibioclic* est un SADM en ligne[5] destiné aux médecins généralistes ; il produit une préconisation individualisée concernant l'indication et le traitement de diverses infections. Son objectif est de limiter l'antibiorésistance à l'échelle populationnelle en considérant également le coût, la facilité de prise, et la tolérance des antibiotiques. Il a une utilité pratique pour le

[3] En anglais, « *knowledge based CDSSs* »
[4] Non intégrés au dossier médical électronique, nécessitant une double saisie des données, ciblant peu de procédures de soins ou prenant en considération peu de caractéristiques individuelles, tels qu'Antibioclic
[5] Antibioclic.com : SADM en ligne développé et financé par trois sociétés savantes françaises : la SPILF (Société de Pathologie Infectieuse de Langue Française), le CMG (Collège de Médecine Générale), et le CNGE (Collège National des Généralistes Enseignants)

médecin généraliste qui y trouve différentes directives cliniques régulièrement mises à jour et adaptées à la situation individuelle du patient[6].

Si ces SADM symboliques semblent utiles dans tous les contextes de soins, leur efficacité n'est pas encore prouvée en soins primaires sur des critères de mortalité, de morbidité, ou d'amélioration du taux de décisions conformes aux directives cliniques.(15–17) De plus, leur utilisation en dehors de systèmes de santé précaires pourrait présenter le risque de dévoyer le paradigme de la médecine fondée sur les faits prouvés en réduisant le processus décisionnel à une procédure a-rationnelle[7]. Le praticien pratiquerait moins une médecine centrée sur le patient qu'une médecine centrée sur le problème.(18,19) En effet, si ces SADM permettraient aux médecins de déléguer des décisions simples et ainsi de libérer du temps médical, ils pourraient aussi les réduire à un rôle de technicien à l'esprit critique émoussé par le biais d'automatisation(20) qui consiste à valider une préconisation issue d'un algorithme informatique réputé fiable. Ainsi, les SADM à approche symbolique devraient autant que possible proposer des préconisations sous une forme qui facilite la délibération avec le patient plutôt que sous une forme paternaliste. Bien que cette crainte d'une standardisation du soin ne soit pas nouvelle, la capacité du SADM à faire des inférences et à proposer des préconisations individualisées au cœur du colloque singulier entre le soignant et le soigné justifie sa reformulation. Alors que la médecine fondée sur les faits prouvés ambitionne à ses débuts d'assurer la scientificité de la médecine par la mise en œuvre de méthodes de recherche rationnelles, l'enjeu n'est sans doute plus de défendre la science médicale mais de marquer ses limites pour assurer au médecin sa capacité à assumer son rôle de garantie humaine.(21)

Les SADM à approche probabiliste s'opposent aux SADM à approche symbolique car ils se basent sur des données plutôt que des connaissances structurées.(22) Ils permettent de calculer des risques individualisés, comme le risque cardiovasculaire. Sans l'aide du SADM, cette évaluation du risque et des bénéfices attendus d'interventions préventives est inaccessible par le médecin qui n'a ni les capacités ni le temps de faire ces calculs. Les SADM à approche probabiliste répondent donc aux défis décrits par l'OMS de l'utilisation insuffisante des données et du manque d'accès aux informations utiles à la décision médicale partagée. En effet, l'évaluation de risque présentée par le SADM permettrait au médecin de mieux décider avec son patient du traitement de chaque facteur de risque, en

[6] Le SADM *Antibioclic* prend en compte cinq variables individuelles : adulte, enfant, grossesse, allaitement, insuffisance rénale.

[7] Selon le concept de rationalité procédurale proposé dans les années 1970 par Herbert Simon, ce n'est pas la procédure, si fiable soit-elle, qui fonde la rationalité d'une décision : c'est plutôt le caractère approprié de la réflexivité dans la délibération

fonction de l'impact de celui-ci sur des évènements de santé que le patient souhaite éviter. Ces outils proposent une évaluation plutôt qu'une préconisation ; ils promettent une délibération riche et éclairée avec le patient mais ils ne doivent cependant pas faire oublier l'incertitude associée aux risques calculés[8] ainsi que leur explicabilité.

La santé numérique est donc associée à des enjeux majeurs qui sont liés à la modification de la pratique du soin, depuis la prise de rendez-vous jusqu'à la prise de décision partagée. Dès 1998, l'utilité potentielle des technologies de l'information et de la communication pour la santé faisaient pressentir à des praticiens de soins primaires la problématique essentielle de la conciliation entre la pratique d'une médecine centrée sur le patient et l'utilisation d'outils de santé numérique comme instruments de standardisation du soin.(23) Au plan économique, le marché de la santé numérique avait une valeur mondiale de 90 milliards d'euros en 2019 et sa croissance entre 2019 et 2023 est attendue à 160%. Au plan éthique, les acteurs institutionnels, les chercheurs et les praticiens ont la responsabilité de prendre en compte une diversité d'enjeux, parmi lesquels la sécurité du stockage et de l'accès aux données de santé, l'accompagnement de l'illectronisme chez des patients âgés ou porteurs de handicap et plus largement la prise en compte du niveau de littératie en santé du fait que les patients sont inégalement limités dans leur capacité à comprendre les enjeux et informations de santé.

1.4. Objectif de la thèse

La nécessité de développer des SADM à la fois efficaces, utiles et applicables justifie l'exploration des obstacles et facilitateurs à leur utilisation, qui peuvent être intrinsèques (aspects techniques) ou extrinsèques (humains, organisationnels). A cette fin, plusieurs revues systématiques ont évalué des SADM particuliers selon leur type ou les procédures de soins ou problèmes de santé ciblés, mais aucune n'a évalué les obstacles ou facilitateurs à leur utilisation en soins primaires. Pourtant, leur utilisation dans ce contexte peut être associée à des obstacles et facilitateurs spécifiques. Ce travail de thèse a consisté à réaliser une revue systématique dont l'objectif était d'identifier et de quantifier les obstacles et facilitateurs à l'utilisation de systèmes d'aide à la décision médicale en soins primaires. Ses résultats offrent un éclairage de terrain qui devrait contribuer à la construction participative d'un système d'aide à la décision partagée.

[8] Cet enjeu correspond à la validité externe des modèles d'effets. Par exemple, un surrisque présenté en pourcentage par rapport à une population non exposée (risque relatif) doit s'interpréter en fonction du risque absolu qui peut être différent de la population d'étude sur lequel se base le modèle d'effet. De même, le risque est assorti d'un intervalle de confiance puisqu'il se base sur des données populationnelles. Pour en savoir plus, lire É. Giroux, « Chapitre 10. Les modèles de risque en médecine. Quelles conséquences pour la définition des normes et pour le jugement clinique ? Exemple du calcul du risque cardiovasculaire global », dans L'émergence de la médecine scientifique, s. l., Éditions Matériologiques, 2012

2. Références de l'introduction générale

1. [En ligne]. Organisation Mondiale de la Santé. Global Observatory for eHealth; 2022 [cité le 27 mars 2022]. Disponible: https://www.who.int/observatories/global-observatory-for-ehealth

2. Organisation mondiale de la Santé. Stratégie mondiale pour la santé numérique 2020-2025 [En ligne]. Genève : Organisation mondiale de la Santé; 2021 [cité le 11 avr 2022]. 54 p. Disponible: https://apps.who.int/iris/handle/10665/344250

3. [En ligne]. Organisation Mondiale de la Santé. Classification des interventions de santé numérique; 2022 [cité le 27 mars 2022]. Disponible: https://apps.who.int/iris/handle/10665/352499

4. Sim I, Gorman P, Greenes RA, Haynes RB, Kaplan B, Lehmann H, et al. Clinical decision support systems for the practice of evidence-based medicine. J Am Med Inform Assoc déc 2001;8(6):527-34.

5. Sutton RT, Pincock D, Baumgart DC, Sadowski DC, Fedorak RN, Kroeker KI. An overview of clinical decision support systems: benefits, risks, and strategies for success. Npj Digit Med. Nature Publishing Group; 6 févr 2020;3(1):1-10.

6. Feinstein AR. An Analysis of Diagnostic Reasoning. Yale Journal of Biology and Medicine. 1973;21.

7. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud P-AC, et al. Why Don't Physicians Follow Clinical Practice Guidelines?: A Framework for Improvement. JAMA. American Medical Association; 20 oct 1999;282(15):1458-65.

8. Praveen D, Patel A, Raghu A, Clifford GD, Maulik PK, Mohammad Abdul A, et al. SMARTHealth India: Development and Field Evaluation of a Mobile Clinical Decision Support System for Cardiovascular Diseases in Rural India. JMIR MHealth UHealth. 8 déc 2014;2(4):e54.

9. Marcolino M., X Maia J., Oliveira J.A.Q., Cimini C.C.R., A Pinto V., Sá T.Q.V., et al. Development and implementation of a clinical support system for the management of hypertension and diabetes in the primary care setting: A substudy of healthrise Brazil. Diabetes Technol Ther. 2019;21((Marcolino M.) Universidade Federal de Minas Gerais, Department of Internal Medicine andTelehealth Center, University Hospital, Belo Horizonte, Brazil):A68-9.

10. Bessat C, Zonon NA, D'Acremont V. Large-scale implementation of electronic Integrated Management of Childhood Illness (eIMCI) at the primary care level in Burkina Faso: a qualitative study on health worker perception of its medical content, usability and impact on antibiotic prescription and resistance. BMC Public Health. BioMed Central; 2019;19(1):449-449.

11. Raynaud C. Identification des systèmes d'aide à la décision médicale évalués en soins primaires : une revue systématique de la littérature [Thèse d'exercice]. Université Claude Bernard Lyon 1, UFR de médecine Lyon Sud; 2021.

12. Belghoula Haddadi D. Diffusion des systèmes d'aide à la décision médicale: état des lieux, attentes et obstacles : étude quantitative descriptive auprès de 645 médecins généralistes français [Thèse d'exercice]. Université Pierre et Marie Curie (Paris). UFR de médecine Pierre et Marie Curie; 2017.

13. Delory T, Jeanmougin P, Lariven S, Aubert J-P, Peiffer-Smadja N, Boëlle P-Y, et al. A computerized decision support system (CDSS) for antibiotic prescription in primary care-Antibioclic: implementation, adoption and sustainable use in the era of extended antimicrobial resistance. J Antimicrob Chemother. England; 1 août 2020;75(8):2353-62.

14. Osheroff JA. Physicians' Information Needs: Analysis of Questions Posed during Clinical Teaching. Ann Intern Med. 1 avr 1991;114(7):576.

15. Kwan JL, Lo L, Ferguson J, Goldberg H, Diaz-Martinez JP, Tomlinson G, et al. Computerised clinical decision support systems and absolute improvements in care: meta-analysis of controlled clinical trials. BMJ. 17 sept 2020;m3216.

16. Heselmans A, Van de Velde S, Donceel P, Aertgeerts B, Ramaekers D. Effectiveness of electronic guideline-based implementation systems in ambulatory care settings - a systematic review. Implement Sci [En ligne]. déc 2009 [cité le 1 févr 2019];4(1). Disponible: http://implementationscience.biomedcentral.com/articles/10.1186/1748-5908-4-82

17. Souza NM, Sebaldt RJ, Mackay JA, Prorok JC, Weise-Kelly L, Navarro T, et al. Computerized clinical decision support systems for primary preventive care: a decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. Implement Sci. janv 2011;6(1):87-87.

18. Mold JW. Failure of the Problem-Oriented Medical Paradigm and a Person-Centered Alternative. Ann Fam Med. 1 mars 2022;20(2):145-8.

19. Reach G. Simplistic and complex thought in medicine: the rationale for a person-centered care model as a medical revolution. Patient Prefer Adherence. Dove Press; 5 avr 2016;10:449-57.

20. Goddard K, Roudsari A, Wyatt JC. Automation bias: empirical results assessing influencing factors. Int J Med Inf. mai 2014;83(5):368-75.

21. Dumesnil J. Art médical et normalisation du soin [En ligne]. Presses Universitaires de France; 2011 [cité le 12 avr 2022]. Disponible: http://www.cairn.info/art-medical-et-normalisation-du-soin--9782130590835.htm

22. Séroussi B, Bouaud J. Systèmes informatiques d'aide à la décision en médecine : panorama des approches utilisant les données et les connaissances. Prat Neurol - FMC. déc 2014;5(4):303-16.

23. af Klercker T, Zetraeus S. Dilemmas in introducing World Wide Web-based information technology in primary care: a focus group study. Fam Pract. England; 1998;15(3):205-10.

ARTICLE

Barriers and Facilitators to the Use of Clinical Decision Support Systems in Primary Care: a Mixed-Methods Systematic Review

Pierre-Yves Meunier[1,2], Camille Raynaud[1], Emmanuelle Guimaraes[1], François Gueyffier[3,4], Laurent Letrilliart[1,2]

[1] Collège universitaire de médecine générale, Université Claude Bernard Lyon 1, Lyon, France

[2] Research on Healthcare Performance (RESHAPE), INSERM U1290, Université Claude Bernard Lyon 1, Lyon, France

[3] Laboratoire de biométrie et biologie évolutive, département biostatistiques et modélisation pour la santé et l'environnement, CNRS UMR5558, Université Claude Bernard Lyon 1, Lyon, France

[4] Fédération de Recherche Santé Lyon Est, PAM Santé Publique, Hospices Civils de Lyon, France

Correspondence to: Pierre-Yves Meunier, Collège universitaire de médecine générale, Université Claude Bernard Lyon 1, 8 avenue Rockefeller, 69003, Lyon, France, py.meun@gmail.com

Summary box

What is already known on this topic

- A comprehensive understanding of barriers and facilitators to the use of clinical decision support systems (CDSSs) is key to their successful implementation.
- No systematic review has identified and quantified barriers and facilitators to the use of CDSSs by primary care providers (PCPs).

What this study adds

- This systematic review ranked well-known barriers and facilitators to CDSS use and identified new organisational and technological ones in primary care.
- Human and organisational factors impacted CDSS use the most, whereas the technological factor had a neutral impact and the net benefits dimension a positive impact.
- Although benefits reported by PCPs support the potential effectiveness of CDSS use in improving quality and safety of care, they also highlight its lack of efficiency.
- We inferred 11 intrinsic and contextual CDSS features expected to make them used in primary care.

INTRODUCTION

Achieving best practice in primary care is a challenge since primary care providers (PCPs) face a variety of healthcare issues and cannot always identify and access all the relevant information within the timeframe of the consultation.[1,2] Clinical decision support systems (CDSSs) are software designed to be a direct aid to clinical decision-making, in which an interface engine matches the features of an individual patient to a computerised clinical knowledge base or a machine learning algorithm and then presents patient-specific assessments or recommendations to the clinician or the patient for a decision.[3,4] CDSSs are intended to improve the quality, safety, and efficiency of care.[5–7] In primary care, they have not yet proven effectiveness on clinical outcomes, such as morbidity or mortality.[8,9] However, according to a large recent meta-analysis of controlled trials in any settings, CDSSs increase the proportion of patients receiving the desired element of care by 5.8% overall, with a trend towards a worse outcome in the outpatient setting.[10]

Several meta-analyses identified features associated with CDSS effectiveness, such as requesting the reason to override a recommendation and the provision of recommendations to both clinicians and patients.[11–15] However, to be operational in real-life clinical settings, these CDSS features must also be accepted by their users. Qualitative evaluations are therefore needed to obtain a comprehensive understanding of the barriers and facilitators to CDSS use, which are key to their implementation success.[16,17] For this purpose, several systematic reviews focused on specific types of CDSS (knowledge-based CDSS,[18] clinical reminders[19]), specific processes of care (drug prescription,[20,21] diagnosis[22]), or specific health issues (antibiotics prescription,[23] HIV management[24]) without any restriction to their context of use. However, health information systems implementation or evaluation models such as the HOT-fit framework (Human, Organisation, Technology[25]) and others[26–30] emphasise the influence of context-specific factors in the use of health information systems. This is all the more important for the primary care setting owing to the unique combination of the diversity and complexity of health issues managed (often multiple in the same consultation), its patient-centred care approach, and its particular decision making context,[31] which may generate specific needs for decision support systems.

The objective of the present mixed-methods systematic review was therefore to identify and quantify the barriers and facilitators to the use of CDSSs by PCPs.

METHODS

The present study was a mixed-methods systematic review that followed the PRISMA reporting guideline. The study protocol was registered on PROSPERO on 14 July 2020 (CRD42020185199).

Search strategy

The search strategy was built in cooperation with medical librarians. We searched PubMed/MEDLINE, PsycInfo, EMBASE, CINAHL, and the Cochrane library for relevant studies. We tracked citations from included studies to identify additional relevant references. The search was initially performed on 5 July 2021.

Eligibility criteria

We included all qualitative, quantitative, and mixed methods studies for which the primary or secondary objectives were to identify barriers and facilitators to the use of CDSSs in primary care. For studies involving various professions or specialties, we only considered those that had at least 50% PCPs in the study sample. We included CDSSs that provided recommendations to PCPs (and possibly to patients) and were intended for use during the consultation.

We excluded publication types that were posters, dissertations or theses, conference proceedings, commentaries, letters, or editorials. We excluded the following health information systems that were not considered as being CDSSs: drug-drug interaction alert systems, risk assessment tools that provide assessments but not recommendations, and clinical decision supports without interface engine. We excluded the following CDSSs: decision aids only used by patients, CDSSs described as concepts or prototypes, and CDSSs evaluated with simulated clinical scenarios.

Selection process

The selection process was performed using Covidence software.[32] After automatic removal of duplicates, two authors (PYM and CR) independently screened titles and abstracts, and excluded irrelevant records. They independently screened potentially relevant articles in full text while documenting reasons for exclusion. The concordance of this process was estimated by the Cohen's Kappa coefficient from the abstract and full text screening at 0.62 and 0.72 respectively. The disagreements were resolved by seeking consensus between the two authors.

Quality appraisal

The quality of the included studies was independently appraised by two authors (PYM and CR) using the Covidence software. We applied the QuADS tool that has been designed to appraise the methodological and reporting quality of qualitative, quantitative, and mixed-methods studies in systematic reviews, based on 13 common criteria.[33] Each criterion is assessed according to the four following proposals: no mention at all, very slightly, moderately, complete. The concordance (Kappa) was 0.39. The disagreements were resolved by seeking consensus between the two authors.

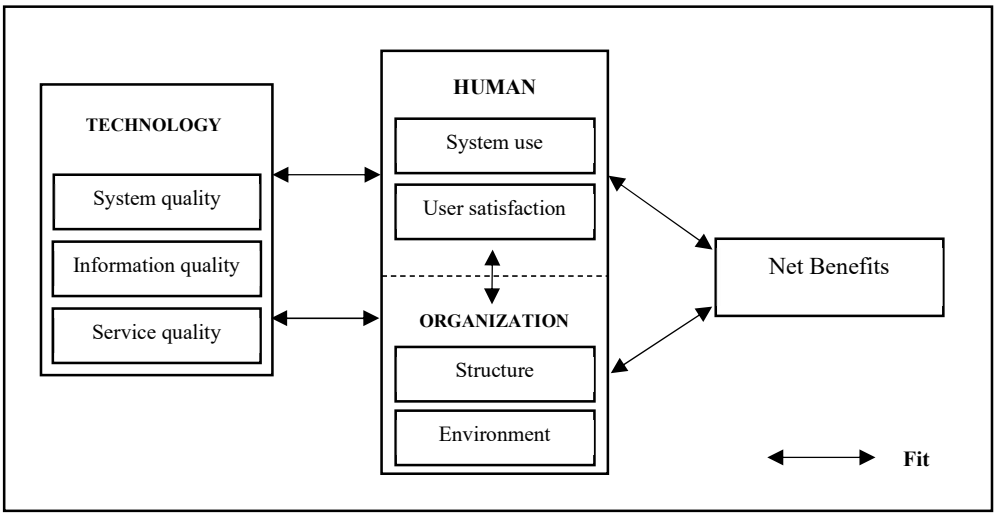
Data extraction

We used a structured data collection form to extract CDSS features (available in Supplementary appendix 1) and methodological features of the included studies. The extraction process was performed independently by two authors (PYM and CR); disagreements were resolved by seeking consensus between them. We contacted the main authors of the included studies to obtain data on CDSS features not reported in the published article.

The HOT-fit framework

The HOT-fit framework describes the interdependent human, organisational and technological factors related to health information system adoption. These three factors are described through seven dimensions: system use and user satisfaction related to the human factor; environment and structure related to the organisational factor; system, information and service quality related to the technological factor. The framework is complemented by an additional dimension, net benefits, which captures the positive and negative effects of CDSS recommendations on PCPs at the individual (human) and organisational levels (Figure 1).[25] Each HOT-fit dimension includes several evaluation measures. The HOT-fit framework was chosen as it assesses barriers and facilitators to the use of health information systems from a pragmatic, user-centred approach.

Figure 1: HOT-fit framework, derived from Yusof et al.[34]

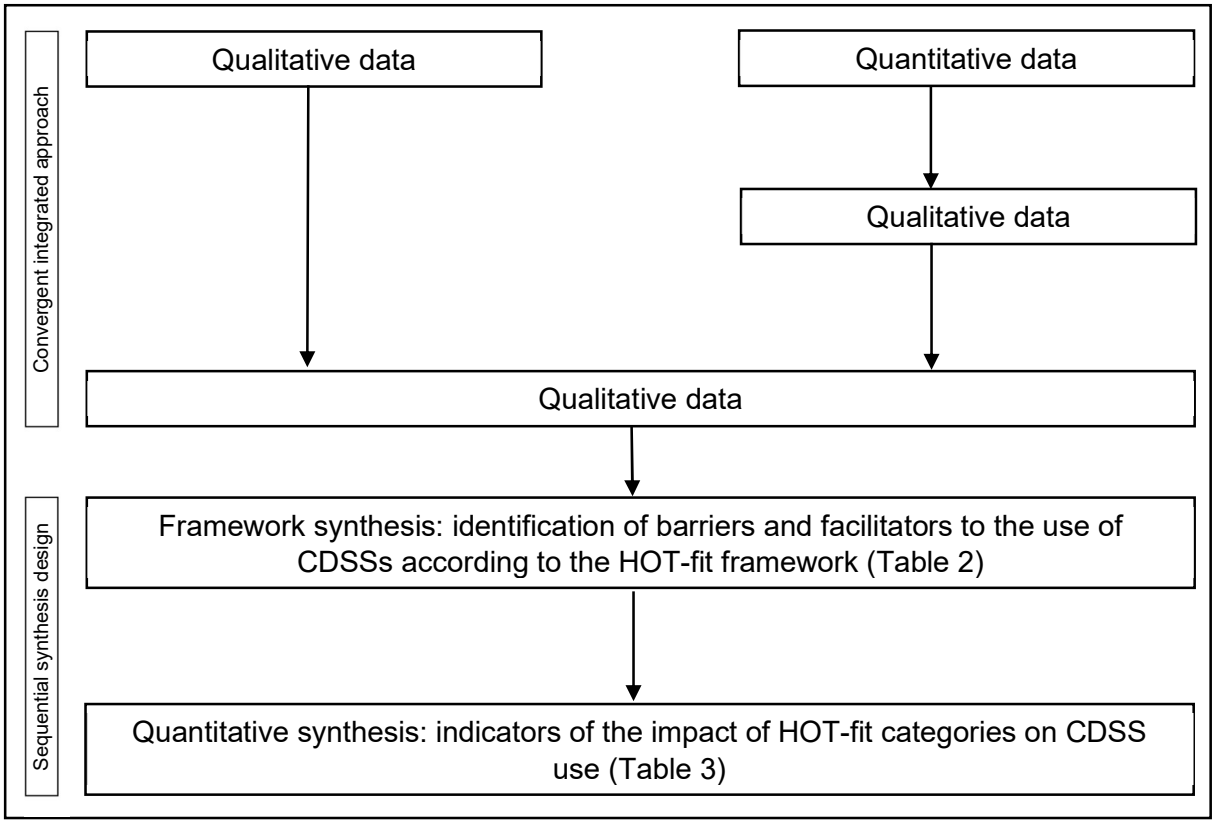


The HOT-fit framework describes the interdependent human, organizational and technological factors related to health information system adoption. A fit between these four categories is required for the adoption of these systems.

Data synthesis

The review followed a sequential synthesis design, using a framework synthesis to inform the quantitative synthesis (Figure 2).[35–37] Firstly, a convergent integrated approach built up a common set of qualitative data from the included qualitative and quantitative data. It involved data transformation through a narrative interpretation of quantitative data.[36] The framework synthesis was based on the HOT-fit framework. Secondly, we performed a quantitative synthesis by calculating the balance between barriers and facilitators categorised according to the HOT-fit framework.

Figure 2: Mixed-methods synthesis design



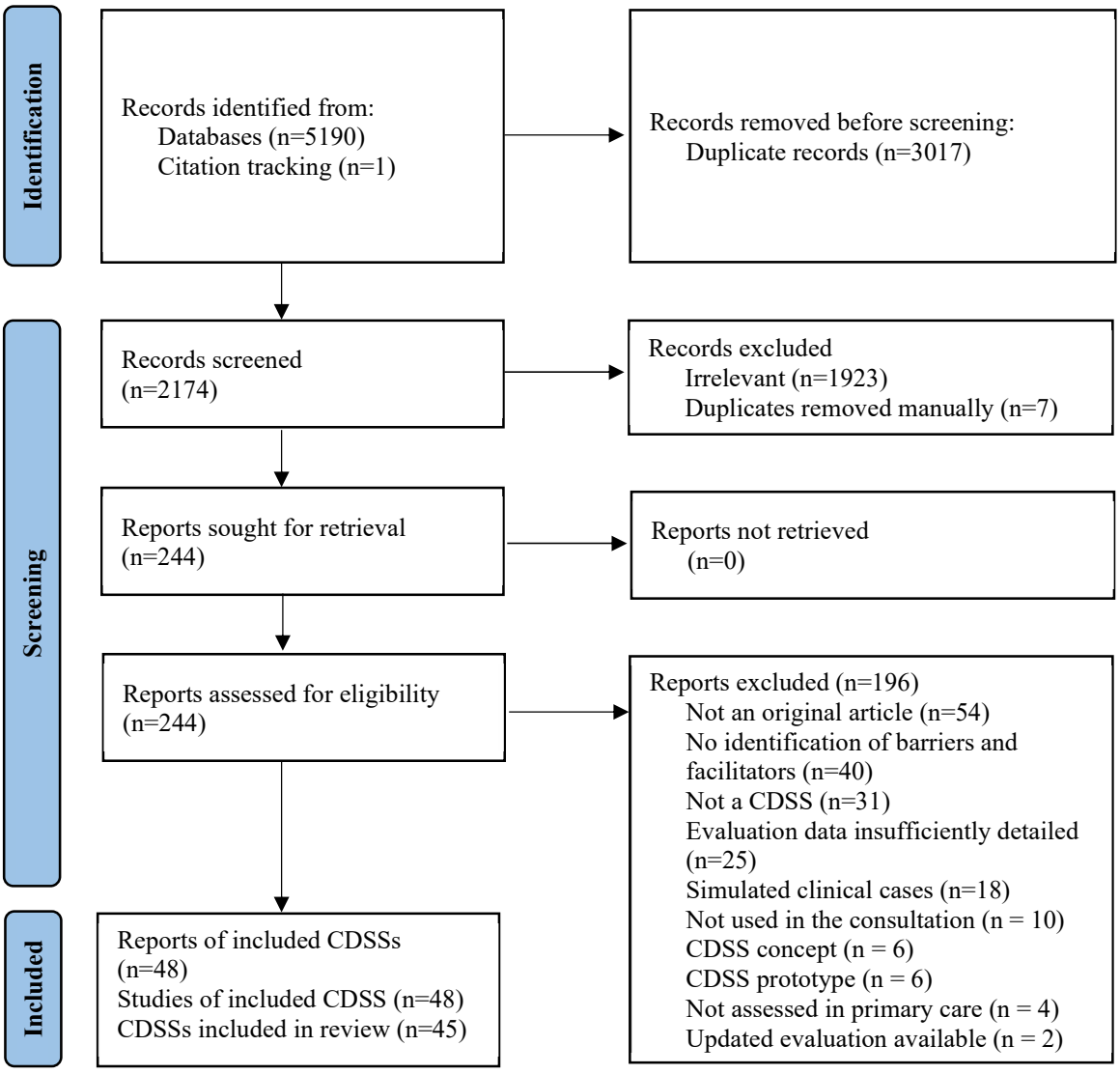
The framework synthesis was performed using NVivo (released in March 2020).[38] Barriers and facilitators to the use of CDSSs were coded inductively as concepts and then classified into the appropriate HOT-fit evaluation measures.[37] This was done independently by two authors (PYM and EG), who reviewed together every coded citation and reached consensus on the concepts and the associated HOT-fit evaluation measures. We extended the HOT-fit framework to include a few concepts we were unable to classify in existing evaluation measures. Due to the various level of detail in the description of the barriers and facilitators to CDSS use in the included studies, certain codes were considered as explanatory elements of higher concepts that we named main barriers and facilitators. We finally merged the two data sets, and one author (PYM) checked for data consistency by using a specific NVivo matrix coding query to identify citations assigned to more than one code.

We carried out a quantitative synthesis of the framework synthesis findings by calculating a mean indicator of the impact of each of the four HOT-fit categories (human, organisation, technology, net benefits) on CDSS use. Individual indicators were calculated for each CDSS by summing the main barriers and facilitators classified in each category; facilitators to CDSS use were quantified as +1 and barriers as -1. Barriers and facilitators were only considered once for each CDSS, regardless of the number of studies or citations reporting the same barrier or facilitator.

RESULTS

A total of 48 studies assessing 45 CDSSs were included in the review (Figure 3).[39–86] Of these, 29 were mixed-methods studies, 15 were qualitative studies, and 4 were quantitative studies. Included studies were published from 1998 to 2021 (median year: 2016). Three CDSSs (EBMeDS, NHGDoc, and PRIMA-EDS) were assessed in two studies.

Figure 3: PRISMA flow-chart



Description of the CDSSs

CDSSs were mainly developed (n=18) and used (n=17) in the US. The main users were primary care physicians (n=37) and nurses (n=22). CDSSs were used for preventive care (n=27), treatment (n=21), management of chronic disease(s) (n=13), and/or diagnosis (n=7). All CDSSs were knowledge-based; none integrated a machine learning algorithm. Updates to the knowledge database were made in 11/33 CDSSs for which this information was available. The strength of evidence of CDSS recommendations was provided in 4/19 studies for which the information was available. Twenty-three CDSSs provided a direct link to the source of recommendations. Thirteen CDSSs provided educational materials to help patients with shared decision-making. PCPs were trained to the use of 36 CDSSs. Most CDSSs were partially or fully integrated in the electronic health record (EHR; n=28), operated passively (n=29), non-interruptively (n=33), and in pull mode (n=43). Of the 21 CDSSs fully integrated into the EHR, 14 operated actively. Data entry was performed during the consultation for 43 CDSSs, and patients entered information before the consultation for five CDSSs. Duplication of data entry was necessary for 20 CDSSs. Four CDSSs required the reason for overriding recommendations. The main features of the included CDSS are described in Table 1 and detailed features in Supplementary appendix 2. The Box 1 defines CDSS features with no obvious meanings.

Box 1: Definitions of CDSS features with no obvious meaning

Fully integrated	CDSS integrated into the EHR, with bidirectional information exchange
Partially integrated	CDSS used outside the EHR with at least unidirectional information exchange (from the EHR to the CDSS, or the opposite)
Not integrated	CDSS used outside the EHR without any information exchange
Duplication of data entry	The user must enter data that is already collected in one of the software (EHR, or CDSS)
Active	A recommendation appears without user request
Passive	A recommendation appears only on user request
Interruptive	The recommendation must be processed to allow the user to continue his previous task
Non interruptive	The recommendation does not prevent the user from continuing his previous task
Push	The recommendation contains the full recommendation of the CDSS
Pull	The recommendation contains a link to a full version of the recommendation

Table 1: Main features of the 45 identified CDSSs

CDSS n=45 in 48 studies	**Name**	**Country of use**	**Care procedures**	**Targeted health issues**
Abimbola et al. (2019)	Health Tracker	Australia	Prevention (disease, test ordering)	Cardiovascular risk management
af Klercker et al. (1998)		Sweden	Diagnosis	Ear, nose, throat diseases
Alagiakrishnan (2016)	SMART-CDS	Canada	Prevention (iatrogenesis)	Adaption of medication to renal function from the patient's EHR
Arts et al. (2018)		The Netherlands	Management of chronic disease(s)	Diabetes mellitus type II, atrial fibrillation, hypertension, medication prescriptions relating to care of older adults
Ash et al. (2011)		USA	Diagnosis, Therapeutics (prescribing, vaccination)	Drug-drug, drug-condition, and drug-allergy interaction checking, patient care plan dashboard with reminders, nearly 3000 condition specific point-and-click templates for documentation
Bandong et al. (2019)	My Whiplash Navigator	Australia	Therapeutics (prescribing, vaccination)	Whiplash-associated disorders
Bessat et al. (2019)	REC	Burkina Faso	Diagnosis, Therapeutics (prescribing, vaccination)	Follow-up and treatment of children under the age of 5 years in developing countries
Bindels et al. (2003)	GRIF Automated Feedback System	The Netherlands	Prevention (disease, test ordering)	Comments on the appropriateness of diagnostic tests ordered by general practitioners
Curry et al. (2011)	Decision Support Server	Canada	Prevention (disease, test ordering)	Prescription of diagnostic imaging
Dixon et al. (2013)		USA	Prevention (disease, test ordering), Management of chronic disease(s)	Diabetes mellitus type II, hypertension, coronary artery disease
Doerr et al. (2014)	My Family	USA	Prevention (disease, test ordering)	Cancer risk management
Edelman et al. (2014)	The Pregnancy and Health Profile (PHP)	USA	Prevention (disease, test ordering)	Prenatal genetic screening
Feldstein et al. (2013)	Patient Panel-Support Tool (PST)	USA	Prevention (iatrogenesis, disease, test ordering) Management of chronic disease	Graphically displays ''care gaps'' (e.g. for screening, medication use, monitoring, risk-factor control, vaccination)
Guenter et al. (2019)	McMaster Pain Assistant (MPA)	Canada	Diagnosis, Therapeutics (prescribing, vaccination)	Neuropathic pain
Helldén et al. (2015)	The renal button	Sweden	Prevention (iatrogenesis)	Adaption of medication to renal function from the patient's EHR
Heselmans et al. (2020) and Koskela et al. (2016)	EBMeDS	Belgium, Estonia, Finland, Italy	Prevention (iatrogenesis, disease, test ordering), Therapeutics (prescribing, vaccination), Management of chronic disease	> 1000 NICE-accredited international guidelines
Jensen et al. (2019)	eIMCI	South Africa	Prevention (disease, test ordering), Therapeutics (prescribing, vaccination)	Management of Childhood Illness
Jenssen et al. (2016)		USA	Prevention (disease, test ordering), Therapeutics (prescribing, vaccination)	Smoking cessation
Kempe et al. (2017)	Immunisation information systems	USA	Prevention (disease, test ordering)	Vaccination
Lam Shin Cheung et al. (2020)	eAMS	Canada	Therapeutics (prescribing, vaccination), Management of chronic disease(s)	Asthma
Lemke et al (2020)	GWA	USA	Prevention (disease, test ordering)	Genetic risk assessment

Litvin et al. (2012)	ABX-TRIP CDSS	USA	Prevention (disease, test ordering), Diagnosis, Therapeutics (prescribing)	Acute respiratory infections
Litvin et al. (2016)		USA	Prevention (disease, test ordering)	Identification and management of chronic kidney disease
Lugtenberg et al. (2015) (2 articles)	NHGDoc	The Netherlands	Prevention (disease, test ordering, iatrogenesis) Therapeutics (prescribing, vaccination) Management of chronic disease(s)	Diabetes mellitus type II, cardiovascular risk management, asthma/COPD, thyroid disorders, viral hepatitis and other liver diseases, atrial fibrillation, subfertility
Maia et al. (2016)		Brazil	Management of chronic disease(s)	Diabetes mellitus type II
Marcolino et al. (2021)		Brazil	Prevention (disease, test ordering), Management of chronic diseases	Diabetes mellitus type II, hypertension, cardiovascular risk treatment
Minian et al. (2021)		Canada	Prevention (disease, test ordering)	Alcohol cessation
Montini et al. (2013)		Brazil	Prevention (disease, test ordering) Therapeutics (prescribing, vaccination)	Tobacco cessation
Pannebakker et al (2019)		England	Prevention (disease, test ordering)	Pigmented skin lesions
Peiris et al. (2014)		Australia	Diagnosis, Therapeutics (prescribing, vaccination)	Back pain management
Praveen et al. (2014)		India, Indonesia, Thailand	Management of chronic disease(s)	Cardiovascular risk management
Price et al. (2017)		Canada	Prevention (iatrogenesis)	Potentially inappropriate prescriptions in the elderly
Richardson et al. (2019)		USA	Therapeutics (prescribing, vaccination)	Sore throat, upper respiratory tract infections
Rieckert et al. (2018, 2019)	PRIMA-EDS	Germany, Austria, Italy, England	Prevention (iatrogenesis)	Polypharmacy in older and chronically ill people
Rousseau et al. (2003)		England	Therapeutics (prescribing, vaccination), Management of chronic disease(s)	Asthma and angina in adults
Rubin et al. (2006)		USA	Therapeutics (prescribing, vaccination), Diagnosis	Acute respiratory tract infections
Silveira et al. (2019)	TeleHAS	Brazil	Prevention (disease, test ordering) Therapeutics	Cardiovascular risk management, hypertension
Sukums et al. (2015)	QUALMAT	Burkina Faso, Ghana, Tanzania	Therapeutics (prescribing, vaccination)	Antenatal and intrapartum care
Toth-Pal et al. (2008)	Evibase	Sweden	Management of chronic disease(s)	Congestive heart failure
Trafton et al. (2010)	ATHENA-OT	USA	Therapeutics (prescribing, vaccination)	Opioid therapy for chronic, non-cancer pain
Trinkley et al. (2021)		USA	Therapeutics (prescribing, vaccination)	Heart failure
Wan et al. (2012)		Australia	Management of chronic disease(s)	Diabetes mellitus type 2
Williams et al. (2016)		USA	Prevention (disease, test ordering)	Paediatric cardiovascular risk
Wilson et al. (2007)	EMPOWER	Australia	Prevention (disease, test ordering) Therapeutics (prescribing, vaccination)	Cardiovascular risk management, hypertension
Zheng et al (2005)	CRS	USA	Prevention (iatrogenesis, disease, test ordering), Therapeutics (prescribing, vaccination), Management of chronic disease(s)	Diabetes mellitus type II, hyperlipidaemia, steroid-induced osteoporosis, influenza, pneumonia, breast cancer, cervical cancer

*COPD: Chronic obstructive pulmonary disease

Quality assessment

The rationale for the choice of the data collection tool was not mentioned at all in 18 studies and very slightly in six studies. The format and content of the data collection tool was estimated as completely appropriate to meet the stated research objectives in 27 studies, and moderately appropriate in 19 studies. The justification for analytic method was not mentioned at all in 24/44 qualitative or mixed-methods studies and very slightly in seven. The final consensus on the 13 quality criteria of the QuADS tool is presented in Supplementary appendix 3. The methodological features of the included studies are presented in Supplementary appendix 4.

Framework synthesis

We complemented the HOT-fit framework by adding an evaluation measure called “hardware” in the dimension “structure” of the factor “organisation” to describe barriers and facilitators related to hardware issues in PCPs facilities. In total, 186 main barriers and facilitators and 69 explanatory elements were identified. These were reported for 41 CDSSs in the human factor, 41 in the organisational factor, 45 in the technological factor, and 42 in the net benefits dimension. Among the main barriers and facilitators, 43 were classified as human factors, 49 as organisational factors, 70 as technological factors, and 24 in the net benefits dimension. The full list is presented in Supplementary appendix 5, and those identified in more than five CDSSs and their explanatory elements are described in Table 2. The mean number of barriers or facilitators identified per CDSS was 28.9; this ranged from 8 to 86 (Supplementary appendix 6).

The most frequent “net benefits” barriers and facilitators concerned the increased workload associated with CDSS use (barrier), and its potential to improve quality of care (facilitator), including through preventive care. The increased workload was explained by the lack of time for using the CDSS during the consultation. This time constraint was itself explained by the time required to collect structured information or duplicate data entry. PCPs strategies to cope with increased workload were extending consultation time, using CDSSs before or after the consultation, or rescheduling consultations. Conversely, saving time was also reported as a net benefit of CDSS use by PCPs. Other net benefits were frequently identified, such as facilitating decision-making, helping to focus on patient education, supporting knowledge update, and identifying unrecognised information needs.

The most frequent human barriers and facilitators concerned the perceived usefulness of CDSSs, conflicts between CDSS recommendations and PCPs’ expertise or beliefs, and information overload. Regarding the conflicts between CDSS recommendations and PCPs’ expertise or beliefs, PCPs reported that even with comprehensive data collection, CDSS recommendations did not reflect the complexity of the clinical situation, or that they may result

in over-referral. Information overload was explained by alert fatigue and the lack of concise synthesis of the recommendations.

The most frequent organisational barriers and facilitators concerned CDSS disruptiveness on PCPs' usual workflow and physicians' need for more teamwork to reduce the workload associated with the use of the CDSS. Among the 25 CDSSs considered disruptive, 15 were partially or not integrated in the EHR. The need for more staff was explained by physicians' fear of the increased workload. Other primary care professionals appreciated extending their skills and their role in helping physicians and improving patient care. In addition, some PCPs experienced difficulties in using CDSSs for patients comanaged by other specialists, either because of missing information or of disagreement with specialist prescriptions.

The most frequent technological barriers and facilitators concerned the user-friendliness of the CDSS, the relevance and reliability of its recommendations, and its integration in the EHR. The lack of user-friendliness was explained by the need to switch windows while using the CDSS and by difficulties in accessing recommendations. Recommendations were sometimes perceived as irrelevant because they were unrelated to patient complaints or too general. Regarding the reliability of CDSS recommendations, PCPs considered that it depended on the quality and completeness of patient information collected. In addition, in only one of the four CDSSs for which the feature of requesting the reason to override the recommendation was reported, PCPs identified it as either a barrier or a facilitator (see supplementary appendix 5).[42]

Table 2: Main barriers and facilitators reported in more than 5 CDSSs, and their explanatory elements, classified according to the HOT-fit framework

HOT-fit framework		Main barriers (-) and facilitators (+)	Explanatory elements
Factors and dimensions [n CDSSs]	**Evaluation measures** [n CDSSs]	[n CDSSs]*	[n CDSSs]
Human [n=41]			
User satisfaction [n=31]	Perceived usefulness [n=24]	(+) Perceived usefulness of the CDSS [n=23]	
	Software satisfaction [n=12]	(+) PCPs would continue to use the CDSS [n=9]	
		(+) PCPs will recommend the CDSS to colleagues [n=6]	
	Overall satisfaction [n=7]	(+) CDSSs increase PCPs satisfaction [n=7]	
System Use [n=39]	Resistance or reluctance [n=19]	(-) Conflicts between CDSS recommendations and PCP expertise or beliefs [n=18]	CDSS recommendations do not reflect the complexity of the situation [n=12] CDSS recommendations may result in over-referral [n=3] Concerns about overdiagnosis [n=2] Perceived shortcomings of evidence-based medicine explain PCP refusal of CDSS recommendations [n=1]
		(-) PCPs reluctance due to patient disagreement with CDSS recommendations [n=6]	
	Report acceptance [n=15]	(-) Information overload [n=15]	Alert fatigue [n=13/15] Lack of a concise synthesis of the CDSS recommendation [n=7/15]
	Training [n=18]	(-) Training before use is needed [n=11]	The training session to the CDSS is inadequate or too short [n=4/11] PCPs are not aware of customisation options [n=2/11]
		(+) Training before use is appreciated [n=10]	
	Attitude [n=21]	(-) PCPs don't need help with the targeted health issue [n=8]	
		(-) Lack of engagement from PCPs (inertia of previous practice) [n=8]	
	Knowledge and expertise [n=7]	(-) Lack of computer skills [n=7]	
	Motivation to use [n=18]	(-) Ask for financial compensation to use the CDSS [n=7]	Need to reward support staff for their productivity with the CDSS (n=1/7]
		(+) Patients' perceived usefulness of the CDSS increases PCPs motivation to use it [n=7]	
	Expectations or beliefs [n=12]	(-) Using CDSSs reduces PCPs' expertise and may lead to "cookbook medicine" [n=6]	The recommendation should not be directive but give attention so that they facilitate PCPs' own judgment [n=1/6]
Organisation [n=41]			
Structure [n=39]	Clinical process [n=35]	(-) Using CDSS disrupts usual workflow [n=25]	
		(+) Natural integration of the CDSS in the clinical workflow [n=13]	
	Teamwork [n=19]	(-) Need of more teamwork with other PCPs to help physicians with CDSS's increased workload [n=13]	Physicians fear more the CDSS workload than assistants or nurses [n=4/13] Nurses unfortunately not allowed to code diagnosis [n=1/13] CDSS could be an opportunity for increasing interprofessional collaboration [n=1/13]
		(+) Other professionals ease physician's increased workload with the CDSS [n=6]	Expansion of skill set and roles in assisting physicians and patients in meeting care needs [n=3/6]
	Autonomy [n=10]	(+) Producing reports of quality measures through collected data increases the value from the CDSS's use in clinical practice [n=7]	
	Hardware [n=16]	(-) Lack or computers or tablets [n=7]	
		(-) Poor internet or wireless connectivity [n=6]	
	Leadership [n=7]	(+) Available leadership support [n=6]	Identified clinical champion in the facility [n=5/6] Identified technical champion in the facility [n=3/6]
Environment [n=18]	Inter-organisational relationship [n=11]	(-) Difficulty to use CDSSs for patients comanaged by other specialists [n=11]	Information is sometimes missing or not integrated from external sources [n=6/11] Disagreement between CDSS recommendations and prescriptions of other specialists [n=2/11]
Technology [n=45]			
System quality [n=45]	Ease of use [n=39]	(+) The CDSS is user-friendly (ergonomic) [n=30]	No need to switch windows in the EHR while using CDSSs [n=1/30]
		(-) The CDSS is not user-friendly [n=21]	Need to switch windows in the EHR while using CDSSs [n=9/21] Location of CDSS recommendations should be changed [n=8/21] Need to switch windows between the EHR and the CDSS [n=5/21]

			CDSS should be designed to help shared decision making [n=1/21]
		(+) CDSS recommendations are easy to understand [n=9]	
	Turnaround time [n=18]	(-) CDSS slowness [n=16]	CDSS's slowness impairs the interaction with the patient and increases the consultation time [n=5/16]
	Usefulness of system features and functions [n=33]	(-) CDSS not fully integrated in the EHR [n=14]	A CDSS not fully integrated in the EHR is time consuming and disrupts workflow [n=4/14] The most current information collected in the EHR is sometimes not updated in the CDSS [n=3/14]
		(+) Reminders [n=8]	
		(-) Lack of learning capacity of the CDSS [n=6]	
	Database contents [n=18]	(-) The CDSS should target more health issues [n=11]	
		(-) Questioning validity of CDSS's knowledge database [n=7]	Concerns about the CDSS's independence from pharmaceutical industry [n=3/7]
	Ease of learning [n=9]	(+) Easy to use after a short learning period [n=9]	
	Flexibility [n=13]	(-) Need of customisation options [n=8]	
Information quality [n=40]	Relevance [n=19]	(+) Recommendations are relevant [n=11]	
		(-) Recommendations are not relevant [n=11]	Conflicts between patient complaints and unrelated CDSS recommendations [n=7/11] General recommendations are often irrelevant [n=4/11] Irrelevant alerts for different PCP groups (such as for nurses and GPs) [n=1/11]
	Reliability [n=17]	(-) Doubtful reliability of the recommendations [n=12]	The reliability of the recommendations depends on the quality and completeness of the information collected [n=11/12]
		(+) Recommendations are reliable [n=9]	General agreement with the validity of recommendations [n=4/9] Full guidelines linked to each recommendation [n=1/9]
	Usefulness [n=21]	(+) Information provided is useful for the targeted process of care [n=13]	
		(-) Recommendations are not helpful [n=8]	The recommendation is sometimes too vague to be useful [n=2/8]
		(+) Educational materials for patients are valuable [n=7]	
	Format [n=18]	(-) Format of recommendations (length, structure, font colors) [n=13]	
		(+) Pleasing visual layout [n=12]	
	Conciseness [n=16]	(+) Conciseness of the recommendation [n=6]	
Service quality [n=11]	Technical support [n=11]	(+) Satisfaction with the CDSS service support [n=7]	CDSS technical staff availability [n=6/7]
Net Benefits [n=42]	Efficiency [n=37]	(-) Increased workload during the consultation [n=33]	Lack of time to use the CDSS during the consultation [n=31/33] Structured data collection takes too much time [n=15/31] Duplication of data collection [n=12/31] Coping strategies: increased consultation time [n=14/33], need of additional time to use the CDSS outside the consultation [n=8/33], scheduling follow-up consultations [n=5/33]
		(+) Using CDSS saves time [n=22]	Shortening documentation time [n=8/22] Giving a quick patient evaluation from relevant data in patients' EHRs [n=6/22]
	Effectiveness [n=25]	(+) Potential to improve the quality of care [n=23]	Brings preventive care to the forefront [n=7/23] Helps to systematise assessment of every patient [n=13/23] Facilitates patient care management [n=9/23]
		(+) CDSS helps PCPs to improve guideline adherence [n=11]	
	Decision making quality [n=25]	(+) CDSS facilitates decision-making [n=22]	CDSS is facilitating decision-making about referral [n=5/22]
	Communication [n=26]	(+) CDSS helps focus on patient education [n=18]	CDSS helps increase patient engagement [n=14/18]
		(+) CDSS eases patient-PCP communication [n=13]	
		(-) Negative effect on patient-PCP communication [n=7]	
	Clinical practice [n=22]	(+) CDSS is a way to update PCP's knowledge [n=17]	
		(+) CDSS leads to better teamwork in primary care [n=7]	
		(+) CDSS increases PCPs' self-confidence [n=7]	
	Error reduction [n=17]	(+) CDSS helps PCPs to identify unrecognised information needs [n=17]	

*Main barriers and facilitators are ranked by their frequency or by the frequency of pairs describing the same concept, if any (e.g. relevance of CDSS recommendations)

Quantitative synthesis

Organisational (mean: -1.9, 95% confidence interval, CI [-2.6; -1.1]) and human HOT-fit factors (-1.5, (95% CI [-2.2; -0.8]) had an overall negative impact on CDSS use by PCPs. The technological factor had a neutral overall impact (-0.5, 95% CI [-1.5; 0.5]), and the net benefits dimension an overall positive impact on CDSS use (+3.1, 95% CI [2.2; 3.9]; Table 3).

Table 3: Indicators of the impact of HOT-fit categories on CDSS use

	Human	Organisation	Technology	Net Benefits
Main barriers (n=109)	n=31	n=34	n=38	n=6
Main facilitators (n=77)	n=12	n=15	n=32	n=18
1 Abimbola et al. (2019)	-5	-8	0	4
2 af Klercker et al. (1998)	-3		-4	-1
3 Alagiakrishnan et al. (2016)	-2	-2	4	5
4 Arts et al. (2018)	0	-2	-6	1
5 Ash et al. (2011)	-2	4	-3	0
6 Bandong et al. (2019)	3	0	1	1
7 Bessat et al. (2019)	-2	-1	-2	7
8 Bindels et al. (2003)	-2	-2	0	2
9 Curry et al. (2011)	0	0	-2	0
10 Dixon et al. (2013)		-2	-4	
11 Doerr et al. (2014)	-3	2	1	11
12 Edelman et al. (2014)	-2	1	-3	4
13 Feldstein et al. (2013)	1	-1	4	9
14 Guenter et al. (2019)	-3		2	2
15 Helldén et al. (2015)	2	-1	3	5
16 Heselmans et al. (2020), Koskela et al. (2016)	-1	-2	4	2
17 Jensen et al (2019)	0	0	2	7
18 Jenssen et al. (2016)	2		0	1
19 Kempe et al. (2017)	-1	-2	-3	-1
20 Lam Shin Cheung et al. (2020)	-1	-4	5	6
21 Lemke et al (2020)	-6	-4	-7	7
22 Litvin et al. (2012)	-1	-4	-1	3
23 Litvin et al. (2016)	-3	-3	2	5
24 Lugtenberg et al. (2015) (2 articles)	-5	-3	-9	0
25 Maia et al. (2016)	1	-1	0	1
26 Marcolino et al. (2021)	3	-1	7	6
27 Minian et al. (2021)	-3	-3	1	0
28 Montini et al. (2013)		-4	0	2
29 Pannebakker et al (2019)	-3	-1	-2	4
30 Peiris et al. (2014)	-3	-1	-5	2
31 Praveen et al. (2014)	-3	-4	1	6
32 Price et al. (2017)		0	-3	
33 Richardson et al. (2019)	-1	-1	-3	1
34 Rieckert et al. (2018, 2019)	-2	-3	0	8
35 Rousseau et al. (2003)	-5	-4	-3	1
36 Rubin et al. (2006)		-1	1	2
37 Silveira et al. (2019)	-1	-1	2	4
38 Sukums et al. (2015)	-4	-10	-5	0
39 Toth-Pal et al. (2008)	-7	-2	2	3
40 Trafton et al. (2010)	1	-2	4	2
41 Trinkley et al. (2021)	0	1	3	2
42 Wan et al. (2012)	-1	-2	-5	5
43 Williams et al. (2016)	1		-2	
44 Wilson et al. (2007)	-1	-2	2	1
45 Zheng et al (2005)	-1	-2	-2	0
Mean indicators of the impact of HOT-fit categories on CDSS use	**-1.5**	**-1.9**	**-0.5**	**+3.1**
95% CI	[-2.2; -0.8]	[-2.6; -1.1]	[-1.5; 0.5]	[2.2; 3.9]

Red: negative value, Yellow: neutral, Green: positive value, Blank: missing data

DISCUSSION

This mixed-methods systematic review assessed 45 CDSSs and identified 186 main barriers and facilitators to their use in primary care. The most frequent barriers primarily concerned the increased workload associated with the CDSS, and also the need for PCP teamwork, information overload, the disruption of usual workflow, and conflicts with CDSS recommendations. The most frequent facilitators concerned the general perception of the usefulness of CDSSs, their potential to improve quality of care, but also timesaving, patient education, improvement of PCP knowledge, identification of unrecognised information needs, and full integration in the EHRs. Frequent pairs of barriers and facilitators concerned CDSS user-friendliness, and the relevance and reliability of its recommendations. All barriers and facilitators were distributed across the three HOT-fit factors and the net benefits dimension, with a predominance of the technological factors. The quantitative synthesis found uneven impacts of these four categories on CDSS use; the human and organisational factors had overall negative impacts whereas the technological factor a variable but neutral impact, and the net benefits dimension an overall positive impact on CDSS use. The net benefits reported by PCPs support the potential effectiveness of CDSSs in improving quality and safety of care. However, they seem unable to improve care efficiency since they are believed to increase PCP workload.

Comparison with other studies

This review is the first to identify and quantify barriers and facilitators to the use of CDSSs by PCPs. In 2017, Kilsdonk et al. conducted a systematic review of barriers and facilitators to the use of knowledge-based CDSSs in various settings according to the HOT-fit framework,[18] including studies based on simulated clinical scenarios. They identified barriers and facilitators mostly concerning lack of time, workflow, integration in the EHR, user-friendliness, relevance of the recommendations, and particular usefulness for less experienced practitioners. These findings were consistent with a previous systematic review of medication-related CDSSs conducted by Moxey et al. that analysed both healthcare providers' general views on, and use of CDSSs including computerised guidelines or risk assessment tools, in various settings.[20] The present systematic review confirms these barriers and facilitators and adds some explanatory elements. For example, lack of user-friendliness could be explained by the burden of switching between windows while using CDSS, and lack of relevance by conflicts between patient complaints and unrelated CDSS recommendations. Although the reviews conducted by Kilsdonk et al.[18] and Moxey et al.[20] as well as this review consistently show a predominance of technological barriers and facilitators, our quantitative synthesis highlights their overall neutral impact on the use of CDSSs, which indicates a balance between

technological barriers and facilitators. This neutral impact can probably be explained by the diversity of CDSSs and by improvements over time in CDSS design and PCPs' computer skills. Beside the technological barriers, increased workload appears as the leading barrier to CDSS use in primary care.

Moxey et al. conducted a subgroup analysis that identified the lack of CDSS integration into the EHR and patient negative opinion as barriers specific to the ambulatory care setting.[20] Poor CDSS integration was also identified as a main technological barrier in our review. The diversity of EHRs developed for primary care may explain the persistence of this barrier over time.[87] Patient negative opinion was reported in the present review but has not been considered as a major barrier to the CDSS use in primary care, presumably because of their increasing acceptance over time of the use of health information systems during consultations.[88] Other barriers and facilitators identified in the present review are original as compared to previous reviews.[18,20] Firstly, teamwork needs and benefits of using CDSSs were frequently reported. The importance of teamwork could not be identified previously since it is just emerging in primary care in many healthcare systems, contrarily to the hospital setting.[89,90] Secondly, PCPs expressed difficulties in using CDSSs with patients co-managed by specialists, due to discrepancies between specialist and CDSS recommendations or to outdated patient information in the EHR. Thirdly, PCPs expected CDSSs covering a large array of conditions, in agreement with the diversity of the health issues they manage. Fourth, the contribution of CDSSs to reporting on quality measures was valued by PCPs, in a context of evaluation programmes implemented in primary care.

Several meta-analyses of randomised controlled trials identified two main CDSS features critical to their efficacy on patient outcomes: requiring reasons to override recommendations[12–14] and providing recommendations to both clinicians and patients.[13,14] However, to be effective in real-life clinical settings, CDSSs that contain these features must also be accepted by their users. The present systematic review found little influence of these two features on the use of CDSSs by PCPs. The feature of requesting the reason to override CDSS recommendation concerned only a few CDSSs and was associated with ambivalent perceptions. The provision of recommendations to both clinicians and patients refers to CDSSs that are accessible to patients, either directly, or indirectly through paper documents transmitted by physicians.[13] None of the CDSSs in the present review was designed to be accessed directly by patients. However, several CDSSs enable the physicians to transmit them educational documents that PCPs perceived as valuable and, in this way, may support shared decision-making by presenting the most understandable and personalised information to patients.

Strengths and weaknesses

The CDSSs evaluated in previous systematic reviews[18,20] were very diverse, probably due to the blurry frontier between CDSSs and other decision supports. To reduce this diversity, we used a definition for CDSSs adapted from Sim et al.[3] and Sutton et al.[4], large enough to include knowledge-based and non-knowledge-based CDSSs but not decision supports without interface engine. We excluded CDSSs only evaluated with simulated clinical scenarios in order to explore real-life primary care practice. Our review may not be fully representative of the various CDSS developed for primary care, as some of them were not studied regarding barriers and facilitators to their use.

Frequency-based indicators of the impact of HOT-fit categories on CDSS use were useful for comparison purposes; they were however limited by the heterogeneity of CDSS barriers and facilitators and by the impossibility to weight them individually according to their perceived importance. In addition, PCPs attributed some barriers such as conflicts between CDSS recommendations and their own expertise or lack of computer skills, while the first barrier is more likely related to the use of guidelines[91], and the second to the uptake of EHRs.[92,93] The classification of barrier and facilitators in the evaluation measures was sometimes subjective because of similarities between, or lack of clear definition of some HOT-fit evaluation measures, as already reported by other authors.[18] For instance, the HOT-fit evaluation measure “clinical process” in the dimension “structure” of the organisational factor is close to the evaluation measure “clinical practice” of the net benefits dimension.

Implications

The present systematic review highlights barriers and facilitators to the use of CDSSs related to its feasibility (e.g. increased workload), acceptability (e.g. conflicts with PCPs expertise or beliefs), meaningfulness (e.g. relevance of recommendations), and effectiveness (net benefits dimension). These different forms of evidence refer to the FAME evidence-based model,[94] which is necessary to understand complex interventions such as implementing CDSSs. Based on these findings, we inferred an operational list of 11 intrinsic and contextual CDSS features expected to make them more feasible, acceptable, meaningful, and effective in primary care (Box 2).

Box 2: Expected features of a CDSS for primary care

Intrinsic features
1. Including preventive care
2. Covering a large array of conditions
3. Providing reminders personalised to the patient
4. Minimising information overload
5. Providing educational material to patients
6. Integrated in the EHR, with the fewest possible duplicate data entries
7. Fast processing

Contextual features
8. Developed in close collaboration with PCPs
9. Providing the rationale for the selection of sources of its knowledge base
10. With teamwork for data collection and use of the CDSS
11. With systematic training for its use

They are spread across the three interdependent human, organisational, and technological factors. Among intrinsic features, the expectation of decision support for preventive care is consistent with the great importance of prevention in primary care practice. The expectation of a large array of conditions covered by CDSSs is explained by the preference of PCPs for a single comprehensive system rather than several CDSSs with limited clinical coverage displaying recommendations in separate windows, each requiring a specific training. Information overload, which includes alert fatigue,[95] refers to PCPs facing more information than they have the time or cognitive ability to process.[96,97] CDSSs aim at both rationalising patient management while avoiding overwhelming PCPs with information, and minimising information overload can be achieved by CDSSs providing concise recommendations and prioritising the most appropriate interventions recommended for each patient.[98] In addition, the feature of providing patients with educational material supports shared decision-making within a patient-centred approach. Among contextual features, developing CDSSs in close collaboration with PCPs according to a bottom-up approach is needed to improve their perceived usefulness and user-friendliness and the relevance of their recommendations. Providing the rationale for selecting the sources of the CDSS knowledge base is expected to increase CDSS reliability. This seems critical, even more for future non-knowledge-based CDSSs, as healthcare professionals are exposed to automation bias, which consists in over-relying on automated advice.[99] Several of these intrinsic and contextual features may allow the leading barrier, increased workload, to be overcome.

We recommend that future studies on barriers and facilitators to CDSS use systematically evaluate human and organisational factors, since our findings demonstrate they are the most impeding factors to CDSS use. In addition, quantitative studies are particularly needed to assess the weight of the main barriers and facilitators identified through the present framework synthesis.

Box 2: Expected features of a CDSS for primary care

Conclusion

Although benefits reported by PCPs support the potential effectiveness of CDSS use in improving quality and safety of care, they also highlight its lack of efficiency due to increased workload. Our findings emphasise the need for CDSS developers to better address human and organisational issues in addition to technological stakes. We inferred core intrinsic and contextual CDSS features, covering theses three categories, expected to make them used in primary care.

OTHER INFORMATION

Ethical approval

Not required

Study registration

Protocol registered on PROSPERO (CRD42020185199) (no amendments to information provided in the protocol)

Acknowledgements

We would like to thank Mathieu Fauvernier and Maxime Bonjour (Service de Biostatistiques des Hospices Civils de Lyon, France; UMR5558, Laboratoire de Biométrie et Biologie Évolutive, Équipe Biostatistique-Santé, Villeurbanne, France) for their comments on the data synthesis method. We would like to thank Colin Sidre and Bastien Blanchon (BIU Santé Médecine, Paris, France) for help with the search strategy. We also thank Philip Robinson (DRS, Hospices Civils de Lyon) for help in manuscript preparation.

Contributor and guarantor information

Pierre-Yves Meunier contributed to the conceptualization (lead), the data curation (lead), the formal analysis (lead), funding acquisition (lead), methodology (equal), and to the writing of this manuscript (leading the original draft and supporting review & editing). Camille Raynaud contributed to formal analysis (supporting) and validation (supporting). Emmanuelle Guimaraes contributed to formal analysis (supporting) and validation (supporting). François Gueyffier supported the validation and the review & editing of the manuscript. Laurent Letrilliart contributed to the conceptualization (supporting), the methodology (equal), the supervision (lead), the validation (lead), and to the writing of this manuscript (supporting the writing of the original draft and leading review & editing). Laurent Letrilliart is being responsible for the overall content as guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Transparency declaration

Laurent Letrilliart affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been

omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

Grant funding for research but no other competing interest

All authors have completed the ICMJE uniform disclosure form at http://www.icmje.org/disclosure-of-interest/ and declare: Pierre-Yves Meunier had financial support from Agence Régionale de Santé Auvergne-Rhône-Alpes for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Role of the funding source

The study funder was a public health institution (Agence Régionale de Santé Auvergne-Rhône-Alpes) through a grant attributed to Pierre-Yves Meunier. The study funder did not interfere in the conduct of this study. All authors confirm the independence of researchers from funders. All authors had full access to all of the data (including tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

REFERENCES

1 World Health Organisation. Technical series on primary health care: quality in primary health care. World Health Organisation 2018. https://www.who.int/docs/default-source/primary-health-care-conference/quality.pdf (accessed 5 Oct 2021).

2 Van der Keylen P, Tomandl J, Wollmann K, *et al.* The Online Health Information Needs of Family Physicians: Systematic Review of Qualitative and Quantitative Studies. *J Med Internet Res* 2020;22:e18816. doi:10.2196/18816

3 Sim I, Gorman P, Greenes RA, *et al.* Clinical decision support systems for the practice of evidence-based medicine. *J Am Med Inform Assoc* 2001;8:527–34. doi:10.1136/jamia.2001.0080527

4 Sutton RT, Pincock D, Baumgart DC, *et al.* An overview of clinical decision support systems: benefits, risks, and strategies for success. *Npj Digit Med* 2020;3:1–10. doi:10.1038/s41746-020-0221-y

5 World Health Organisation. *WHO guideline: Recommendations on digital interventions for health system strengthening*. World Health Organisation 2019. https://apps.who.int/iris/handle/10665/331883 (accessed 5 Oct 2021).

6 Osheroff JA, Teich JM, Middleton B, *et al.* A Roadmap for National Action on Clinical Decision Support. *J Am Med Inform Assoc* 2007;14:141–5. doi:10.1197/jamia.M2334

7 Tcheng JE, National Academy of Medicine (U.S.), editors. *Optimizing strategies for clinical decision support: summary of a meeting series*. Washington, DC: National Academy of Medicine 2017.

8 Heselmans A, Van de Velde S, Donceel P, *et al.* Effectiveness of electronic guideline-based implementation systems in ambulatory care settings - a systematic review. *Implement Sci* 2009;4. doi:10.1186/1748-5908-4-82

9 the CCDSS Systematic Review Team, Souza NM, Sebaldt RJ, *et al.* Computerized clinical decision support systems for primary preventive care: A decision-maker-researcher partnership systematic review of effects on process of care and patient outcomes. *Implement Sci* 2011;6. doi:10.1186/1748-5908-6-87

10 Kwan JL, Lo L, Ferguson J, *et al.* Computerised clinical decision support systems and absolute improvements in care: meta-analysis of controlled clinical trials. *BMJ* 2020;m3216. doi:10.1136/bmj.m3216

11 Garg AX, Adhikari NKJ, McDonald H, *et al.* Effects of Computerized Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes: A Systematic Review. *JAMA* 2005;293:1223–38. doi:10.1001/jama.293.10.1223

12 Kawamoto K, Houlihan CA, Balas EA, *et al.* Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ* 2005;330:765. doi:10.1136/bmj.38398.500764.8F

13 Roshanov PS, Fernandes N, Wilczynski JM, *et al.* Features of effective computerised clinical decision support systems: meta-regression of 162 randomised trials. *BMJ* 2013;346:f657. doi:10.1136/bmj.f657

14 Fillmore CL, Rommel CA, Welch BM, *et al.* The perils of meta-regression to identify clinical decision support system success factors. *J Biomed Inform* 2015;56:65–8. doi:10.1016/j.jbi.2015.05.007

15 Van de Velde S, Heselmans A, Delvaux N, *et al.* A systematic review of trials evaluating success factors of interventions with computerised clinical decision support. *Implement Sci IS* 2018;13:114. doi:10.1186/s13012-018-0790-1

16 Lobach DF. The road to effective clinical decision support: are we there yet? *BMJ* 2013;346:f1616. doi:10.1136/bmj.f1616

17 Sarkar U, Samal L. How effective are clinical decision support systems? *BMJ* 2020;m3499. doi:10.1136/bmj.m3499

18 Kilsdonk E, Peute LW, Jaspers MWM. Factors influencing implementation success of guideline-based clinical decision support systems: A systematic review and gaps analysis. *Int J Med Inf* 2017;98:56–64. doi:10.1016/j.ijmedinf.2016.12.001

19 Saleem JJ, Patterson ES, Militello L, *et al.* Exploring Barriers and Facilitators to the Use of Computerized Clinical Reminders. *J Am Med Inform Assoc* 2005;12:438–47. doi:10.1197/jamia.M1777

20 Moxey A, Robertson J, Newby D, *et al.* Computerized clinical decision support for prescribing: provision does not guarantee uptake. *J Am Med Inform Assoc* 2010;17:25–33. doi:10.1197/jamia.M3170

21 Westerbeek L, Ploegmakers KJ, de Bruijn G-J, *et al.* Barriers and facilitators influencing medication-related CDSS acceptance according to clinicians: A systematic review. *Int J Med Inf* 2021;152:104506. doi:10.1016/j.ijmedinf.2021.104506

22 Nurek M, Kostopoulou O, Delaney BC, *et al.* Reducing diagnostic errors in primary care. A systematic meta-review of computerized diagnostic decision support systems by the LINNEAUS collaboration on patient safety in primary care. *Eur J Gen Pract* 2015;21 Suppl:8–13. doi:10.3109/13814788.2015.1043123

23 Laka M, Milazzo A, Merlin T. Factors That Impact the Adoption of Clinical Decision Support Systems (CDSS) for Antibiotic Management. *Int J Environ Res Public Health* 2021;18. doi:10.3390/ijerph18041901

24 Oluoch T, Santas X, Kwaro D, *et al.* The effect of electronic medical record-based clinical decision support on HIV care in resource-constrained settings: a systematic review. *Int J Med Inf* 2012;81:e83-92. doi:10.1016/j.ijmedinf.2012.07.010

25 Yusof MMohd, Kuljis J, Papazafeiropoulou A, *et al.* An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit). *Int J Med Inf* 2008;77:386–98. doi:10.1016/j.ijmedinf.2007.08.011

26 William H. Delone, Ephraim R. McLean. The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. *J Manag Inf Syst* 2003;19:9–30. doi:10.1080/07421222.2003.11045748

27 Damschroder LJ, Aron DC, Keith RE, *et al.* Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implement Sci IS* 2009;4:50. doi:10.1186/1748-5908-4-50

28 Sittig DF, Singh H. A New Socio-technical Model for Studying Health Information Technology in Complex Adaptive Healthcare Systems. *Qual Saf Health Care* 2010;19:i68–74. doi:10.1136/qshc.2010.042085

29 Venkatesh V, Thong J, Xu X. Unified Theory of Acceptance and Use of Technology: A Synthesis and the Road Ahead. *J Assoc Inf Syst* Published Online First: 2016. doi:10.17705/1jais.00428

30 Greenhalgh T, Wherton J, Papoutsi C, *et al.* Beyond Adoption: A New Framework for Theorizing and Evaluating Nonadoption, Abandonment, and Challenges to the Scale-Up, Spread, and Sustainability of Health and Care Technologies. *J Med Internet Res* 2017;19:e367. doi:10.2196/jmir.8775

31 Dr Justin Allen, Pr Bernard Gay, Pr Harry Crebolder, *et al.* The european definition of general practice / family medicine. WONCA EUROPE 2011. https://www.woncaeurope.org/file/520e8ed3-30b4-4a74-bc35-87286d3de5c7/Definition%203rd%20ed%202011%20with%20revised%20wonca%20tree.pdf (accessed 20 Feb 2022).

32 Veritas Health Innovation. *Covidence systematic review software*. Melbourne, Australia: www.covidence.org

33 Harrison R, Jones B, Gardener P, *et al.* Quality assessment with diverse studies (QuADS): an appraisal tool for methodological and reporting quality in systematic reviews of mixed- or multi-method studies. *BMC Health Serv Res* 2021;21:144. doi:10.1186/s12913-021-06122-y

34 Yusof MMohd. A case study evaluation of a Critical Care Information System adoption using the socio-technical and fit approach. *Int J Med Inf* 2015;84:486–99. doi:10.1016/j.ijmedinf.2015.03.001

35 Hong QN, Pluye P, Bujold M, *et al.* Convergent and sequential synthesis designs: implications for conducting and reporting systematic reviews of qualitative and quantitative evidence. *Syst Rev* 2017;6:61. doi:10.1186/s13643-017-0454-2

36 Lizarondo L, Stern C, Carrier J, *et al.* Chapter 8: Mixed Methods Systematic Reviews. In: Aromataris E, Munn Z, eds. *JBI Manual for Evidence Synthesis*. JBI 2020. doi:10.46658/JBIMES-20-09

37 Dixon-Woods M. Using framework-based synthesis for conducting reviews of qualitative studies. *BMC Med* 2011;9:39. doi:10.1186/1741-7015-9-39

38 QSR International Pty Ltd. *NVivo (released in November 2021)*. 2021. https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

39 Abimbola S, Patel B, Peiris D, *et al.* The NASSS framework for ex post theorisation of technology-supported change in healthcare: worked example of the TORPEDO programme. *BMC Med* 2019;17:233. doi:10.1186/s12916-019-1463-x

40 af Klercker T, Zetraeus S. Dilemmas in introducing World Wide Web-based information technology in primary care: a focus group study. *Fam Pract* 1998;15:205–10. doi:10.1093/fampra/15.3.205

41 Alagiakrishnan K, Wilson P, Sadowski C, *et al.* Physicians' use of computerized clinical decision supports to improve medication management in the elderly; the Seniors Medication Alert and Review Technology intervention. *Clin Interv Aging* 2016;:73. doi:10.2147/CIA.S94126

42 Arts DL, Medlock SK, van Weert HCPM, *et al.* Acceptance and barriers pertaining to a general practice decision support system for multiple clinical conditions: A mixed methods evaluation. *PLOS ONE* 2018;13:e0193187. doi:10.1371/journal.pone.0193187

43 Ash JS, Sittig DF, Wright A, *et al.* Clinical decision support in small community practice settings: a case study. *J Am Med Inform Assoc* 2011;18:879–82. doi:10.1136/amiajnl-2010-000013

44 Bandong AN, Mackey M, Leaver A, *et al.* An Interactive Website for Whiplash Management (My Whiplash Navigator): Process Evaluation of Design and Implementation. *JMIR Form Res* 2019;3:e12216. doi:10.2196/12216

45 Bessat C, Zonon NA, D'Acremont V. Large-scale implementation of electronic Integrated Management of Childhood Illness (eIMCI) at the primary care level in Burkina Faso: a qualitative study on health worker perception of its medical content, usability and impact on antibiotic prescription and resistance. *BMC Public Health* 2019;19:449. doi:10.1186/s12889-019-6692-6

46 Bindels R. User satisfaction with a real-time automated feedback system for general practitioners: a quantitative and qualitative study. *Int J Qual Health Care* 2003;15:501–8. doi:10.1093/intqhc/mzg076

47 Curry L, Reed MH. Electronic decision support for diagnostic imaging in a primary care setting. *J Am Med Inform Assoc* 2011;18:267–70. doi:10.1136/amiajnl-2011-000049

48 Dixon BE, Simonaitis L, Goldberg HS, *et al.* A pilot study of distributed knowledge management and clinical decision support in the cloud. *Artif Intell Med* 2013;59:45–53. doi:10.1016/j.artmed.2013.03.004

49 Doerr M, Edelman E, Gabitzsch E, *et al.* Formative Evaluation of Clinician Experience with Integrating Family History-Based Clinical Decision Support into Clinical Practice. *J Pers Med* 2014;4:115–36. doi:10.3390/jpm4020115

50 Edelman EA, Lin BK, Doksum T, *et al.* Evaluation of a novel electronic genetic screening and clinical decision support tool in prenatal clinical settings. *Matern Child Health J* 2014;18:1233–45. doi:10.1007/s10995-013-1358-y

51 Feldstein AC, Schneider JL, Unitan R, *et al.* Health Care Worker Perspectives Inform Optimization of Patient Panel-Support Tools: A Qualitative Study. *Popul Health Manag* 2013;16:107–19. doi:10.1089/pop.2012.0065

52 Guenter D, Abouzahra M, Schabort I, *et al.* Design Process and Utilization of a Novel Clinical Decision Support System for Neuropathic Pain in Primary Care: Mixed Methods Observational Study. *JMIR Med Inform* 2019;7:e14141. doi:10.2196/14141

53 Helldén A, Al-Aieshy F, Bastholm-Rahmner P, *et al.* Development of a computerised decisions support system for renal risk drugs targeting primary healthcare. *BMJ Open* 2015;5:e006775. doi:10.1136/bmjopen-2014-006775

54 Heselmans A, Delvaux N, Laenen A, *et al.* Computerized clinical decision support system for diabetes in primary care does not improve quality of care: a cluster-randomized controlled trial. *Implement Sci* 2020;15:5. doi:10.1186/s13012-019-0955-6

55 Jensen C, McKerrow NH, Wills G. Acceptability and uptake of an electronic decision-making tool to support the implementation of IMCI in primary healthcare facilities in KwaZulu-Natal, South Africa. *Paediatr Int Child Health* 2020;40:215–26. doi:10.1080/20469047.2019.1697573

56 Jenssen BP, Bryant-Stephens T, Leone FT, *et al.* Clinical Decision Support Tool for Parental Tobacco Treatment in Primary Care. *PEDIATRICS* 2016;137:e20154185–e20154185. doi:10.1542/peds.2015-4185

57 Kempe A, Hurley LP, Cardemil CV, *et al.* Use of Immunization Information Systems in Primary Care. *Am J Prev Med* 2017;52:173–82. doi:10.1016/j.amepre.2016.07.029

58 Koskela T, Sandström S, Mäkinen J, *et al.* User perspectives on an electronic decision-support tool performing comprehensive medication reviews - a focus group study with physicians and nurses. *BMC Med Inform Decis Mak* 2016;16:6. doi:10.1186/s12911-016-0245-z

59 Lam Shin Cheung J, Paolucci N, Price C, *et al.* A system uptake analysis and GUIDES checklist evaluation of the Electronic Asthma Management System: A point-of-care computerized clinical decision support system. *J Am Med Inform Assoc* 2020;27:726–37. doi:10.1093/jamia/ocaa019

60 Lemke AA, Thompson J, Hulick PJ, *et al.* Primary care physician experiences utilizing a family health history tool with electronic health record–integrated clinical decision support: an implementation process assessment. *J Community Genet* 2020;11:339–50. doi:10.1007/s12687-020-00454-8

61 Litvin CB, Hyer JM, Ornstein SM. Use of Clinical Decision Support to Improve Primary Care Identification and Management of Chronic Kidney Disease (CKD). *J Am Board Fam Med* 2016;29:604–12. doi:10.3122/jabfm.2016.05.160020

62 Litvin CB, Ornstein SM, Wessell AM, *et al.* Adoption of a clinical decision support system to promote judicious use of antibiotics for acute respiratory infections in primary care. *Int J Med Inf* 2012;81:521–6. doi:10.1016/j.ijmedinf.2012.03.002

63 Lugtenberg M, Weenink J-W, van der Weijden T, *et al.* Implementation of multiple-domain covering computerized decision support systems in primary care: a focus group study on perceived barriers. *BMC Med Inform Decis Mak* 2015;15:82. doi:10.1186/s12911-015-0205-z

64 Lugtenberg M, Pasveer D, van der Weijden T, *et al.* Exposure to and experiences with a computerized decision support intervention in primary care: results from a process evaluation. *BMC Fam Pract* 2015;16:141. doi:10.1186/s12875-015-0364-0

65 Maia JX, de Sousa LAP, Marcolino MS, *et al.* The Impact of a Clinical Decision Support System in Diabetes Primary Care Patients in a Developing Country. *Diabetes Technol Ther* 2016;18:258–63. doi:10.1089/dia.2015.0253

66 Marcolino MS, Oliveira JAQ, Cimini CCR, *et al.* Development and Implementation of a Decision Support System to Improve Control of Hypertension and Diabetes in a Resource-Constrained Area in Brazil: Mixed Methods Study. *J Med Internet Res* 2021;23:e18872. doi:10.2196/18872

67 Minian N, Noormohamed A, Lingam M, *et al.* Integrating a brief alcohol intervention with tobacco addiction treatment in primary care: qualitative study of health care practitioner perceptions. *Addict Sci Clin Pract* 2021;16:17. doi:10.1186/s13722-021-00225-x

68 Montini T, Schenkel AB, Shelley DR. Feasibility of a Computerized Clinical Decision Support System for Treating Tobacco Use in Dental Clinics. *J Dent Educ* 2013;77:458–62. doi:10.1002/j.0022-0337.2013.77.4.tb05491.x

69 Pannebakker MM, Mills K, Johnson M, *et al.* Understanding implementation and usefulness of electronic clinical decision support (eCDS) for melanoma in English primary care: a qualitative investigation. *BJGP Open* 2019;3. doi:10.3399/bjgpopen18X101635

70 Peiris D, Williams C, Holbrook R, *et al.* A Web-Based Clinical Decision Support Tool for Primary Health Care Management of Back Pain: Development and Mixed Methods Evaluation. *JMIR Res Protoc* 2014;3:e17. doi:10.2196/resprot.3071

71 Praveen D, Patel A, Raghu A, *et al.* SMARTHealth India: Development and Field Evaluation of a Mobile Clinical Decision Support System for Cardiovascular Diseases in Rural India. *JMIR MHealth UHealth* 2014;2:e54. doi:10.2196/mhealth.3568

72 Price M, Davies I, Rusk R, *et al.* Applying STOPP Guidelines in Primary Care Through Electronic Medical Record Decision Support: Randomized Control Trial Highlighting the Importance of Data Quality. *JMIR Med Inform* 2017;5:e15. doi:10.2196/medinform.6226

73 Richardson S, Feldstein D, McGinn T, *et al.* Live Usability Testing of Two Complex Clinical Decision Support Tools: Observational Study. *JMIR Hum Factors* 2019;6:e12471. doi:10.2196/12471

74 Rieckert A, Sommerauer C, Krumeich A, *et al.* Reduction of inappropriate medication in older populations by electronic decision support (the PRIMA-eDS study): a qualitative study of practical implementation in primary care. *BMC Fam Pract* 2018;19:110. doi:10.1186/s12875-018-0789-3

75 Rieckert A, Teichmann A-L, Drewelow E, *et al.* Reduction of inappropriate medication in older populations by electronic decision support (the PRIMA-eDS project): a survey of general practitioners' experiences. *J Am Med Inform Assoc* 2019;26:1323–32. doi:10.1093/jamia/ocz104

76 Rousseau N. Practice based, longitudinal, qualitative interview study of computerised evidence based guidelines in primary care. *BMJ* 2003;326:314–314. doi:10.1136/bmj.326.7384.314

77 Rubin MA, Bateman K, Donnelly S, *et al.* Use of a Personal Digital Assistant for Managing Antibiotic Prescribing for Outpatient Respiratory Tract Infections in Rural Communities. *J Am Med Inform Assoc* 2006;13:627–34. doi:10.1197/jamia.M2029

78 Silveira DV, Marcolino MS, Machado EL, *et al.* Development and Evaluation of a Mobile Decision Support System for Hypertension Management in the Primary Care Setting in Brazil: Mixed-Methods Field Study on Usability, Feasibility, and Utility. *JMIR MHealth UHealth* 2019;7:e9869–e9869. doi:10.2196/mhealth.9869

79 Sukums F, Mensah N, Mpembeni R, *et al.* Promising adoption of an electronic clinical decision support system for antenatal and intrapartum care in rural primary healthcare facilities in sub-Saharan Africa: The QUALMAT experience. *Int J Med Inf* 2015;84:647–57. doi:10.1016/j.ijmedinf.2015.05.002

80 Toth-Pal E, Wårdh I, Strender L-E, *et al.* Implementing a clinical decision-support system in practice: A qualitative analysis of influencing attitudes and characteristics among general practitioners. *Inform Health Soc Care* 2008;33:39–54. doi:10.1080/17538150801956754

81 Trafton J, Martins S, Michel M, *et al.* Evaluation of the Acceptability and Usability of a Decision Support System to Encourage Safe and Effective Use of Opioid Therapy for Chronic, Noncancer Pain by Primary Care Providers. *Pain Med* 2010;11:575–85. doi:10.1111/j.1526-4637.2010.00818.x

82 Trinkley KE, Kroehl ME, Kahn MG, *et al.* Applying Clinical Decision Support Design Best Practices With the Practical Robust Implementation and Sustainability Model Versus Reliance on Commercially Available Clinical Decision Support Tools: Randomized Controlled Trial. *JMIR Med Inform* 2021;9:e24359. doi:10.2196/24359

83 Wan Q, Makeham M, Zwar NA, *et al.* Qualitative evaluation of a diabetes electronic decision support tool: views of users. *BMC Med Inform Decis Mak* 2012;12:61. doi:10.1186/1472-6947-12-61

84 Williams PA, Furberg RD, Bagwell JE, *et al.* Usability Testing and Adaptation of the Pediatric Cardiovascular Risk Reduction Clinical Decision Support Tool. *JMIR Hum Factors* 2016;3:e17. doi:10.2196/humanfactors.5440

85 Wilson A, Duszynski A, Turnbull D, *et al.* Investigating patients' and general practitioners' views of computerised decision support software for the assessment and management of cardiovascular risk. *J Innov Health Inform* 2007;15:33–44. doi:10.14236/jhi.v15i1.642

86 Zheng K, Padman R, Johnson MP, *et al.* Understanding technology adoption in clinical care: Clinician adoption behavior of a point-of-care reminder system. *Int J Med Inf* 2005;74:535–43. doi:10.1016/j.ijmedinf.2005.03.007

87 Turbow S, Hollberg JR, Ali MK. Electronic Health Record Interoperability: How Did We Get Here and How Do We Move Forward? *JAMA Health Forum* 2021;2:e210253. doi:10.1001/jamahealthforum.2021.0253

88 Luchenski SA, Reed JE, Marston C, *et al.* Patient and Public Views on Electronic Health Records and Their Uses in the United Kingdom: Cross-Sectional Survey. *J Med Internet Res* 2013;15:e160. doi:10.2196/jmir.2701

89 Zijl AL van, Vermeeren B, Koster F, *et al.* Interprofessional teamwork in primary care: the effect of functional heterogeneity on performance and the role of leadership. *J Interprof Care* 2021;35:10–20. doi:10.1080/13561820.2020.1715357

90 Harris M, Advocat J, Crabtree B, *et al.* Interprofessional teamwork innovations for primary health care practices and practitioners: evidence from a comparison of reform in three countries. *J Multidiscip Healthc* 2016;:35. doi:10.2147/JMDH.S97371

91 Cabana MD, Rand CS, Powe NR, *et al.* Why Don't Physicians Follow Clinical Practice Guidelines?: A Framework for Improvement. *JAMA* 1999;282:1458–65. doi:10.1001/jama.282.15.1458

92 Ancker JS, Kern LM, Edwards A, *et al.* How is the electronic health record being used? Use of EHR data to assess physician-level variability in technology use. *J Am Med Inform Assoc* 2014;21:1001–8. doi:10.1136/amiajnl-2013-002627

93 Boonstra A, Broekhuis M. Barriers to the acceptance of electronic medical records by physicians from systematic review to taxonomy and interventions. *BMC Health Serv Res* 2010;10:231. doi:10.1186/1472-6963-10-231

94 Pearson A, Wiechula R, Court A, *et al.* The JBI model of evidence-based healthcare. *Int J Evid Based Healthc* 2005;3:207–15. doi:10.1111/j.1479-6988.2005.00026.x

95 Ancker JS, Edwards A, Nosal S, *et al.* Effects of workload, work complexity, and repeated alerts on alert fatigue in a clinical decision support system. *BMC Med Inform Decis Mak* 2017;17:1–9. doi:10.1186/s12911-017-0430-8

96 Schick AG, Gordon LA, Haka S. Information overload: A temporal approach. *Account Organ Soc* 1990;15:199–220. doi:10.1016/0361-3682(90)90005-F

97 Eppler MJ, Mengis J. The Concept of Information Overload - A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines (2004). 2008. 271–305. doi:10.1007/978-3-8349-9772-2_15

98 Taksler GB, Hu B, DeGrandis F Jr, *et al.* Effect of Individualized Preventive Care Recommendations vs Usual Care on Patient Interest and Use of Recommendations: A Pilot Randomized Clinical Trial. *JAMA Netw Open* 2021;4:e2131455. doi:10.1001/jamanetworkopen.2021.31455

99 Goddard K, Roudsari A, Wyatt JC. Automation bias: empirical results assessing influencing factors. *Int J Med Inf* 2014;83:368–75. doi:10.1016/j.ijmedinf.2014.01.001

ANNEXES

Appendix 1: Search equations

PubMed/MEDLINE

("decision support systems, clinical"[mh] OR "decision making, computer-assisted"[mh] OR "clinical decision support"[tw] OR CDSS[tw] OR CCDSS[tw])

AND (integrat*[tw] OR implement*[tw] OR "health knowledge, attitudes, practice"[mh] OR "professional competence" [mh] OR "attitude to computers"[mh] OR "attitude of health personnel"[mh] OR attitude[tw] OR satisfaction[tw] OR feedback*[tw] OR drawback*[tw] OR imped*[tw] OR facilitat*[tw] OR adherence[tw] OR hinder*[tw] OR barrier*[tw] OR perception*[tw] OR opinion*[tw] OR compliance[tw] OR acceptability[tw] OR acceptance[tw] OR insight*[tw])

AND ("primary health care"[mh] OR "physicians, family"[mh] OR "family practice"[mh] OR "primary care nursing"[mh] OR "physicians, primary care"[mh] OR "primary care"[tw] OR "primary healthcare"[tw] OR "primary health care"[tw] OR "family physician*"[tw] OR "general practice*"[tw] OR "general practitioner*"[tw] OR gp[tw] OR gps[tw] OR "primary care nursing"[tw] OR "community setting*"[tw])

Filtres : french, english, journal article

EMBASE

('decision support system'/exp OR 'decision support system' OR 'clinical decision support system'/exp OR 'clinical decision support system')

AND ('barriers' OR 'adherence' OR 'health personnel attitude'/exp OR 'health personnel attitude' OR 'satisfaction'/exp OR satisfaction OR barrier* OR opinion OR adherence OR acceptability)

AND ('primary health care'/exp OR 'primary health care' OR 'family medicine'/exp OR 'family medicine' OR 'general practice'/exp OR 'general practice' OR 'general practitioner'/exp OR 'general practitioner')

PsycInfo, CINAHL (EBSCO)

S1 ;"decision support system" OR CDSS OR CCDSS OR "decision making, computer assisted" S2 ;integrat* OR implement* OR attitude* OR satisfaction OR feedback* OR drawback* OR imped* OR facilitat* OR "adherence" OR hinder* OR barrier* OR perception* OR opinion* OR compliance OR acceptability OR acceptance OR insight*

S3 ;"primary health care" OR "family practice" OR "primary nursing" OR "primary care" OR "primary healthcare" OR "primary health care" OR "family physician*" OR "general practice" OR "general practitioner*" OR gp OR "primary nurse*" OR "primary nursing" OR "community setting*"

S4 ; S1 AND S2 AND S3

The Cochrane Library

("decision support systems, clinical" OR "decision making, computer-assisted" OR "clinical decision support" OR CDSS OR CCDSS):ti,ab,kw

AND ("health knowledge, attitudes, practice" OR "professional competence" OR "attitude to computers" OR "attitude of health personnel" OR attitude? OR satisfaction OR feedback? OR drawback? OR imped* OR facilitat* OR adherence OR hinder? OR barrier? OR perception? OR opinion? OR compliance OR acceptability OR acceptance OR insight):ti,ab,kw

AND ("primary health care" OR "physicians, family" OR "family practice" OR "primary care nursing" OR "physicians, primary care" OR "primary care" OR "primary healthcare" OR "primary health care" OR "family physician?" OR "general practice?" OR "general practitioner?" OR gp? OR "primary care nursing" OR "community setting?"):ti,ab,kw"

Appendix 2: CDSS features extracted from the included studies, with some definitions

Features extracted	
Background information	
CDSS name	
Country of development	
Country of use	
Supported language(s)	
Commercialisation status	Yes / Ongoing / No / Not anymore / Unknown
Developed in collaboration with PCPs	Yes / No / Unknown
Targets	
Users	Primary care physicians / Other specialists / Primary care residents / Nurses / Other PCPs (non-physicians)
Care procedures	Prevention (iatrogenesis) / Prevention (disease, test ordering) / Diagnosis / Therapeutics / Management of chronic disease(s)
Health issue(s)	
Knowledge base	
Knowledge-based CDSS	Yes / No / Unknown
Updates of the knowledge base	Yes / No / Unknown
Cites the strength of evidence	Yes / No / Unknown
Provides links to the sources of the recommendations	Yes / No / Unknown
Provides educational materials to assist patients in shared decision-making	Yes / No / Unknown
Interface	
PCPs trained to the CDSS	Yes / No/ Unknown
EHR integration	Fully integrated / Partially integrated / Not integrated
Data entry by the PCP	Yes, during consultations / Yes, outside and/or during consultations / No
Data entry by the patient	Yes, before the consultation / No
Duplication of data entry	Yes / No
Active/Passive	
Push/Pull	
Interruptive or not	
Requires reason to override	Yes / No / Unknown

Appendix 3: Detailed features of included CDSSs

Table 1: Background information

	Study	CDSS Name	Country of development	Country of use	Supported language(s)	Commercialization	Developed in collaboration with PCPs
1	Abimbola et al, 2019	HealthTracker	Australia	Australia	English	Ongoing	Yes
2	afKlercker et al, 1998	Unknown	Sweden	Sweden	Swedish	Unknown	Yes
3	Alagiakrishnan et al, 2016	SMART CDS	Canada	Canada	English	Unknown	Yes
4	Arts et al, 2018	Unknown	The Netherlands	The Netherlands	English	Unknown	Yes
5	Ash et al, 2011	Unknown	United States of America	United States of America	English	Yes	Yes
6	Bandong et al, 2019	My Whiplash Navigator	Australia	Australia	English	Yes	Yes
7	Bessat et al, 2019	Registre Electronique des Consultations (REC)	Switzerland	Burkina Faso	French	Yes	Yes
8	Bindels et al, 2003	GRIF Automated Feedback System	The Netherlands	The Netherlands	Dutch	Unknown	Unknown
9	Curry et al, 2011	Decision Support Server	Canada	Canada	English	Not commercialized	Unknown
10	Dixon et al, 2013	Unknown	United States of America	United States of America	English	Not commercialized	Yes
11	Doerr et al, 2014	My Family	United States of America	United States of America	English	Yes	Yes
12	Edelman et al, 2014	The Pregnancy and Health Profile (PHP)	United States of America	United States of America	English	Yes	Yes
13	Feldstein et al, 2013	Patient Panel-Support Tool (PST)	United States of America	United States of America	English	Unknown	Yes
14	Guenter et al, 2019	McMaster Pain Assistant (MPA)	Canada	Canada	English	Not anymore	Yes
15	Helldèn et al, 2015	The renal button	Sweden	Sweden	English	Unknown	Yes
16	Heselmans et al, 2020, Koskela et al, 2016	EBMeDS	Finland	Finland, Estonia, Belgium, Italy	Finnish, Swedish, English, Estonian, French, Dutch, Italian, German (Russian being translated)	Yes	Yes
17	Jensen et al, 2019	eIMCI	South Africa	South Africa	English	Yes	Yes
18	Jenssen et al, 2016	Unknown	United States of America	United States of America	English	Not commercialized	Yes
19	Kempe et al, 2017	Immunization information systems	United States of America	United States of America	English	Unknown	Unknown
20	LamShinCheung et al, 2020	eAMS (Electronic Asthma Management System)	Canada	Canada	English	Ongoing	Yes
21	Lemke et al, 2020	The Genetic and Wellness Assessment	United States of America	United States of America	English	Yes	Unknown
22	Litvin et al, 2012	ABX-TRIP CDSS	United States of America	United States of America	English	Not commercialized	Yes
23	Litvin et al, 2016	Unknown	United States of America	United States of America	English	Not commercialized	Yes
24	Lugtenberg et al, 2015 (2 articles)	NHGDoc	The Netherlands	The Netherlands	Dutch	Yes	No
25	Maia et al, 2016	Unknown	Brazil	Brazil	Portuguese	Not commercialized	Yes
26	Marcolino et al, 2021	Unknown	Brazil	Brazil	Portuguese	Yes	Yes
27	Minian et al, 2021	Unknown	Canada	Canada	English	Not commercialized	Yes

28	Montini et al, 2013	Unknown	United States of America	United States of America	English	Not commercialized	Yes
29	Pannebakker et al, 2019	Unknown	England	England	English	Unknown	Yes
30	Peiris et al, 2014	Unknown	Australia	Australia	English	Not commercialized	Yes
31	Praveen et al, 2014	Unknown	Inde + Australia + England + United States of America	Inde + Indonesia + Thailand	English, Telugu, Hindi, Bahasa, Thai	Ongoing	Yes
32	Price et al, 2017	Unknown	Canada	Canada	English	Yes	Yes
33	Richardson et al, 2019	Unknown	United States of America	United States of America	English	Not commercialized	Unknown
34	Rieckert et al, 2018 and 2019 (2 articles)	PRIMA-eDS tool	Finland	Germany + Austria + Italy + England	German, Italian, English	Yes	Yes
35	Rousseau et al, 2003	Unknown	England	England	English	Not commercialized	Unknown
36	Rubin et al, 2006	Unknown	United States of America	United States of America	English	Unknown	Yes
37	Silveira et al, 2019	TeleHAS	Brazil	Brazil	Portuguese	Not commercialized	Yes
38	Sukums et al, 2015	The QUALMAT eCDSS	Germany	Ghana + Tanzania + Burkina Faso	Unknown	Unknown	Yes
39	Toth-Pal et al, 2008	Evibase	Sweden	Sweden	Swedish	Not anymore	Yes
40	Trafton et al, 2010	ATHENA-OT	United States of America	United States of America	English	Not commercialized	Yes
41	Trinkley et al, 2021	Unknown	United States of America	United States of America	English	Not commercialized	Yes
42	Wan et al, 2012	Unknown	Australia	Australia	English	Not commercialized	Yes
43	Williams et al, 2016	Pediatric Cardiovascular Risk Reduction CDS Tool	United States of America	United States of America	English	Unknown	Unknown
44	Wilson et al, 2007	EMPOWER	Australia	Australia	English	Not commercialized	Yes
45	Zheng et al, 2005	Clinical Reminder System (CRS)	United States of America	United States of America	English	Not commercialized	Yes

Table 2: CDSS targets

	Study	CDSS Name	Users	Care procedures	Health issues
1	Abimbola et al, 2019	HealthTracker	Primary care physicians	Prevention (disease, test ordering)	Treatment of cardiovascular risk
2	afKlercker et al, 1998	Unknown	Primary care physicians, nurses	Diagnosis	Ear, nose, and throat diseases
3	Alagiakrishnan et al, 2016	SMART CDS	Primary care physicians, other specialists	Prevention (iatrogenesis)	Giving rapid recommendations on the adaption of medication to renal function from the patient's EHR
4	Arts et al, 2018	Unknown	Primary care physicians	Global management of chronic disease(s)	Atrial fibrillation, diabetes, hypertension, medication prescriptions relating to care of older adults
5	Ash et al, 2011	Unknown	Primary care physicians, Nurses, Other PCPs (non-physicians)	Diagnosis, therapeutics (prescribing, vaccination)	Drug-drug, drug-condition, and drug-allergy interaction checking; patient care plan dashboard that includes alerts and reminders; nearly 3000 condition specific point-and-click templates for documentation
6	Bandong et al, 2019	My Whiplash Navigator	Primary care physicians, primary care residents, other PCPs (non-physicians), patients	Therapeutics (prescribing, vaccination)	Whiplash-associated disorders
7	Bessat et al, 2019	Registre Electronique des Consultations (REC)	Nurses, other PCPs (non-physicians)	Diagnosis, therapeutics (prescribing, vaccination)	Assessment, classification, and treatment of children under the age of 5 year
8	Bindels et al, 2003	GRIF Automated Feedback System	Primary care physicians	Prevention (disease, test ordering)	Comments on the appropriateness of diagnostic tests ordered by general practitioners based on recommendations from accepted national and regional practice guidelines
9	Curry et al, 2011	Decision Support Server	Primary care physicians	Prevention (disease, test ordering)	Diagnostic imaging prescriptions
10	Dixon et al, 2013	Unknown	Primary care physicians, other specialists	Prevention (disease, test ordering), global management of chronic disease(s)	Hypertension, diabetes, coronary artery disease
11	Doerr et al, 2014	My Family	Primary care physicians, other specialists, nurses	Prevention (disease, test ordering)	Cancer risk management
12	Edelman et al, 2014	The Pregnancy and Health Profile (PHP)	Primary care physicians, other specialists, nurses	Prevention (disease, test ordering)	Prenatal genetic screening and clinical decision support
13	Feldstein et al, 2013	Patient Panel-Support Tool (PST)	Primary care physicians, nurses, other PCPs (non-physicians)	Prevention (iatrogenesis, disease, test ordering), global management of chronic disease(s)	Graphically displays care gaps (e.g., for screening, medication use, monitoring, risk-factor control, immunizations)
14	Guenter et al, 2019	McMaster Pain Assistant (MPA)	Primary care physicians, nurses, primary care residents	Diagnosis, therapeutics (prescribing, vaccination)	Neuropathic pain
15	Helldèn et al, 2015	The renal button	Primary care physicians	Prevention (iatrogenesis)	Giving rapid recommendations on the adaption of medication to renal function from the patient's EHR
16	Heselmans et al, 2020, Koskela et al, 2016	EBMeDS	Primary care physicians, nurses	Prevention (iatrogenesis, disease, test ordering), therapeutics (prescribing, vaccination), global management of chronic disease(s)	Guideline assistant, drug interaction and contraindication reminders, drug choice suggestions (indications), reminders of drug restrictions and dosing in renal malfunction, reminders of drug restrictions during pregnancy and lactation, other rules related to > 1000 international guidelines, form assistant to help with duplication of data collection
17	Jensen et al, 2019	eIMCI	Nurses	Prevention (disease, test ordering), therapeutics (prescribing, vaccination)	Management of childhood illness
18	Jenssen et al, 2016	Unknown	Nurses, other specialists	Prevention (disease, test ordering), Therapeutics (prescribing, vaccination)	Smoking cessation
19	Kempe et al, 2017	Immunization information systems	Primary care physicians, other specialists	Prevention (disease, test ordering)	Management of vaccination
20	LamShinCheung et al, 2020	eAMS (Electronic Asthma Management System)	Primary care physicians, nurses, primary care residents	Therapeutics (prescribing, vaccination), global management of chronic disease(s)	Asthma
21	Lemke et al, 2020	The Genetic and Wellness Assessment	Primary care physicians, other specialists	Prevention (disease, test ordering)	Identifying patients who have an increased probability of an inherited condition (related to cancer, cardiology, neurology, and endocrinology), and facilitating appropriate follow-up and care
22	Litvin et al, 2012	ABX-TRIP CDSS	Primary care physicians, nurses, other PCPs (non-physicians)	Prevention (disease, test ordering), diagnosis, therapeutics (prescribing)	Management of acute respiratory infections

23	Litvin et al, 2016	Unknown	Primary care physicians, nurses, other PCPs (non-physicians)	Prevention (disease, test ordering)	Identification and management of chronic kidney disease
24	Lugtenberg et al, 2015 (2 articles)	NHGDoc	Primary care physicians, nurses	Prevention (disease, test ordering, iatrogenesis) therapeutics (prescribing, vaccination), global management of chronic disease(s)	Cardiovascular risk management, asthma/COPD, diabetes mellitus type II, thyroid disorders, viral hepatitis and other liver diseases, atrial fibrillation, and subfertility
25	Maia et al, 2016	Unknown	Primary care physicians, nurses	Global management of chronic disease(s)	Diabetes (T2)
26	Marcolino et al, 2021	Unknown	Primary care physicians, nurses, other PCPs (non-physicians)	Prevention (disease, test ordering), global management of chronic diseases	Diabetes (T2), hypertension, cardiovascular risk treatment
27	Minian et al, 2021	Unknown	Nurses, other PCPs (non-physicians)	Prevention (disease, test ordering)	Alcohol intervention
28	Montini et al, 2013	Unknown	Other PCPs (non-physicians)	Prevention (disease, test ordering), therapeutics (prescribing, vaccination)	Tobacco use screening and treatment
29	Pannebakker et al, 2019	Unknown	Primary care physicians	Prevention (disease, test ordering)	Assessment of pigmented skin lesions
30	Peiris et al, 2014	Unknown	Primary care physicians	Diagnosis, therapeutics (prescribing, vaccination)	Management of back pain
31	Praveen et al, 2014	Unknown	Primary care physicians, other PCPs (non-physicians)	Global management of chronic disease(s)	Cardiovascular risk management and referral
32	Price et al, 2017	Unknown	Primary care physicians, nurses	Prevention (iatrogenesis)	Potentially inappropriate prescriptions in the elderly
33	Richardson et al, 2019	Unknown	Primary care physicians, nurses	Therapeutics (prescribing, vaccination)	Sore throat, upper respiratory tract infection
34	Rieckert et al, 2018 and 2019 (2 articles)	PRIMA-eDS tool	Primary care physicians	Prevention (iatrogenesis)	Potentially inappropriate prescriptions in the elderly
35	Rousseau et al, 2003	Unknown	Primary care physicians, nurses, other PCPs (non-physicians)	Therapeutics (prescribing, vaccination), global management of chronic disease(s)	Asthma and angina in adults
36	Rubin et al, 2006	Unknown	Primary care physicians, nurses, other specialists, other PCPs (non-physicians)	Diagnosis, therapeutics (prescribing, vaccination)	Acute respiratory tract infections
37	Silveira et al, 2019	TeleHAS	Primary care physicians	Prevention (disease, test ordering), therapeutics	Cardiovascular risk and hypertension
38	Sukums et al, 2015	The QUALMAT eCDSS	Other PCPs (non-physicians)	Therapeutics (prescribing, vaccination)	Antenatal and intrapartum care
39	Toth-Pal et al, 2008	Evibase	Primary care physicians	Global management of chronic disease(s)	Congestive heart failure
40	Trafton et al, 2010	ATHENA-OT	Primary care physicians, nurses	Therapeutics (prescribing, vaccination)	Opioid therapy for chronic, noncancer pain
41	Trinkley et al, 2021	Unknown	Primary care physicians, other specialists	Therapeutics (prescribing, vaccination)	Heart failure
42	Wan et al, 2012	Unknown	Primary care physicians, nurses	Global management of chronic disease(s)	Diabetes (T2)
43	Williams et al, 2016	Pediatric Cardiovascular Risk Reduction CDS Tool	Primary care physicians	Prevention (disease, test ordering)	Pediatric cardiovascular risk management
44	Wilson et al, 2007	EMPOWER	Primary care physicians	Prevention (disease, test ordering), therapeutics (prescribing, vaccination)	Cardiovascular risk and hypertension
45	Zheng et al, 2005	Clinical Reminder System (CRS)	Primary care residents	Prevention (iatrogenesis, disease, test ordering), therapeutics (prescribing, vaccination), global management of chronic disease(s)	Diabetes (T2), hyperlipidemia, steroid-induced osteoporosis, influenza, pneumonia, breast cancer, cervical cancer

Table 3: CDSS knowledge base

	Study	CDSS Name	Knowledge-based CDSS	Updates of the knowledge database	Cites the strength of evidence	Provides links to the sources of recommendations	Provides educational materials to assist patients in shared decision-making
1	Abimbola et al, 2019	HealthTracker	Yes	Yes	Unknown	No	Yes
2	afKlercker et al, 1998	Unknown	Yes	Unknown	No	No	No
3	Alagiakrishnan et al, 2016	SMART CDS	Yes	Unknown	Yes	Yes	No
4	Arts et al, 2018	Unknown	Yes	Unknown	No	Yes	No
5	Ash et al, 2011	Unknown	Yes	Yes	Unknown	Unknown	No
6	Bandong et al, 2019	My Whiplash Navigator	Yes	Unknown	Unknown	Unknown	Yes
7	Bessat et al, 2019	Registre Electronique des Consultations (REC)	Yes	Unknown	Unknown	Unknown	No
8	Bindels et al, 2003	GRIF Automated Feedback System	Yes	Unknown	Unknown	Yes	No
9	Curry et al, 2011	Decision Support Server	Yes	No	Unknown	Yes	No
10	Dixon et al, 2013	Unknown	Yes	No	Unknown	Yes	No
11	Doerr et al, 2014	My Family	Yes	Unknown	Unknown	Yes	Yes
12	Edelman et al, 2014	The Pregnancy and Health Profile (PHP)	Yes	Unknown	Unknown	Unknown	Yes
13	Feldstein et al, 2013	Patient Panel-Support Tool (PST)	Yes	Unknown	No	No	Yes
14	Guenter et al, 2019	McMaster Pain Assistant (MPA)	Yes	No	No	Yes	Yes
15	Helldèn et al, 2015	The renal button	Yes	Unknown	Unknown	Yes	No
16	Heselmans et al, 2020, Koskela et al, 2016	EBMeDS	Yes	Yes	Yes	Yes	No
17	Jensen et al, 2019	eIMCI	Yes	Yes	No	Unknown	No
18	Jenssen et al, 2016	Unknown	Yes	Yes	No	Yes	No
19	Kempe et al, 2017	Immunization information systems	Yes	Unknown	Unknown	Unknown	No
20	LamShinCheung et al, 2020	eAMS (Electronic Asthma Management System)	Yes	Yes	No	No	Yes
21	Lemke et al, 2020	The Genetic and Wellness Assessment	Yes	Unknown	No	No	No
22	Litvin et al, 2012	ABX-TRIP CDSS	Yes	No	No	Yes	Yes
23	Litvin et al, 2016	Unknown	Yes	No	Unknown	Yes	No
24	Lugtenberg et al, 2015 (2 articles)	NHGDoc	Yes	Yes	No	Unknown	No
25	Maia et al, 2016	Unknown	Yes	No	No	No	No
26	Marcolino et al, 2021	Unknown	Yes	Yes	Unknown	Yes	Unknown
27	Minian et al, 2021	Unknown	Yes	Yes	No	No	No
28	Montini et al, 2013	Unknown	Yes	No	Unknown	No	No
29	Pannebakker et al, 2019	Unknown	Yes	Unknown	Unknown	Unknown	No
30	Peiris et al, 2014	Unknown	Yes	No	Unknown	Yes	Yes
31	Praveen et al, 2014	Unknown	Yes	Yes	No	Yes	No
32	Price et al, 2017	Unknown	Yes	No	Yes	Yes	No
33	Richardson et al, 2019	Unknown	Yes	No	Unknown	No	Yes
34	Rieckert et al, 2018 and 2019 (2 articles)	PRIMA-eDS tool	Yes	Unknown	Unknown	Yes	No
35	Rousseau et al, 2003	Unknown	Yes	No	Yes	Yes	Yes
36	Rubin et al, 2006	Unknown	Yes	Unknown	Unknown	Unknown	No
37	Silveira et al, 2019	TeleHAS	Yes	Yes	Unknown	Yes	No
38	Sukums et al, 2015	The QUALMAT eCDSS	Yes	Unknown	Unknown	Unknown	No
39	Toth-Pal et al, 2008	Evibase	Yes	Unknown	Unknown	Yes	No
40	Trafton et al, 2010	ATHENA-OT	Yes	No	Unknown	Yes	No
41	Trinkley et al, 2021	Unknown	Yes	No	Unknown	Yes	No
42	Wan et al, 2012	Unknown	Yes	No	No	No	Yes
43	Williams et al, 2016	Pediatric Cardiovascular Risk Reduction CDS Tool	Yes	Unknown	Unknown	Unknown	No
44	Wilson et al, 2007	EMPOWER	Yes	No	Unknown	Unknown	Yes
45	Zheng et al, 2005	Clinical Reminder System (CRS)	Yes	No	No	Yes	No

Table 4: CDSS interface

Study		CDSS Name	Participants trained to the CDSS	EHR integration	Data entry by the PCP	Data entry by the patient	Duplication of data entry	Active or passive	Push or pull	Interruptive or not	Requires reason for over-ride
1	Abimbola et al, 2019	HealthTracker	No	Partially integrated	During the encounter	No	No	Active	Pull	Not interruptive	No
2	afKlercker et al, 1998	Unknown	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
3	Alagiakrishnan et al, 2016	SMART CDS	Yes	Fully integrated	During the encounter	No	No	Active and Passive	Pull	Interruptive	Yes
4	Arts et al, 2018	Unknown	Yes	Partially integrated	During the encounter	No	Yes	Active	Pull	Not interruptive	Yes
5	Ash et al, 2011	Unknown	Yes	Fully integrated	During the encounter	No	No	Active and Passive	Pull	Interruptive and not interruptive (depending on what aspect of the CDSS is triggered)	No
6	Bandong et al, 2019	My Whiplash Navigator	Yes	Not integrated	During the encounter	Yes - before the encounter	Yes	Passive	Pull	Not interruptive	No
7	Bessat et al, 2019	Registre Electronique des Consultations (REC)	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
8	Bindels et al, 2003	GRIF Automated Feedback System	Unknown	Partially integrated	During the encounter	No	Yes	Active	Pull	Interruptive	Yes
9	Curry et al, 2011	Decision Support Server	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Interruptive	Unknown
10	Dixon et al, 2013	Unknown	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Not interruptive	No
11	Doerr et al, 2014	My Family	Yes	Fully integrated	No	Yes - before the encounter	No	Passive	Pull	Not interruptive	No
12	Edelman et al, 2014	The Pregnancy and Health Profile (PHP)	Yes	Not integrated	No	Yes - before the encounter	Yes	Passive	Pull	Not interruptive	No
13	Feldstein et al, 2013	Patient Panel-Support Tool (PST)	Yes	Partially integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
14	Guenter et al, 2019	McMaster Pain Assistant (MPA)	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Not interruptive	Unknown
15	Helldèn et al, 2015	The renal button	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Not interruptive	No
16	Heselmans et al, 2020, Koskela et al, 2016	EBMeDS	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Interruptive	No
17	Jensen et al, 2019	eIMCI	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Interruptive	No
18	Jenssen et al, 2016	Unknown	Yes	Fully integrated	During the encounter	No	Yes	Active	Pull	Not interruptive	No
19	Kempe et al, 2017	Immunization information systems	No	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
20	LamShinCheung et al, 2020	eAMS (Electronic Asthma Management System)	Yes	Fully integrated	During the encounter	Yes - before the encounter	No	Active	Pull	Interruptive	No
21	Lemke et al, 2020	The Genetic and Wellness Assessment	Unknown	Fully integrated	During the encounter	Yes - before the encounter	No	Active	Unknown	Unknown	Unknown
22	Litvin et al, 2012	ABX-TRIP CDSS	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
23	Litvin et al, 2016	Unknown	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
24	Lugtenberg et al, 2015 (2 articles)	NHGDoc	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
25	Maia et al, 2016	Unknown	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	Unknown
26	Marcolino et al, 2021	Unknown	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
27	Minian et al, 2021	Unknown	Yes	Not integrated	During the encounter	No	No	Passive	Pull	Interruptive	No
28	Montini et al, 2013	Unknown	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No

29	Pannebakker et al, 2019	Unknown	Yes	Fully integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
30	Peiris et al, 2014	Unknown	Unknown	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
31	Praveen et al, 2014	Unknown	Yes	Not integrated	During the encounter	No	No	Passive	Pull	Not interruptive	No
32	Price et al, 2017	Unknown	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Not interruptive	No
33	Richardson et al, 2019	Unknown	Unknown	Fully integrated	During the encounter	No	No	Active	Pull	Interruptive	No
34	Rieckert et al, 2018 and 2019 (2 articles)	PRIMA-eDS tool	Yes	Not integrated	Outside and/or during the encounter	No	Yes	Passive	Pull	Not interruptive	No
35	Rousseau et al, 2003	Unknown	Yes	Fully integrated	During the encounter	No	No	Active	Pull	Interruptive	No
36	Rubin et al, 2006	Unknown	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
37	Silveira et al, 2019	TeleHAS	No	Not integrated	Outside and/or during the encounter	No	Yes	Passive	Pull	Not interruptive	No
38	Sukums et al, 2015	The QUALMAT eCDSS	Yes	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
39	Toth-Pal et al, 2008	Evibase	Yes	Not integrated	Outside and/or during the encounter	No	Yes	Passive	Pull	Not interruptive	Unknown
40	Trafton et al, 2010	ATHENA-OT	Yes	Fully integrated	Outside and/or during the encounter	No	No	Active	Pull	Interruptive	No
41	Trinkley et al, 2021	Unknown	Yes	Fully integrated	During the encounter	No	No	Active	Push	Interruptive	Yes
42	Wan et al, 2012	Unknown	No	Partially integrated	During the encounter	No	Yes	Active	Pull	Not interruptive	No
43	Williams et al, 2016	Pediatric Cardiovascular Risk Reduction CDS Tool	No	Not integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No
44	Wilson et al, 2007	EMPOWER	Yes	Partially integrated	During the encounter	No	No	Passive	Pull	Not interruptive	Unknown
45	Zheng et al, 2005	Clinical Reminder System (CRS)	Yes	Partially integrated	During the encounter	No	Yes	Passive	Pull	Not interruptive	No

Appendix 4: Quality assessment of the included studies (QuADS criteria)

		QuADS criteria												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	Abimbola et al, 2019	C	M	M	C	VS	C	C	C	VS	NM	M	C	M
2	afKlercker et al, 1998	M	C	C	C	C	C	C	C	NM	VS	C	NM	M
3	Alagiakrishnan et al, 2016	C	C	M	C	NM	NM	M	M	M	NM	M	C	C
4	Arts et al, 2018	C	C	C	C	M	C	C	C	C	NM	M	M	C
5	Ash et al, 2011	C	C	C	M	M	M	M	M	VS	NM	C	C	NM
6	Bandong et al, 2019	C	C	C	C	C	NM	M	C	C	NM	M	C	M
7	Bessat et al, 2019	C	C	C	C	M	NM	C	C	VS	VS	M	VS	M
8	Bindels et al, 2003	C	C	M	C	NM	M	C	M	C	M	C	C	M
9	Curry et al, 2011	C	M	C	M	VS	NM	M	VS	C	NM	M	NM	NM
10	Dixon et al, 2013	C	C	C	M	VS	NM	VS	M	VS	VS	M	M	M
11	Doerr et al, 2014	C	C	C	C	C	M	C	C	NM	M	M	VS	C
12	Edelman et al, 2014	C	C	C	M	M	NM	M	C	C	NM	M	NM	C
13	Feldstein et al, 2013	C	C	C	C	C	M	C	C	C	VS	C	NM	M
14	Guenter et al, 2019	C	C	C	C	M	C	C	M	M	VS	C	C	M
15	Helldèn et al, 2015	C	C	M	C	VS	C	C	M	C	VS	C	C	C
16	Heselmans et al, 2020	C	M	C	M	VS	VS	M	M	C	C	M	NM	C
17	Jensen et al, 2019	C	C	C	C	M	NM	M	C	M	NM	M	C	C
18	Jenssen et al, 2016	C	C	C	C	NM	M	VS	M	VS	NM	M	C	M
19	Kempe et al, 2017	C	C	C	M	C	C	M	C	C	NM	M	C	M
20	Koskela et al, 2016	C	C	C	C	C	NM	M	C	M	NM	M	NM	C
21	LamShinCheung et al, 2020	C	C	C	M	VS	NM	M	C	C	NM	M	C	M
22	Lemke et al, 2020	C	C	C	C	C	C	C	C	VS	M	C	C	C
23	Litvin et al, 2012	C	C	C	C	NM	M	C	M	C	NM	C	C	M
24	Litvin et al, 2016	C	C	C	C	NM	M	C	M	C	NM	M	NM	C
25	Lugtenberg, Pasveer et al, 2015	C	C	C	C	C	C	C	C	C	C	C	NM	M
26	Lugtenberg, Weeninck et al, 2015	C	C	C	C	M	M	M	C	C	M	M	NM	C
27	Maia et al, 2016	C	C	C	M	M	NM	M	VS	M	NM	NM	C	M
28	Marcolino et al, 2021	C	C	C	C	VS	VS	C	M	M	NM	M	C	M
29	Minian et al, 2021	C	C	C	C	C	C	C	C	C	C	C	NM	C
30	Montini et al, 2013	C	M	C	C	VS	M	M	M	M	NM	M	C	VS
31	Pannebakker et al, 2019	C	C	C	C	C	C	C	C	VS	M	C	C	M
32	Peiris et al, 2014	C	C	C	C	VS	M	C	VS	VS	M	C	C	VS
33	Praveen et al, 2014	C	C	C	C	VS	C	C	C	NM	M	C	C	VS
34	Price et al, 2017	C	C	C	C	C	VS	M	VS	C	NM	M	NM	M
35	Richardson et al, 2019	C	C	C	C	C	NM	C	M	VS	C	C	NM	C
36	Rieckert et al, 2018	C	C	C	C	C	NM	M	C	M	M	C	NM	C
37	Rieckert et al, 2019	C	C	C	C	M	C	C	C	C	C	C	NM	C
38	Rousseau et al, 2003	C	M	C	C	C	C	C	C	M	NM	NM	NM	M
39	Rubin et al, 2006	C	C	C	M	VS	NM	M	VS	C	NM	M	NM	M
40	Silveira et al, 2019	C	C	C	C	VS	NM	C	VS	C	NM	M	C	NM
41	Sukums et al, 2015	C	C	C	C	M	M	C	C	VS	M	C	NM	M
42	Toth-Pal et al, 2008	C	C	C	C	M	VS	C	C	C	C	C	NM	M
43	Trafton et al, 2010	C	M	C	C	VS	NM	C	M	VS	NM	M	C	M
44	Trinkley et al, 2021	C	C	C	C	M	VS	M	M	VS	VS	C	C	C
45	Wan et al, 2012	C	C	C	C	M	NM	C	C	C	NM	C	NM	C
46	Williams et al, 2016	C	C	C	M	VS	NM	M	M	VS	C	M	NM	C
47	Wilson et al, 2007	C	C	C	C	VS	NM	M	M	M	NM	M	NM	VS
48	Zheng et al, 2005	C	C	VS	C	M	VS	C	VS	VS	C	C	NM	VS

C: complete; M: moderately; VS: very slightly; NM: no mention at all

1: Theoretical or conceptual underpinning to the research
2: Statement of research aim(s)
3: Clear description of research settings and target population
4: The study design is appropriate to address the stated research aim/s
5: Appropriate sampling to address the research aim/s
6: Rationale for choice of data collection tool/s
7: The format and content of data collection tool is appropriate to address the stated research aim/s
8: Description of data collection procedure
9: Recruitment data provided
10: Justification for analytic method selected
11: The method of analysis was appropriate to answer the research aim/s
12: Evidence that the research stakeholders have been considered in research design or conduct.
13: Strengths and limitations critically discussed

Appendix 5: Methodological characteristics of included studies

Studies n=48	Data collection	Evaluation framework	Number of interviewed participants
Abimbola et al, 2019	Quantitative (cross-sectional survey) Qualitative (focus group discussions)	NASSS[1] framework	Unknown
af Klercker et al, 1998	Qualitative (focus group)	None	1 primary care physician, 4 nurses
Alagiakrishnan et al, 2016	Quantitative (cross-sectional survey) Qualitative (semi-structured interviews)	None	6 primary care physicians, 2 geriatric medicine specialists
Arts et al, 2018	Quantitative (cross-sectional survey) Qualitative (focus group discussions)	UTAUT[2] framework	34 primary care physicians
Ash et al, 2011	Qualitative (semi-structured interviews)	Socio-Technical Model of Health Information Technology	18 primary care physicians, 14 other specialists, 4 staff members
Bandong et al, 2019	Quantitative (cross-sectional survey) Qualitative (focus group discussions)	NSW[3] Translational Research Framework	24 primary care physicians, 13 other specialists, 60 PCP students
Bessat et al, 2019	Qualitative (in-depth interviews and focus group discussions)	None	21 health workers (non-physicians)
Bindels et al, 2003	Quantitative (longitudinal survey) Qualitative (in-depth interviews)	IBM computer usability satisfaction questionnaire	11 primary care physicians
Curry et al, 2011	Quantitative (cross-sectional survey, log data) Qualitative (semi-structured interviews)	None	19 primary care physicians
Dixon et al, 2013	Quantitative (log data) and Qualitative (meeting minutes)	None	3 primary care physicians
Doerr et al, 2014	Quantitative (cross-sectional survey) Qualitative (semi-structured interviews)	CFIR[4] framework	4 primary care physicians, 4 other specialists, 2 nurses
Edelman et al, 2014	Quantitative (longitudinal survey) Qualitative (semi-structured interviews and open questions in survey)	None	11 primary care physicians, 10 primary care residents
Feldstein et al, 2013	Qualitative (in-depth interview)	None	17 primary care physicians, 4 nurse practitioners or physician assistants, 11 medical assistants, 20 other managerial staff
Guenter et al, 2019	Quantitative (longitudinal survey) Qualitative (focus group discussions)	Pathman awareness-to-adherence model	10 primary care physicians (4 family practitioners, 6 obstetrics-gynecology physicians), 10 primary care residents, 3 nurse practitioners
Helldén et al, 2015	Qualitative (focus group discussions)	Technology Acceptance Model (TAM)	7 primary care physicians
Heselmans et al, 2020	Quantitative (cross-sectional survey)	None	14 primary care physicians
Jensen et al, 2019	Quantitative (log data) Qualitative (focus group discussions and in-depth interview)	None	32 IMCI practitioners (professional nurses who have been trained in primary healthcare), 6 operational managers (senior nurses appointed to oversee the day-to-day operations)
Jenssen et al, 2016	Quantitative (log data, cross-sectional survey) Qualitative (focus group discussions and open questions in survey)	IBM computer usability satisfaction questionnaire	17 primary care physicians
Kempe et al, 2017	Quantitative (cross-sectional survey)	None	907 primary care physicians (325 pediatricians, 310 family practitioners, 272 general internists)
Koskela et al, 2016	Qualitative (focus group discussions)	None	9 primary care physicians, 12 nurses
Lam Shin Cheung et al, 2020	Quantitative (cross-sectional survey) Qualitative (open questions in survey)	System Usability Scale (SUS)	18 primary care physicians, 1 nurse practitioner
Lemke et al, 2020	Qualitative (semi structured interviews)	None	24 primary care physicians (12 general internal medicine, 8 family medicine, and 4 obstetrics-gynecology)

Litvin et al, 2012	Quantitative (log data) Qualitative (semi structured interviews)	None (based on previous findings)	27 primary care physicians, 6 nurse practitioners, 6 physician's assistants
Litvin et al, 2016	Quantitative (log data) Qualitative (semi structured interviews)	None (based on previous findings)	25 primary care physicians and 15 midlevel providers
Lugtenberg et al, 2015	Qualitative (focus group discussions)	None (based on previous findings)	15 primary care physicians, 4 primary care residents, 5 practice nurses
Lugtenberg et al, 2015	Quantitative (cross-sectional survey)	None (based on previous findings)	112 primary care physicians, 52 practice nurses
Maia et al, 2016	Quantitative (cross-sectional survey) Qualitative (open questions in survey)	None	2 primary care physicians, 10 nurses
Marcolino et al, 2021	Quantitative (cross-sectional survey) Qualitative (focus group discussions)	None (based on previous findings)	25 primary care physicians, 44 nurses, 27 other PCPs (non-physicians)
Minian et al, 2021	Qualitative (semi structured interviews)	Hexagon Tool framework	13 nurses, 4 pharmacists, 7 other PCPs (non-physicians)
Montini et al, 2013	Quantitative (log data) Qualitative (semi structured interviews)	Technology Acceptance Model (TAM)	10 associate student dentists
Pannebakker et al, 2019	Qualitative (semi structured interviews)	CFIR[4] framework	14 primary care physicians
Peiris et al, 2014	Quantitative (log data) Qualitative (semi structured interviews)	None	20 primary care physicians
Praveen et al, 2014	Quantitative (cross-sectional survey) Qualitative (semi structured interviews)	COM-B[5] theory of behavior change	3 primary care physicians, 35 ASHAs (accredited social health activist),
Price et al, 2017	Quantitative (log data) Qualitative (semi structured interviews)	None	5 primary care physicians
Richardson et al, 2019	Qualitative (semi structured interviews)	None	3 primary care physicians
Rieckert et al, 2018	Qualitative (semi structured interviews)	None	21 primary care physicians
Rieckert et al, 2019	Quantitative (cross-sectional survey)	None	161 primary care physicians
Rousseau et al, 2003	Qualitative (semi structured interviews)	None	8 primary care physicians, 3 nurses, and 2 practice managers
Rubin et al, 2006	Quantitative (cross-sectional survey) Qualitative (open questions in survey)	None	65 primary care physicians
Silveira et al, 2019	Quantitative (longitudinal survey) Qualitative (semi structured interviews)	None	10 primary care physicians
Sukums et al, 2015	Quantitative (longitudinal survey) Qualitative (semi structured interviews)	FITT[6] framework	56 other PCPs (non-physicians)
Toth-Pal et al, 2008	Quantitative (log data) Qualitative (semi structured interviews)	None	5 primary care physicians
Trafton et al, 2010	Quantitative (longitudinal survey, log data) Qualitative (semi structured interviews)	System Usability Scale (SUS) and Center for Health Care Evaluation adapted provider satisfaction questionnaire	11 primary care physicians, 1 nurse practitioner
Trinkley et al, 2021	Qualitative (semi structured interviews)	Modified System Usability Scale (SUS)	21 primary care physicians
Wan et al, 2012	Qualitative (semi structured interviews)	None	15 primary care physicians, 2 practice nurses
Williams et al, 2016	Quantitative (cross-sectional survey) Qualitative (feedback minutes)	System Usability Scale (SUS)	14 primary care physicians
Wilson et al, 2007	Qualitative (semi structured interviews)	None	5 primary care physicians
Zheng et al, 2005	Quantitative (log data) Qualitative (semi structured interviews)	IBM computer usability satisfaction questionnaire	16 primary care residents

1: Framework for theorizing and evaluating Nonadoption, Abandonment, and challenges to the Scale-Up, Spread, and Sustainability of health and care technologies
2: Unified Theory of Acceptance and Use of Technology
3: New South Wales
4: Consolidated Framework for Implementation Research
5: Capability, Opportunity, and Motivation as three key factors capable of changing behavior (B)
6: Fit between Individual, Task and Technology

Appendix 6: Complete list of identified main barriers and facilitators, and explanatory elements, according to the HOT-fit framework

Classification of inductive codes in the HOT-fit framework [n CDSSs]

- **Human** [n=41]
  - **System use** [n=39]
    - **Attitude** [n=21]
      - (-) PCPs don't need help with the targeted health issue [n=8]
      - (-) Lack of engagement from PCPs (inertia of previous practice) [n=8]
      - (-) Concerns about the explainability of CDSS recommendations [n=5]
      - (-) Fear of patient opinion [n=4]
      - (-) Stress associated with a new task [n=2]
      - (-) Fear of data loss in case of breakdowns [n=1]
      - (+) PCP commitment [n=1]
    - **Expectations or belief** [n=12]
      - (-) Using CDSSs reduces PCPs' expertise and may lead to "cookbook medicine" [n=6]
        - The recommendation should not be directive but give attention so that they facilitate PCPs' own judgment [n=1]
      - (-) CDSS are mostly useful to less experienced PCPs [n=5]
      - (-) Creating a specific to-do list would be useful to later reassess recommendations not completed during the medical consultation [n=2]
      - (-) Not following CDSS recommendations may led PCPs to legal issues [n=2]
      - (-) Concerns regarding the misuse of data by third parties (health inspectorate or health insurance companies) [n=1]
    - **Knowledge and expertise** [n=7]
      - (-) Lack of computer skills [n=7]
    - **Level of use** [n=5]
      - (-) Don't feel qualified to perform CDSS recommendations [n=3]
      - (-) Old age [n=2]
    - **Motivation to use** [n=18]
      - (-) Technical problems hinders the motivation to use the CDSS [n=9]
      - (+) Patients' perceived usefulness of the CDSS increases PCPs' motivation to use it [n=7]
      - (-) Ask for financial compensation to CDSS use [n=7]
        - Need to reward support staff for their productivity with the CDSS [n=1]
      - (+) Using CDSSs is a source of motivation to provide better care (PCPs feels more advanced compared to others) [n=3]
      - (-) No motivational information as to why it is important to use the CDSS [n=2]
      - (+) Positive feedback is appreciated by PCPs when they had completed a CDSS's recommended task [n=1]
      - (-) Positive feedback is wanted by PCPs when they had completed a CDSS's recommended task [n=1]
      - (-) Lack of job security [n=1]
    - **Nature of use** [n=1]
      - (-) Depending on the setting, some clinical information requested by the CDSS is too difficult to obtain [n=1]
    - **Purpose of use** [n=3]
      - (-) CDSS's targeted health care issue represents only a small part of the PCPs' everyday concerns [n=2]
      - (+) CDSS opens teaching opportunities for trainees [n=1]
    - **Report acceptance** [n=15]
      - (-) Information overload [n=15]
        - Alert fatigue [n=13]
        - Lack of concise synthesis of the recommendation [n=7]
    - **Resistance or reluctance** [n=19]
      - (-) Conflicts between CDSS recommendations and PCPs expertise or beliefs [n=18]
        - CDSS recommendations don't reflect the complexity of the situation [n=12]
        - CDSS recommendations may result in over-referral [n=3]
        - Concerns about overdiagnosis [n=2]
        - Perceived shortcomings of evidence-based medicine explain PCP refusal of CDSS recommendations [n=1]
      - (-) PCPs reluctance due to patient disagreement with CDSS recommendations [n=6]
      - (-) Conflicts between CDSSs recommendations and local guidelines [n=1]
      - (-) Too stressful to use the CDSS with the patient present [n=1]

- **Training** [n=18]
  - (-) Training before use is needed [n=11]
    - PCPs are not aware of customization options [n=2]
      - Advanced features are unused or not understood, due to lack of training [n=2]
    - The training session to the CDSS is inadequate or too short [n=4]
  - (+) Training before use is appreciated [n=10]
  - (-) Ask for yearly refresher training [n=2]

User satisfaction [n=31]
- **Decision making satisfaction** [n=0]
- **Enjoyment** [n=0]
- **Overall satisfaction** [n=7]
  - (+) CDSSs increase PCPs satisfaction [n=7]
- **Perceived usefulness** [n=24]
  - (+) Perceived usefulness of the CDSS [n=23]
  - (+) The computerization of decision support is appreciated [n=5]
  - (-) Alert content not consistent with the varying needs of different types of PCPs [n=2]
- **Satisfaction with specific functions** [n=3]
  - (-) CDSS required "extra clicks" [n=1]
  - (-) Impossibility of skipping steps [n=1]
  - (+) Minimal interruptive alerts [n=1]
- **Software satisfaction** [n=12]
  - (+) PCPs would continue to use the CDSS [n=9]
  - (+) PCPs will recommend the CDSS to colleagues [n=6]

Net benefits [n=42]
- **Clinical Practice** [n=22]
  - (+) CDSS is a way to update your knowledge [n=17]
  - (+) CDSS leads to better teamwork in primary care [n=7]
  - (+) The CDSS increases PCPs confidence [n=7]
  - (+) The CDSS helps the PCP to prepare the encounter [n=4]
  - (+) Collecting structured data facilitates follow up of patients [n=2]
  - (+) CDSS enables urgent referral pathways [n=1]
  - (-) CDSS recommendations were hard to realize [n=1]
- **Communication** [n=26]
  - (+) The CDSS helps focus on patient education [n=18]
    - CDSS helps to increase patient engagement [n=14]
  - (+) CDSS facilitates patient-PCP communication [n=13]
  - (-) Negative effect on patient communication [n=7]
  - (+) The CDSS facilitated communication between PCPs and other specialists [n=3]
  - (+) The CDSS is used by PCPs to legitimate their refusal to prescribe unnecessary tests or medications [n=3]
  - (-) Education materials provided to patients are sometimes difficult for them to understand [n=2]
- **Decision making quality** [n=25]
  - (+) CDSS facilitates decision making [n=22]
    - The CDSS facilitate in treatment decision making [n=10]
    - CDSS is facilitating decision making about referral [n=5]
  - (-) No real impact on decision making [n=3]
  - (+) Help PCPs to set priorities for quality improvement [n=2]
- **Error reduction** [n=17]
  - (+) CDSS helps PCPs to identify unrecognized information needs [n=17]
  - (+) Reduced need for clinical supervision [n=1]
- **Perceived effectiveness** [n=25]
  - (+) Potential to improve the quality of care [n=23]
    - CDSS helps to systematize assessment of every patient [n=13]
    - Brings primary and secondary preventive care needs to the forefront [n=7]
  - (+) CDSS helps PCPs to improve guideline adherence [n=11]
  - (+) The CDSS facilitates patient care management [n=9]
  - (+) Perceived effectiveness in the personalization of care [n=4]
  - (-) CDSS did not aid adherence to guidelines [n=1]

- **Perceived efficiency** [n=37]
  - (-) Increased workload during the consultation [n=33]
    - Lack of time to use the CDSS during the encounter [n=31]
      - Duplication of data collection [n=12]
      - Structured data collection takes too much time [n=15]
        - Lack of practice in documenting within the structured form in the EHR [n=1]
        - Comfort with previous habits without the CDSS [n=1]

    - <u>Coping strategies:</u>
    - Increased consultation time [n=14]
      - The CDSS increases discussion time with the patient [n=3]
      - Using CDSS lengthens the decision-making process [n=1]
    - PCPs need additional time using the CDSS outside the consultation [n=8]
      - Having dedicated CDSS time [n=3]
    - Scheduling follow up appointments [n=5]
  - (+) Using CDSS saves time [n=22]
    - Shortening documentation time [n=8]
    - Giving a quick patient evaluation from relevant data in patients′ EHRs [n=6]
      - The CDSS enhances visit productivity [n=3]

- **Organization** [n=41]
  - **Environment** [n=18]
    - **Competition** [n=2]
      - (-) Competing obligations (other incentive programs) [n=2]
    - **External communication** [n=0]
    - **Financing source** [n=2]
      - (-) Cost of the CDSS [n=1]
      - (-) Lack of funding for trainings, support, or hardware maintenance [n=1]
    - **Government** [n=1]
      - (+) Benefits from federal meaningful use initiatives [n=1]
    - **Inter-organizational relationship** [n=11]
      - (-) Difficulty to use the CDSS for patients comanaged by other specialists [n=11]
        - Information is sometimes missing or not integrated from other external sources (other specialists or hospital data) [n=6]
        - Disagreement between CDSS recommendations and prescriptions of other specialists [n=2]
      - (-) No possibility to consult patient data from other practices within the same regional primary care structure [n=2]
    - **Localisation** [n=0]
    - **Politics** [n=0]
      - (+) Being part of a national project [n=1]
      - (+) Bottom-up design of the CDSS within an organised regional primary care structure [n=1]
      - (-) Intellectual property of CDSS's knowledge artifacts translated from guidelines is an obstacle to their customization by PHPs [n=1]
    - **Population served** [n=5]
      - (-) Patients cannot afford CDSS's proposed care [n=3]
        - New consultations programmed to discuss about the CDSS may cost too much for patients [n=1]
      - (-) PCPs think that patients have competing priorities that hinders acceptation of CDSS recommendations [n=3]
  - **Structure** [n=39]
    - **Autonomy** [n=10]
      - (+) Producing reports of quality measures through collected data increases the value from the CDSS's use in clinical practice [n=7]
      - (-) Data generated by the CDSS can't be used to produce reports of quality measures [n=3]
      - (-) Poor availabilities to medication or post referral hinder motivation to use the CDSS [n=3]
        - Frequent running out of stock of medical equipment, supplies, and medicines affected the CDSS use during patient care [n=1]
    - **Clinical process** [n=35]
      - (-) Using CDSS disrupts usual workflow [n=25]
      - (+) Natural integration of the CDSS in clinical workflow [n=13]
      - (-) There were already protocols or CDSS in place for this issue [n=4]
      - (-) No education sheet for patients provided by the CDSS [n=2]
      - (+) Data entry by patients prior to the consultation [n=2]
    - **Communication** [n=4]
      - (-) PCPs not informed of disposable CDSSs integrated in the EHR [n=2]
      - (+) Collaboration between project and site staff to complete protocols and applications [n=1]
      - (+) Regular communication of updates by the clinic manager [n=1]

- **Culture** [n=2]
  - (+) Structures already engaged in quality improvement work (good operational structure) [n=1]
  - (-) The diversity of medical practices involved complicates the development of shared clinical content [n=1]
- **Hardware** [n=16]
  - (-) Lack of computers or tablets in the structure [n=7]
  - (-) Poor internet or wireless connectivity [n=6]
  - (-) Malfunctioning computers [n=5]
    - Slowness of the computers [n=2]
  - (-) Limited printing capabilities preventing use of POC patient education [n=3]
  - (-) Limited battery life (CDSS on tablets) [n=3]
  - (-) Screen damage (CDSS on tablets) [n=1]
  - (-) Small sized computer screens [n=1]
  - (-) Unreliable power supply [n=1]
- **Leadership** [n=7]
  - (+) Available leadership support [n=6]
    - Identified clinical champion in the facility [n=3]
    - Identified technical champion in the facility [n=4]
  - (-) Missing leadership support [n=5]
    - Lack of clinical champion in each facility [n=5]
    - Technical champion is needed [n=3]
- **Mediator** [n=1]
  - (+) Known mediator (e.g., physician association) between the user and the vendor [n=1]
- **Medical sponsorship** [n=0]
- **Nature (type, size)** [n=5]
  - (+) CDSS (on tablets) ease access to isolated population [n=1]
  - (-) Changing to an incompatible EHR [n=1]
  - (+) Equipment and supplies (medical) available [n=1]
  - (-) Limitation of the reach of the CDSS for PCPs without access to technology [n=1]
  - (-) No private space in which patients can complete the questionnaire [n=1]
- **Planning** [n=0]
- **Strategy management** [n=0]
- **Teamwork** [n=19]
  - (-) Need of more teamwork with other PCPs to help physicians with CDSS's increased workload [n=13]
    - Physicians fear more the CDSS workload than assistants or nurses [n=4]
    - CDSS could be an opportunity for increasing interprofessional collaboration [n=1]
    - Nurses not allowed to code diagnosis [n=1]
  - (+) Other professionals ease physician's increased workload with the CDSS [n=6]
    - Expansion of skill set and roles in assisting physicians and patients in meeting care needs [n=3]
  - (-) Staff turnover [n=3]
  - (-) CDSS use in teams may lead to conflicts [n=2]
  - (-) No good communication between physicians and staff about good practice with the CDSS [n=2]
  - (+) Can manage the CDSS without a technical staff member [n=1]
  - (-) Staff assistant express apprehension with their new responsibilities [n=1]
  - (-) Low GP confidence in health workers using the CDSS [n=1]
  - (-) Unclear expectation at the PCP and support staff level as to who completes what task and how to coordinate work [n=1]
- **Top management support** [n=0]

Technology [n=45]

- **Information quality** [n=40]
  - **Accuracy** [n=1]
    - (-) Lack of accuracy of the CDSS recommendations [n=1]
  - **Completeness** [n=13]
    - (-) Incompleteness of CDSS' recommendations [n=7]
    - (+) Completeness of the CDSS [n=4]
    - (-) Documentation provided in CDSS recommendations is too poor [n=2]
    - (-) Data collection surveys for patients are not complete enough [n=1]
  - **Conciseness** [n=6]
    - (+) Conciseness of the recommendations [n=6]
  - **Data entry methods** [n=7]
    - (+) Easy data collection [n=5]
      - Automatic data entry (retrieval from the EHR) [n=1]
    - (-) Data entry by patients is hindered by lack of patient understanding of the CDSS questions [n=1]
    - (-) Some coding is difficult to find [n=1]
  - **Format** [n=18]
    - (-) Format of recommendations (length, structure, font colors) [n=13]

(+) Pleasing visual layout [n=12]
(-) CDSS's notifications are phrased too tentatively [n=1]
Importance [n=0]
Legibility [n=4]
(-) Need for a common vocabulary [n=4]
Terminology used is not understood by PCPs [n=2]
Relevance [n=19]
(-) CDSS recommendations are not relevant [n=11]
Conflict between patient-driven acute needs and CDSS-related care needs [n=7]
General recommendations are often irrelevant [n=4]
General recommendations have less impact on GP's decision-making process [n=1]
The CDSS recommendations don't fit with vague complaints [n=1]
Irrelevant alert for different PCP groups (such as for nurses or GPs) [n=1]
(+) CDSS recommendations are relevant [n=11]
Reliability [n=17]
(-) Doubtful reliability of the recommendations [n=12]
The reliability of the recommendations depends on the quality and completeness of the information collected [n=11]
(+) CDSS recommendations are reliable [n=9]
General agreement with the validity of CDSS recommendations [n=4]
Full guidelines linked to each recommendation [n=1]
Timeliness [n=6]
(-) CDSS recommendations are not displayed at the right time [n=5]
Recommendation appearing after the patient chart was closed or decision was made [n=2]
(+) CDSS recommendations are displayed at the right time [n=1]
(-) CDSS recommendations are not displayed at the right time [n=5]
Recommendation appearing after the patient chart was closed or decision was made [n=2]
(+) CDSS recommendations are displayed at the right time [n=1]
Usefulness [n=21]
(+) Information provided is useful for the targeted process of care [n=13]
(-) CDSS recommendations are not helpful [n=8]
The recommendation is sometimes too vague to be useful [n=2]
(+) Educational material for patients is valuable [n=7]
Service quality [n=11]
Assurance [n=0]
Empathy [n=0]
Follow up service [n=0]
Quick responsiveness [n=0]
Technical support [n=11]
(+) Satisfaction with the CDSS service support [n=7]
CDSS technical staff availability [n=6]
(-) Inadequate or delayed user support [n=5]
(+) Periodic auditing enables to detect technical issues before clinician complaints [n=3]
(-) User manual is too long [n=1]
System quality [n=45]
Availability [n=2]
(+) Tool is consistently available [n=2]
Data accuracy [n=7]
(-) No updates of the CDSS [n=4]
(+) EHR's collected data is more accurate [n=2]
(-) Inaccurate collected data in the EHR [n=2]
Database contents [n=18]
(-) The CDSS should target more health issues [n=11]
(-) Questioning validity of CDSS's knowledge database [n=7]
PCPs expect the tool's independence from the pharmaceutical industry and being free of commercial advertisements [n=3]
CDSS recommendations went too far in recommending brands [n=1]
(-) No link to guidelines [n=1]
Ease of learning [n=9]
(+) Easy to use after a short learning period [n=9]
Ease of use [n=39]
(+) The CDSS is user-friendly (ergonomic) [n=30]
No need to switch windows in the EHR while using CDSSs [n=1]
(-) The CDSS is not user-friendly [n=21]
Need to switch windows in the EHR while using CDSSs [n=9]
Location of CDSS recommendations should be changed [n=8]
Need to switch windows between the EHR and the CDSS [n=5]

Difficulty accessing different CDSS functions [n=3]
The recommendation is not displayed at the right place or difficult to find [n=3]
CDSS should be designed to help shared decision making [n=1]
(+) CDSS recommendations are easy to understand [n=9]
(-) Breakdowns requiring restarts [n=4]
(+) Absence of breakdown [n=1]
(-) CDSS recommendations are not easy to understand [n=1]
(+) Gathering a complete assessment within a single device [n=1]

Efficiency [n=4]
(+) Allows for quick and easy search and retrieval of information for an individual patient or subgroup of patients [n=4]

Flexibility [n=13]
(-) Need of customization options [n=8]
(-) Conflict between usual codes (e.g., diagnostic classification) and codes used by the CDSS = semantic interoperability issue [n=3]
(+) Customization of the CDSS is appreciated [n=3]

Reliability [n=2]
(+) PCPs trust the CDSS knowledge database [n=2]

Resource utilization [n=0]

Response time [n=0]

Security [n=3]
(-) Concerns about data security [n=3]

Technical support [n=1]
(+) Access to technical support integrated into CDSS [n=1]

Turnaround time [n=18]
(-) CDSS slowness [n=16]
CDSS's slowness impairs the interaction with the patient and increases the consultation time [n=5]
(+) CDSS is quick and prompt [n=3]

Usefulness of system features and functions [n=33]
(-) CDSS not fully integrated in the EHR [n=14]
A CDSS not fully integrated in the EHR is time consuming and disrupts workflow [n=4]
The most current information collected in the EHR is sometimes not updated in the CDSS [n=3]
(+) Reminder system [n=8]
(-) Lack of learning capacity of the CDSS [n=6]
(+) Full integration in the EHR [n=3]
(-) CDSS fully integrated but integration to be enhanced [n=3]
(-) Interruptive recommendations hampers clinical workflow [n=3]
(+) Risk assessment within the CDSS [n=2]
(+) Possibility to overview patients concerned with specific recommendation through patient registry [n=2]
(-) No search & find tool [n=2]
(+) Medication order linked to the advice of the CDSS [n=1]
(-) No possibility to add photos [n=1]
(-) Dismiss option encourages dismissal [n=1]
(-) Passive CDSS [n=1]
(+) Pull function [n=1]
(-) Too many login points [n=1]
(+) Guided mode (preferred over critiquing mode) [n=1]
(-) Lack of easy and efficient way to document and track patient refusal of services or team effort made [n=1]
(+) CDSS designed to be independent from internet connection [n=1]
(+) Asking reason to override the recommendation helps physicians communicate with each other about their practice [n=1]
(-) Asking reasons for overriding recommendations is defensive medicine and does not contribute to patient care [n=1]

(-): barriers; (+): facilitators; [n CDSSs]

Appendix 7: Number of barriers and facilitators identified per CDSS

	Total (n/255)	Main barriers and facilitators (n/186)	Explanatory elements (n/69)
1 Abimbola et al. (2019)	64	45	19
2 af Klercker et al. (1998)	12	8	4
3 Alagiakrishnan et al. (2016)	29	25	4
4 Arts et al. (2018)	34	23	11
5 Ash et al. (2011)	29	21	8
6 Bandong et al. (2019)	19	17	2
7 Bessat et al. (2019)	48	36	12
8 Bindels et al. (2003)	31	22	9
9 Curry et al. (2011)	9	8	1
10 Dixon et al. (2013)	11	8	3
11 Doerr et al. (2014)	46	35	11
12 Edelman et al. (2014)	42	28	14
13 Feldstein et al. (2013)	87	59	28
14 Guenter et al. (2019)	13	9	4
15 Helldén et al. (2015)	23	17	6
16 Heselmans et al. (2020) and Koskela et al. (2016)	33	25	8
17 Jensen et al (2019)	29	23	6
18 Jenssen et al. (2016)	8	7	1
19 Kempe et al. (2017)	12	7	5
20 Lam Shin Cheung et al. (2020)	25	20	5
21 Lemke et al (2020)	37	28	9
22 Litvin et al. (2012)	34	23	11
23 Litvin et al. (2016)	30	21	9
24 Lugtenberg et al. (2015) (2 articles)	39	27	12
25 Maia et al. (2016)	16	11	5
26 Marcolino et al. (2021)	35	25	10
27 Minian et al. (2021)	23	17	6
28 Montini et al. (2013)	14	10	4
29 Pannebakker et al (2019)	22	18	4
30 Peiris et al. (2014)	17	15	2
31 Praveen et al. (2014)	26	24	2
32 Price et al. (2017)	10	5	5
33 Richardson et al. (2019)	17	12	5
34 Rieckert et al. (2018, 2019)	50	37	13
35 Rousseau et al. (2003)	42	27	15
36 Rubin et al. (2006)	15	10	5
37 Silveira et al. (2019)	33	22	11
38 Sukums et al. (2015)	48	33	15
39 Toth-Pal et al. (2008)	33	24	9
40 Trafton et al. (2010)	32	29	3
41 Trinkley et al. (2021)	18	14	4
42 Wan et al. (2012)	49	35	14
43 Williams et al. (2016)	15	11	4
44 Wilson et al. (2007)	23	20	3
45 Zheng et al (2005)	20	13	7
Mean	28.9		

Nom, prénom du candidat : Meunier, Pierre-Yves

CONCLUSIONS

Un système d'aide à la décision médicale (SADM) est un logiciel conçu pour être une aide directe à la prise de décision clinique, dans lequel un moteur d'inférence met en correspondance les caractéristiques individuelles du patient avec une base de connaissances informatisée ou un algorithme d'apprentissage automatique pour proposer au professionnel de santé et/ou au patient une évaluation de risque ou des préconisations adaptées. Les SADM sont ainsi destinés à améliorer la qualité, la sécurité et l'efficacité des soins mais leur efficacité n'est pas démontrée en soins primaires et leur implantation est difficile. Ils pourraient être d'une grande utilité en soins primaires, où les praticiens sont confrontés à une variété de problèmes de santé et ne peuvent pas toujours identifier et accéder à toutes les informations pertinentes dans le temps imparti à la consultation. Des revues systématiques sont nécessaires pour avoir une compréhension globale des obstacles et des facilitateurs à l'utilisation de ces logiciels. À cette fin, plusieurs revues systématiques ont évalué des SADM particuliers selon leur type ou les procédures de soins ou problèmes de santé ciblés, mais aucune n'a évalué les obstacles ou facilitateurs à leur utilisation en soins primaires. Pourtant, leur utilisation dans ce contexte peut être associée à des obstacles et facilitateurs spécifiques. L'objectif de cette revue systématique mixte était d'identifier et de quantifier les obstacles et facilitateurs à l'utilisation de systèmes d'aide à la décision médicale en soins primaires. Un schéma d'étude séquentiel a permis aux résultats d'une synthèse qualitative d'informer une synthèse quantitative. La synthèse qualitative a été réalisée à partir de la grille HOT-fit qui permet l'évaluation des obstacles et facilitateurs à l'utilisation des SADM selon trois catégories de facteurs (humains, organisationnels, technologiques) et une dimension de bénéfices nets. La synthèse quantitative a permis le calcul d'un indicateur évaluant l'impact de chacune de ces 4 catégories sur l'utilisation des SADM par les praticiens de soins primaires. Au total, 48 études évaluant 45 SADM ont été incluses, et 186 obstacles et facilitateurs principaux ont été identifiés. Les obstacles les plus fréquents concernaient en premier lieu l'augmentation de la charge de travail associée à l'utilisation du SADM. Les autres obstacles fréquents concernaient le besoin de travail en équipe, la surcharge d'information et les conflits entre l'expertise ou les croyances des praticiens et les recommandations fournies par le SADM. Les facilitateurs les plus fréquents concernaient la perception générale de l'utilité du SADM, son potentiel d'amélioration de la qualité des soins,

l'amélioration de l'information des patients, l'amélioration des connaissances des praticiens, l'identification par le SADM de besoins d'information non reconnus et la pleine intégration du SADM dans les dossiers santé informatisés. Les paires d'obstacles et de facilitateurs les plus fréquentes concernaient la convivialité du SADM ainsi que la pertinence et la fiabilité de ses recommandations. Des éléments explicatifs rapportés par les praticiens ont été associés à ces obstacles et facilitateurs principaux pour préciser leur description. La synthèse quantitative a montré des impacts inégaux des quatre catégories HOT-fit sur l'utilisation des SADM. Les facteurs humains et organisationnels ont eu un impact global négatif, tandis que le facteur technologique a eu un impact variable mais globalement neutre bien qu'il ait été le facteur le plus évalué. La dimension des bénéfices nets a montré un impact positif ; les avantages nets rapportés par les praticiens soutiennent l'efficacité potentielle des SADM pour améliorer la qualité et la sécurité des soins. Cependant, les SADM semblent incapables d'améliorer l'efficience des soins puisqu'ils ont tendance à augmenter la charge de travail des praticiens. Les obstacles et facilitateurs étaient liés à la faisabilité (par exemple, l'augmentation de la charge de travail), l'acceptabilité (par exemple, les conflits avec l'expertise ou les croyances des praticiens), l'utilité pratique (par exemple, la pertinence des recommandations) et à l'efficacité (dimension des avantages nets) des SADM. Ces différents types de preuves renvoient au modèle factuel FAME qui est utile à la compréhension des interventions complexes telles que l'implantation des SADM. Sur la base de ces résultats, nous avons établi une liste de onze caractéristiques opérationnelles, intrinsèques et contextuelles, censées faciliter l'utilisation des SADM en soins primaires. Nous recommandons que les futures études sur les obstacles et les facilitateurs de l'utilisation des SADM évaluent systématiquement les facteurs humains et organisationnels. De plus, des études quantitatives sont nécessaires pour évaluer l'impact individuel des obstacles et facilitateurs identifiés dans cette revue systématique.

Le Président de la thèse,
Professeur François GUEYFFIER

Vu :
Pour le Président de l'Université,
Le Doyen de l'UFR de Médecine Lyon Est

UNIVERSITE CLAUDE BERNARD LYON I

UNIVERSITE CLAUDE BERNARD FACULTÉ DE MÉDECINE LYON EST LYON

Professeur Gilles RODE
Vu et permis d'imprimer
Lyon, le 15 MARS 2022

ABSTRACT

Purpose

To identify and quantify the barriers and facilitators to the use of clinical decision support systems (CDSSs) by primary care providers (PCPs).

Methods

A mixed-methods systematic review was conducted using a sequential synthesis design. A framework synthesis was performed according to the HOT-fit framework, then a quantitative synthesis evaluated the impact of the HOT-fit categories on CDSS use. PubMed/MEDLINE, PsycInfo, EMBASE, CINAHL, and the Cochrane library were searched in July 2021. Qualitative, quantitative, and mixed-methods studies that evaluated CDSSs providing recommendations to PCPs (and possibly patients) and intended for use during a consultation were included. We excluded CDSSs used only by patients, described as concepts or prototypes, used with simulated cases, and decision supports not considered as CDSSs. The quality of studies was assessed using the QuADS tool.

Results

Overall, 48 studies evaluating 45 CDSSs were included, and 186 main barriers or facilitators were identified. The leading barrier associated with the use of CDSSs was an increased workload. The quantitative synthesis found uneven overall impacts of the HOT-fit categories on CDSS use. The human and organizational factors had negative impacts, whereas the technological factor had a variable but neutral impact, and the net benefits dimension a positive impact.

Conclusions

Although benefits reported by PCPs support the potential effectiveness of CDSS use in improving quality and safety of care, they also highlight its lack of efficiency due to increased workload. Our findings emphasize the need for CDSS developers to better address human and organizational issues. We inferred core CDSS features, covering theses three categories, expected to make them used in primary care.

Other

Funding source: Agence Régionale de Santé Auvergne-Rhône-Alpes

Study registration: Protocol registered on PROSPERO (CRD42020185199)

Keywords: Primary health care; information technology; medical informatics; quality of health care; decision support systems, clinical

Abbreviations: CDSS: clinical decision support system; EHR: electronic health record; FAME model: Feasibility, Acceptability, Meaningfulness, Effectiveness model; HOT: Human, Organization, Technology; PCPs: primary care providers; QuADS: quality assessment with diverse studies

UNIVERSITÉ CLAUDE BERNARD LYON 1

MEUNIER, Pierre-Yves

Obstacles et facilitateurs à l'utilisation de systèmes d'aide à la décision médicale en soins primaires : une revue systématique mixte

Barriers and Facilitators to the Use of Clinical Decision Support Systems in Primary Care: a Mixed-Methods Systematic Review

---

Objectif : Identifier et quantifier les obstacles et les facilitateurs à l'utilisation de systèmes d'aide à la décision médicale (SADM) par les praticiens de soins primaires (PSP). **Méthodes :** Une revue systématique mixte a été menée selon une synthèse séquentielle. Une analyse qualitative thématique a été réalisée selon la grille HOT-fit, puis une analyse quantitative a évalué l'impact des catégories de la grille HOT-fit sur l'utilisation des SADM. Les bases de données PubMed/MEDLINE, PsycInfo, EMBASE, CINAHL et la bibliothèque Cochrane ont été requêtées en juillet 2021. Les études qualitatives, quantitatives et à méthodes mixtes qui évaluaient des SADM fournissant des préconisations aux PSP (et éventuellement aux patients) et destinés à être utilisés pendant la consultation étaient incluses. Nous avons exclu les SADM utilisés uniquement par les patients, décrits comme des concepts ou des prototypes, utilisés avec des cas cliniques simulés, ainsi que les aides à la décision non considérées comme des SADM. La qualité des études a été évaluée à l'aide de l'outil QuADS. **Résultats :** Au total, 48 études évaluant 45 SADM ont été incluses, et 186 obstacles et facilitateurs ont été identifiés. Le principal obstacle associé à l'utilisation des SADM est l'augmentation de la charge de travail. La synthèse quantitative a révélé des impacts inégaux des catégories de la grille HOT-fit sur l'utilisation des SADM. Les facteurs humains et organisationnels ont eu des impacts négatifs, tandis que le facteur technologique a eu un impact variable mais neutre, et la dimension des avantages nets un impact positif. **Conclusion :** Bien que les bénéfices nets rapportés par les PSP soutiennent l'efficacité potentielle de l'utilisation des SADM pour améliorer la qualité et la sécurité des soins, ils soulignent également leur manque d'efficience en raison de l'augmentation de la charge de travail. Nos résultats soulignent la nécessité pour les développeurs de SADM de mieux prendre en compte les prérequis humains et organisationnels. Sur la base de ces résultats, nous avons établi une liste de onze caractéristiques opérationnelles, intrinsèques et contextuelles, censées faciliter l'utilisation des SADM en soins primaires.

Mots-clés : Soins de santé primaires ; Qualité des soins de santé ; Technologie de l'information ; Informatique médicale ; Systèmes d'aide à la décision clinique

Keywords: Primary health care; Quality of health care; Information technology; Medical informatics; Decision support systems, clinical

---

JURY

Président :	Monsieur le Professeur François GUEYFFIER
Membres :	Monsieur le Professeur Philippe MICHEL
	Monsieur le Professeur Laurent LETRILLIART
	Monsieur le Docteur Emmanuel VIRY

Date de soutenance : mardi 3 mai 2022
Adresse postale de l'auteur : 1 rue Jacqueline et Roland de Pury 69002 LYON
Email : py.meun@gmail.com