

## **Supplemental Material**

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Supplemental Table 1: Search strategy for records addressing component D (Medline example)

Ovid MEDLINE(R) ALL <1946 to 02 July 2021>

Search 1: chronic kidney disease	exp Renal Insufficiency, Chronic/ OR (chronic adj3 (kidney or renal)).mp OR (CKF or CKD or CRF or CRD).mp OR chronic disease/ and kidney diseases/ OR (predialys* or "pre-dialys*").mp.
Search 2: Non-patient-facing review	((virtual or internet or electronic or "web-based" or digital* or remote*) adj3 (clinic* or consultation* or consulting or referral* or "health system*")).mp. OR Telemedicine/ OR "remote consultation"/ OR telemedicine.mp. OR telenephrolog*.mp. OR telehealth.mp. OR "tele-nephrolog* ".mp. OR "shared care".mp. OR (review* adj5 (remote* or distant*)).mp. OR exp Medical Record Linkage/
Final search	1 AND 2

Supplemental Table 2: Description of included studies, with relevance and quality scoring

**Abbreviations:** RCT: randomized controlled trial; CKD: chronic kidney disease; PCP: primary care practices; T2DM: Type 2 Diabetes; RAAS: renin-aldosterone-angiotensin system; CV: cardiovascular; eGFR: estimated glomerular filtration rate; QI: quality improvement; BP: blood pressure; PTH: parathyroid hormone

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
1	Abdel-Kader <sup>31</sup> 2011	USA 30 PCPs	Cluster RCT 248 patients with CKD stage 3b or greater not under nephrology care	<i>Intervention group:</i> Automated alert on primary care EPR for patients with eGFR<45ml/min/1.73m <sup>2</sup> , advising nephrology referral and testing of albumin: creatinine ratio  <i>Comparator:</i> Usual care  CKD educational sessions for PCPs in both groups	No significant difference between groups in referral to nephrology or testing for albuminuria	++	++
2	Akbari <sup>32</sup> 2004	Canada One PCP	Before-after study 324 patients	Automated eGFR reporting Educational program for GPs	Improved recording of CKD diagnosis in notes after intervention	-	+
3	Alamartine <sup>33</sup> 2010	France	Service report	Electronic communication between GPs and nephrologists	Few GPs engaged with the website, and it was costly, so was closed	++	-
4	Barrett <sup>34</sup> 2011	Canada 5 PCPs	RCT 474 patients with CKD 3-4	<i>Intervention group:</i> Nurse-coordinated clinical recommendations to GPs with access to nephrologist advice  <i>Comparator:</i> usual care	No change in eGFR decline or control of risk-factors	++	++
5	Bello <sup>35</sup> 2017	Canada	Focus group study for patients, GPs, nephrologists, policymakers	IT platform allowing communication between GPs and nephrologists in lieu of avoid patient-facing nephrology consult	Favorable responses from stakeholders on this system	++	++

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
6	Bello <sup>36</sup> 2019	Canada All PCPs in Alberta	Service report 118 advice requests for patients with CKD	IT platform allowing communication between GPs and nephrologists in lieu of avoid patient-facing nephrology consult (as in Belo, 2017)	31 of 118 (26%) of advice requests indicated a face-to-face nephrology consult. Mean response time 5.7 days	++	-
7	Betancourt <sup>37</sup> 2020 [Abstract]	USA PCPs in Florida	Service report 169 patients with CKD	'Telenephrology' clinic including video-on-demand, telemedicine and e-consultation, implemented during the COVID-19 pandemic	Improved blood pressure control and biochemical parameters	+	-
8	Boom <sup>38</sup> 2020	Netherlands Referrals to 3 nephrology centers from any PCP	Service report 173 consultations with patients with CKD	e-consultation system implemented to allow GPs to consult directly with nephrologist	141 of 173 e-consultations resulted in a nephrology clinic appointment.	++	-
9	Brimble <sup>39</sup> 2020	Canada 2 nephrology sites and referring PCPs	Before-after study All patients with CKD	Online toolkit promoting CKD management and appropriate nephrology referral, promoted to GPs via consultation letters and other means	No difference found in appropriateness of referrals after implementation	++	+
10	Carroll <sup>40</sup> 2018	USA 30 PCPs	Cluster RCT 6699 patients with CKD stages 3 and 4	<i>Intervention group:</i> Clinical decision support system (point of care prompts for screening, diagnosis, and management of CKD) with practice facilitation and CKD registry development  <i>Comparator:</i> Clinical decision support alone.	Reduction in CKD progression in the intervention group	++	++

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
11	Carter <sup>41</sup> 2015	USA 32 PCPs	Cluster RCT 625 patients with CKD 3-5, diabetes, and uncontrolled hypertension	<i>Intervention groups:</i> 9- or 24-month intervention with community pharmacist making recommendations to GP based on clinical data  <i>Comparator:</i> usual care	No difference in BP control but reduction in mean BP	++	++
12	Chang <sup>42</sup> 2016	USA 6 PCPs	Cluster RCT Patients with CKD 3a	<i>Intervention group:</i> Pharmacist intervention to promote albuminuria testing, statin prescription and BP treatment  <i>Comparator:</i> usual care	No difference in albuminuria screening. Positive feedback from patients, pharmacists, and GPs	++	++
13	Cooney <sup>43</sup> 2015	USA 13 PCPs	RCT 2199 patients with CKD 3b-5	<i>Intervention group:</i> training, education, access to CKD registry, pharmacist phone calls to patients  <i>Comparator:</i> usual care	No difference in BP control. Increased monitoring of PTH, improved guideline adherence	++	++
14	Cortés-Sanabria <sup>44</sup> 2008	Mexico	Pilot study for cluster RCT 96 patients with T2DM CKD under the care of 40 GPs	<i>Intervention group:</i> Participative GP educational program  <i>Comparator:</i> usual care	GP 'clinical competence' (based on a questionnaire) was greater in the intervention group  No significant difference in patient's clinical parameters between groups	+	+
15	Crowley <sup>45</sup> 2017	USA Veterans affairs healthcare system	Service report Military veterans with CKD	Description of synchronous and asynchronous nephrology consultation systems	Description of benefits includes improved access to care, patient choice, patient-centered care	+	+

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
16	Donald <sup>47</sup> 2021	Canada  Available worldwide but promoted to PCPs in Alberta	Before-after study  345,058 patients, most with CKD3a identified through linked health record data	Online 'CKD pathway' treatment guidance document	Improvement in albuminuria screening in regions where the intervention was used	++	+
17	Drawz <sup>48</sup> 2012	USA  2 PCPs	Cluster RCT  781 patients with CKD	<i>Intervention group:</i> Access to and training in use of CKD registry identifying patient with CKD  <i>Comparator:</i> usual care  CKD lecture to PCPs in both groups	Primary outcome (PTH measurement) – improvement in both groups  Secondary outcomes (other clinical measures, BP improvement and treatment with RAAS blocker – no difference	++	++
18	Elsayed <sup>49</sup> 2013  [Abstract]	UK  Referring PCPs for Sheffield renal service	Service report  77 patients with CKD not expected to require RRT within 12 months	Remote monitoring via CKD nurse reviewing laboratory parameters and BP	Feasibility, reduced travel time, positive patient feedback	++	-
19	Ennis <sup>50</sup> 2015	Canada  All PCPs where intervention is available	Matched cohort study  12,353 patients with CKD 3-4	Automated clinical decision support system (compared to usual care) available to GPs receiving reports from a commercial laboratory	Improved adherence to testing guidelines among GPs using the system	++	+

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
20	Erler <sup>51</sup> 2012	Frankfurt, Germany 44 PCPs	Cluster RCT 404 patients with CKD (or over 70 with hypertension)	<i>Intervention group:</i> Provision of software program to aid drug dose adjustment in CKD; GP training <i>Comparator:</i> usual care	Reduction in prescription of contraindicated drugs or dosing in excess of recommended maximum doses	+	++
21	Feldstein <sup>52</sup> 2011 [Abstract]	USA 20 PCPs	Service report and GP survey 67 patients with CKD	Web-based tool including patient-specific treatment recommendations, clinical guideline access, electronic nephrology consultation, and patient education material	Use of the tool associated with increased attainment of treatment guidelines, improvement in GP test scores, but no change in GP self-efficacy.	++	-
22	Fox <sup>53</sup> 2008	Buffalo, NJ, USA 2 PCPs in area with high level of deprivation	QI intervention 181 patients with CKD	GP educational visits, reminders, data provision, electronic decision-making support.	Improved CKD recognition and reduced prescription of NSAIDs and metformin. Small improvement in eGFR after intervention	++	+
23	Haley <sup>54</sup> 2014	USA 9 PCPs	QI project	Promotion of a toolkit aiming to improve CKD identification, management, and communication	Improved CKD identification, referral, management, and eGFR recording	++	+
24	Al-Hamarneh <sup>55</sup> 2017	Alberta, Canada 56 PCPs	Subgroup analysis of RCT 290 patients with CKD stages 3-5	<i>Intervention:</i> Individualized patient CV risk assessment and treatment recommendations with regular monthly follow-up <i>Comparator:</i> usual care	Improved CV risk profile in intervention group	++	++
25	Hardy <sup>56</sup> 2019 [Abstract]	UK 55 PCPs	Service report Patients with CKD and diabetes	Standardized review of patients on CKD and diabetes registers at surgeries. Video consultation events where 20 patients were discussed	Feasibility of this service model	++	-

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
26	Harnett <sup>57</sup> 2018	UK PCPs for patients discharged from a CKD clinic in Southend	Service report Patients with CKD discharged from nephrology follow-up	'Virtual clinic': laboratory tests performed in primary care with non-patient-facing nephrologist review and management advice, including recall to nephrology clinic.	Feasibility. No patients required emergency dialysis initiation. Patient survival was comparable to patients with CKD discharged without virtual clinic monitoring	++	-
27	Hull <sup>58</sup> 2020	UK PCPs served by an East London renal unit	Service report	Electronic patient record detection of patients with progressive CKD with embedded management advice, non-patient-facing nephrologist review, GP education.	3-fold increase in nephrology referrals, reduced time to (non-patient-facing) nephrologist consultation, increased CKD coding, positive feedback from GPs and nephrologists	++	-
28	Humphreys <sup>59</sup> 2017	Manchester, UK 49 PCPs	Phased QI projects	Educational workshops, clinical decision support tool, clinical facilitators, financial support	Improved coding of CKD in primary care records, improved BP	++	+
29	Jones <sup>60</sup> 2006	UK PCPs served by a single renal unit	Service report 949 referrals for patients with CKD	Shared care scheme – patients have blood and BP monitoring in primary care and are reviewed in absentia by nephrologists	Reduction in requirement for face-to-face clinics.	++	-
30	Katz <sup>61</sup> 2018	Australia PCPs served by a single renal unit	Service report 70 patients with CKD from primary care and nephrology clinics	Monitoring of CKD via specialist nurse and non-patient-facing nephrology review.	Feasibility, safety, and improved access to nephrology advice	++	-



	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
31	Keely <sup>62</sup> 2018	Canada PCPs submitting requests to Ottawa hospital	Service report 155 nephrology eConsults for CKD	e-consultation service	Avoided face-to-face consult in 45%. Nature of clinical questions is described	++	-
32	Khoong <sup>63</sup> 2019	USA 79 PCPs	Cluster RCT protocol 582 patients with CKD	<i>Intervention arms:</i> 1) GP access to Clinical decision support system (CDSS) based on serum creatinine, cystatin C and albumin: creatinine ratio readings 2) CDSS plus a pharmacist phone call to GP  <i>Comparator:</i> usual care	Feasibility	++	++
33	Levy <sup>64</sup> 2020 [Abstract]	USA PCPs served by single nephrology department	Service report 62 patients referred for e-consultation	Implementation of e-consultation system	Feasibility Satisfaction with system among GPs Prioritization of patients for face-to-face appointments	++	-
34	Liddy <sup>65</sup> 2013	Canada Regional health district in Ontario	Service report, with recommended steps for implementation in other settings Patients with CKD in Ontario	Implementation of an e-consultation service	Reported steps to success: Establishing key working partnerships, choice of electronic platform, pilot work, designing e-consultation form, information governance, simple processes for physicians, payment, continuous feedback/QI, planning roll-out	++	+

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
35	Litvin <sup>66</sup> 2016	South Carolina, USA 11 PCPs	Before-after study Patients with CKD stages 3-5	Clinical decision support system	Improved albuminuria screening and monitoring. No difference in RAAS blockade prescription or anemia monitoring	++	+
36	de Lusignana <sup>46</sup> 2013	Guildford, UK 93 PCPs	Cluster RCT 41,183 patients with CKD	<i>Intervention 1:</i> 'Audit-based education' feedback and training for GPs at data workshops, provision of printed guidance and target patient lists  <i>Intervention 2:</i> provision of 'guidelines and prompts'  <i>Comparator:</i> usual care	Intervention 1: reduction in BP compared to other groups  No other differences between groups in BP, CV events or eGFR	++	++
37	Major <sup>67</sup> 2019	UK 23 PCPs	Cluster RCT 23,357 patients with CKD stages 3-5 in primary care	<i>Intervention:</i> Electronic screening of primary care EPR generating a database of patients with CKD at each practice, and CKD nurse practitioner interpreting this database to recommend management changes for individual patients.  <i>Comparator:</i> Practice received database results but without nurse practitioner involvement	Improved coding of CKD and proteinuria in the intervention group.  No difference in eGFR at 42 months between groups	++	++
38	Manns <sup>68</sup> 2012	Alberta, Canada 93 Primary care practices	Cluster RCT 5444 Elderly patient with CKD	<i>Intervention:</i> Enhanced eGFR laboratory prompt containing management advice based on eGFR advising albuminuria measurement and prescription of RAAS blockers  <i>Comparator:</i> Standard eGFR prompt	No difference in prescription of RAAS blockers	++	++

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
39	Mark <sup>69</sup> 2011	UK Regional nephrology center	Service report with cost comparison 427 patients	Implementation of a non-patient-facing nephrologist review	12% of overall referrals managed with non-patient-facing review  Improved time to nephrologist response compared to patient-facing clinic	++	-
40	Mendu <sup>71</sup> 2016	USA Single nephrology service and referring PCPs	Service report of pilot study 74 patient referrals	Implementation of e-consultation system	Feasibility  High level of nephrologist and GP satisfaction	++	-
41	Mendu <sup>70</sup> 2019	USA Healthcare system in Massachusetts	Service report 60,503 patients with CKD in primary care	Implementation of CKD registry identifying patients with CKD and recommending monitoring, RAAS blockade, medications optimization, and planning for RRT	Use of CKD registry can identify patients not in receipt of evidence-based treatment	++	-
42	Ong <sup>72</sup> 2019	Canada 52 PCPs	Implementation study 250 standard referrals and 106 electronic consultation referrals	1 year pilot of e-consultation system for nephrology referrals.	Feasibility. Acceptability to clinicians. Shorter time to nephrology input compared to standard referrals	++	+
43	Peralta <sup>74</sup> 2019 [Abstract]	Abstract describing study 45 (Peralta 2020), also described in study 33 (protocol)					

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
44	Peralta <sup>73</sup> 2020	USA 80 PCPs	Cluster RCT 524 patients with CKD	<i>Intervention arms:</i> 1) GP access to Clinical decision support system (CDSS) based on serum creatinine, cystatin C and albumin: creatinine ratio readings 2) CDSS plus a pharmacist phone call to GP  <i>Comparator:</i> usual care	No difference in blood pressure between groups  GPs had increased awareness of CKD in intervention groups	++	++
45	Rayner <sup>75</sup> 2013	UK Regional renal service	Before-after study	Multiple interventions including education sessions for GPs, multidisciplinary care for patients nearing ESKD, routine eGFR reporting, eGFR decline surveillance with nephrologist oversight, communication to patients by letter	Reduced incidence of RRT initiation  Increased use of peritoneal dialysis or hemodialysis initiation with permanent vascular access  Majority of patients planned for conservative (non-dialysis) treatment of kidney failure were managed outside hospital	++	+
46	Regan <sup>76</sup> 2017	USA 80 PCPs	GP survey	Clinical algorithm embedded in primary care EPR  Education for practice clinicians	Acceptability to GPs  Improved knowledge among primary care clinicians	++	-
47	Richards <sup>77</sup> 2007	UK 34 PCPs	Before-after study 483 patients with CKD stage 4-5	Automated patient identification with advice on clinical management delivered by community-based CKD nurses	Improvement in CV risk parameters and reduction in eGFR decline after intervention	++	+

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
48	Scherpbier-de Haan <sup>78</sup> 2013 [initial implementation....]	Netherlands 28 PCPs served by 5 nephrology practices	Service report 122 new consultations	Non-patient-facing nephrology consultation system implemented	Face to face consultation required in minority of patients referred to the non-patient-facing service  Reduction in nephrologist time required for consultation	++	-
49	Scherpbier-de Haan <sup>79</sup> 2013 [effect of shared....]	Netherlands 9 PCPs	Cluster RCT	<i>Intervention:</i> 'Shared care' model for CKD. Education for primary care clinicians, protocolized review of care, nurse practitioner appointments under GP supervision  <i>Comparator:</i> usual care	Reduced blood pressure and increased use of RAAS blockade and statins in intervention group	++	++
50	Shen <sup>80</sup> 2020	China CKD service of a provincial hospital	Protocol for a mixed-methods study and (effectiveness-implementation) hybrid type 2 trial'	Self-management intervention for patients with CKD	Protocol only	+	-
51	Stoves <sup>81</sup> 2010	Bradford, UK 17 PCPs	Before-after study 466 patients	e-consultation for CKD as initial nephrology contact, replacing nephrology clinic as default option	Reduction in referrals; positive feedback from GPs and nephrologists	++	+
52	Strait <sup>82</sup> 2017	USA 39 PCPs	Post-implementation survey and focus group study  39 GPs surveyed, two focus groups with non-medical primary care staff, eight focus groups with patients	Primary care CKD registry with point-of-care EPR notifications and quarterly feedback document. Patient self-management support material and automated telephone coaching	Acceptability to primary care teams.  Patients found automated telephone advice impersonal	++	+

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
53	Thomas <sup>83</sup> 2014	UK 29 PCPs	Quality improvement project	'Self-management care bundle' including: 1) Measurement of proteinuria and prescription of RAAS blockade as indicated 2) Documentation of BP 3) calculating cardiovascular risk 4) Patient education  Education in self-management coaching for primary care staff	Increase in CKD coding and in the proportion of patients meeting BP targets  Feasibility of care bundle implementation	++	+
54	Thomas <sup>84</sup> 2019	UK 136 PCPs in East London	Service report, qualitative evaluation  Eight semi-structured interviews with GPs and practice staff	Automated detection of CKD progression built in to primary care EPR with alerts to GPs	Primary care clinicians felt the tool promoted patient safety and clinician learning about CKD	++	+
55	Tuot <sup>85</sup> 2018	USA  Two primary care clinics in San Francisco, with high prevalence of CKD	Cluster RCT  746 patients with CKD	<i>Intervention:</i> CKD registry with point of care alerts for patients with CKD not meeting targets for BP, RAAS blockade prescription, or albuminuria testing  <i>Comparator:</i> Usual care	Increased prescription of RAAS blockers  No difference in BP, albuminuria or eGFR	++	++
56	van Gelder <sup>86</sup> 2017	Netherlands  47 PCPs	Cluster RCT  3004 patients with CKD	<i>Intervention:</i> web based non-patient-facing nephrology consultation platform  <i>Comparator:</i> Usual care  CKD management education for all participating practices	Positive opinions from GPs  No difference in rate of referral to standard nephrology clinics  No difference in quality of care or cost	++	++

	<b>Study Year</b>	<b>Country Setting</b>	<b>Study design Patient characteristics</b>	<b>Intervention description</b>	<b>Main reported outcomes</b>	<b>Relevance score</b>	<b>Quality score</b>
57	Via-Sosa <sup>87</sup> 2013	Barcelona, Spain  40 community pharmacies	Before-after study  354 patients over 65 with CKD 3-5	Pharmacist recommendations to GPs on drug dosing changes	Increased proportion of adequate drug dosing, reduced frequency of 'drug-related issues which interfere with desired health outcomes'	+	+
58	Xu <sup>88</sup> 2017	Leicester, UK  48 PCPS	Before-after study  Patients with CKD and uncontrolled hypertension	IT tool to identify patients with CKD nurse disseminating information to PCP staff	Increase in CKD coding, improved BP control	++	+
59	Yamagata <sup>89</sup> 2016	Japan  489 GPs at 49 local medical associations	Cluster RCT  2,379 patients with CKD in primary care	<i>Intervention:</i> Patient education, patient letters updating them on CKD status, alerts to GPs highlighting patients not receiving recommended treatments  <i>Comparator:</i> Usual care	Improved clinic attendance, higher nephrology referral rates, and reduced progression of CKD in the intervention group	++	++
60	Zuniga <sup>90</sup> 2020	Chile  Nephrology services in 2 cities	Service report  4668 nephrologist consultations	Implementation of non-patient-facing nephrologist consultation service	Feasibility  Reduced time to nephrology consultation	+	-

Supplemental Table 3: PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported
<b>TITLE</b>			
Title	1	Identify the report as a systematic review.	Title, abstract, methods
<b>ABSTRACT</b>			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Intro
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Intro
<b>METHODS</b>			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary methods 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methods
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Not applicable to our methodology
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Methods
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Methods
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Methods



Section and Topic	Item #	Checklist item	Location where item is reported
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Methods
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Methods
<b>RESULTS</b>			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Results
Study characteristics	17	Cite each included study and present its characteristics.	Supplementary table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplementary table 1
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	N/A
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	N/A
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Supplementary table 1
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Discussion
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A
<b>DISCUSSION</b>			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion
	23b	Discuss any limitations of the evidence included in the review.	Discussion
	23c	Discuss any limitations of the review processes used.	Discussion
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion
<b>OTHER INFORMATION</b>			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Methods
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Methods
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Methods
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Title page
Competing	26	Declare any competing interests of review authors.	Disclosure

Section and Topic	Item #	Checklist item	Location where item is reported
interests			
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Search terms in Appendix

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71  
For more information, visit: <http://www.prisma-statement.org/>

Supplemental Table 4: Description of mechanisms and contexts and examples from the included studies

	Description	Illustrative examples
<b>Distal Mechanisms</b>		
<i>Clinician Motivation [DM1]</i>	<p>The motivation of all clinicians involved in CKD to accept new ways of working, integrate them into practice, and to learn from this process.</p> <p>Higher levels of <i>clinician motivation</i> increase the likelihood of successful <i>learning while doing</i>, and clinicians' <i>ability to focus and act</i>.</p>	<p>A quality improvement initiative aiming to improve blood pressure control in patients with CKD<sup>59</sup> provided financial reimbursement for primary care services</p> <p>An 'audit based education' intervention<sup>46</sup> compared regional practices' rates of recommended CKD management, potentially motivating through competition</p> <p>General practitioners found that an automated system for identifying CKD risk "<i>stirred up or created greater awareness [of CKD]... amongst us</i>"<sup>84</sup></p>
<i>Learning while doing [DM2]</i>	<p>Clinicians' learning through the process of delivering care for patients with CKD, supported by the components of the intervention.</p> <ul style="list-style-type: none"> <li>• <i>Situational learning [DM2a]</i>: gaining skills by encountering and solving clinical problems for the first time</li> <li>• <i>Contextual learning [DM2b]</i>: learning by applying knowledge in new contexts</li> <li>• <i>Longitudinal learning [DM2c]</i>: learning through longer-term management of patients with CKD, or management at population- rather than at individual-level</li> </ul> <p>Successful <i>learning while doing</i> increases <i>motivation</i>, through professional satisfaction, and empowers clinicians with the required knowledge to <i>focus and act</i>.</p>	<p>General practitioners engaging with a 'virtual CKD' service<sup>58</sup> reported learning through this process: "<i>The quality of [responses] is good....I understand a bit more now about the tests.</i>"</p> <p>Nephrologists delivering a non-patient-facing review service in the Netherlands<sup>78</sup> reported a 'learning curve' in the types of clinical queries they received from GPs.</p> <p>A multi-level intervention aimed at improving blood pressure control included quarterly feedback reports to general practitioners,<sup>82</sup> who reported '<i>it enhanced their ability to identify patients who had CKD, needed better blood pressure control or were due albuminuria quantification</i>'.</p> <p>Healthcare professionals visiting practices or reviewing patient data to support decision-making around CKD care<sup>53, 67, 88</sup> aim to support the process of <i>learning while doing</i>.</p>
<i>Workflow integration [DM3]</i>	<p>Integrating intervention components into the normal working lives of clinicians. Successful workflow integration will promote <i>learning while doing</i> and increase clinicians' <i>ability to focus and act</i>.</p>	<p>In a multifaceted intervention, point of care notifications to GPs<sup>82</sup> rated highly – 94% of GPs reported benefits to clinic workflow</p> <p>Use of computer decision support systems with individualized care recommendations for patients<sup>53</sup> or EPR-based reminders<sup>66</sup> demonstrated improvements in care delivery.</p> <p>Several interventions provided access to online guidance, integrated within electronic patient records or clinical decision support systems.<sup>39, 47, 53, 66</sup></p>

<p><i>Accessible/dynamic interfaces [DM4]</i></p>	<p>The accessibility and dynamism of clinician interfaces with IT systems, or with other clinicians.</p> <p>IT systems should provide relevant information to clinicians at a relevant timepoint in care, allow appropriate action to be taken easily and quickly, and be accessible to all appropriate caregivers. Provision of support material should be integrated and rapid. If professional advice (nephrologist, pharmacist) is required then this should be easy to access, timely, and focused.</p>	<p>The success of a virtual CKD service<sup>58</sup> was attributed in part to shared (GP/nephrologist) access to the primary care EPR, allowing communication by these means.</p> <p>A web-based nephrology consultation service<sup>78</sup> ‘offers the ability to break down walls between primary and secondary care’. A similar service<sup>72</sup> was described as a ‘virtual corridor’ which helped GPs feel supported and empowered.</p> <p>Other interventions improved access to secondary care advice through remote/virtual consultation<sup>33, 86</sup> or direct engagement with primary care practices.<sup>88</sup></p>
<p><b>Proximal mechanisms</b></p>		
<p><i>Clinician ability to focus/act [PM1]</i></p>	<p>The ability (through knowledge, skills, experience, confidence, <i>motivation</i>, time, opportunity) of clinicians to focus on and deliver effective CKD care</p>	<p>An automated system identifying patients with worsening renal function, with supporting clinician education and nephrologist consultation service was reported to encourage a movement from reactive to proactive care of CKD by GPs.<sup>84</sup></p> <p>Computerized decision-support systems<sup>53, 66, 88</sup> aimed to increase the focus of primary care clinicians (by providing <i>accessible/dynamic interfaces with workflow integration</i>)</p>
<p><i>Patient identification, recall and retention [PM2a]</i></p>	<p>Identifying patients with biochemical evidence of CKD but without a coded diagnosis, with resulting CKD ‘coding’ or registration, which supports recall of patients for testing, treatment, and monitoring. Retention of patients within treatment and monitoring structures</p>	<p>In Manchester, UK<sup>59</sup> a quality improvement program in 49 GP practices introduced a multi-faceted intervention to improve recall systems for patients, resulting in an increase in reported CKD prevalence.</p> <p>In East London,<sup>58</sup> the use of IT packages to flag patients with CKD was associated with increased rates of CKD coding.</p> <p>A community pharmacy-based CKD case finding and intervention program using CKD targeted screening guidelines was successful in identifying patients with CKD, with 41% having previously unrecognized CKD.<sup>55</sup></p>
<p><i>Evidence-based process adherence [PM2b]</i></p>	<p>Clinicians’ adherence to evidence-based processes in practice. Promoted by their <i>ability to focus and act</i></p>	<p>A multifaceted quality improvement program in GP practices in Manchester<sup>59</sup> which included a clinical decision support tool and education resulted in a greater proportion of patients with CKD achieving target BP control.</p> <p>Several other interventions specifically mention provision of evidence-based guidance<sup>39, 47, 66</sup></p>

<p><i>Patient factors [PM3]</i></p>	<p>Distinct from clinicians' <i>evidence-based process adherence</i>, this describes any aspect of the patient's characteristics, circumstances, behavior, or access to care which influence the likelihood of patients receiving and implementing lifestyle or medication recommendations.</p> <p>This includes socioeconomic position, social support resources, activation, and health literacy. These factors may interact with the mode of care delivery. For instance, patients with higher levels of activation may respond more positively to treatment advice delivered in novel ways (eg: through no patient-facing nephrology review)</p> <p>The majority of included studies have not attempted to measure or address these important mechanisms, so the relative importance compared to other mechanisms remains unknown.</p>	<p>A pragmatic RCT of 13 US community outpatient clinics<sup>43</sup>redesigned care delivery, introducing a system where pharmacists reviewed medications and lifestyle factors with patients. Patient comments included "I liked that she reminded me to get labs, and made me remember to fill my medications" and "They're looking at me as an individual, individual attention is good, hard to find."</p> <p>A multi-level intervention aimed at improving blood pressure control included a patient-directed intervention in the form of a CKD self-management support programme.<sup>82</sup> Low-income patients appreciated and engaged with a telephone-based CKD-SMS program. They found that telephone health coaching was convenient though the automated telephone system was easy to use but impersonal.</p> <p>When implementing of an eHealth intervention originally used in the Netherlands in a Chinese population, authors describe adapting the intervention to a 'Chinese context'.<sup>80</sup></p>
<p><b>Parallel mechanisms</b></p>		
<p><i>Resource reallocation [ParM1]</i></p>	<p>Changes in resource (infrastructure, IT, clinician time, clinician roles) made to support novel routes to CKD care delivery. These changes promote <i>differentiated care delivery</i> and together these processes promote other mechanisms which allow clinicians to deliver <i>positive population health outcomes</i></p>	<p>A pragmatic RCT of 13 US community outpatient clinics<sup>43</sup>redesigned care delivery, introducing a system where pharmacists reviewed medications and lifestyle factors with patients and provided recommendations to GPs. They reported improved guideline adherence (using the proxy of PTH measurement) with this system.</p> <p>The use of remote nephrology consultation in Nijmegen, Netherlands<sup>78</sup>reduced use of face-to-face nephrology appointments, with reported savings of 493 euro per nephrology appointment 'saved'. Similarly, a specialist advice service allowed GPs to access nephrology advice without patient needing a secondary care clinic appointment.<sup>86</sup></p>

<i>Differentiated care delivery [ParM2]</i>	Broadening the methods and mechanisms used to deliver CKD care	<p>Several electronic or ‘virtual’ nephrology consult systems report that implementation reduced the need for face-to-face nephrology appointments, allowing easier or more rapid access to this resource for patients with more severe CKD.<sup>36, 43, 58, 72, 78</sup></p> <p>Changing the method of care delivery can also improve cost-effectiveness.<sup>53, 88</sup></p> <p>A community pharmacy-based CKD case finding and intervention program e.g., prescribing and ordering laboratory investigations reported a 20% reduction in risk of a major cardiovascular events.<sup>55</sup></p>
<b>Contexts</b>		
<i>Credibility [C1]</i>	The value of a clinical service and the advice or guidance it delivers, as perceived by the primary care team.	
<i>Clinical Judgement [C2]</i>	The thought processes allowing clinicians to apply knowledge and guidance based on objective and subjective information about individual patients	An RCT of GPs in the USA <sup>31</sup> randomized clinicians to receive an e-alert to prompt renal referral if the eGFR was below 45ml/min versus no e-alert. No difference in renal referral rates were seen, hypothesized to relate to patient-level factors that would make referral unnecessary or inappropriate.
<i>Clinical data delivery [C3]</i>	The ability of clinical systems including electronic patient records to deliver key data to guide clinical decision-making. Including kidney function expressed as estimated glomerular filtration rate and CKD risk estimation through GFR and albuminuria categories and kidney failure risk equation calculations	
<i>Ambiguity[C4]</i>	Vagueness (or clarity) of the clinical guidance provided to primary care. Ambiguity may inhibit successful <i>learning while doing</i> , and reduce <i>clinician motivation</i>	
<i>Compatibility [C5]</i>	The ease with which novel modes of delivering care are compatible with work structures in primary care. Successful <i>workflow integration</i> depends on the proposed intervention component being compatible with existing work structures	Web-based consultation services <sup>72, 78</sup> reported to be successful were quick and easy to use and “ <i>Save[d] administrative time and charting</i> ”

<p><i>Geography [C6]</i></p>	<p>The geography of the region served by a clinical service, which may influence the ease of care delivery.</p>	<p>In Alberta, Canada, and the surrounding region<sup>36</sup> which has known rural/urban disparities in healthcare delivery, an electronic nephrology consult system was implemented. Higher rates of use were found in areas with lower population density.</p> <p>However, another study in Alberta reported reduced impact of an online clinical pathway for CKD care in rural regions <sup>47</sup>compared to in cities. In the cities of Calgary and Edmonton there were increases in uACR testing and prescription of RAAS blockers and statins, but this was not replicated in rural regions. Authors suggest that ‘the unique challenges experienced treating patients in rural locations, such as access to care barriers and WiFi access and reliability issues’ may explain this difference.</p>
<p><i>Organizational buy-in [C7]</i></p>	<p>Distinct from the mechanism of <i>clinician motivation</i>, ‘<i>buy-in</i>’ describes the commitment of organizations (primary care practices, secondary care nephrology departments) to use intervention components to deliver care</p>	<p>A CKD registry implemented in San Francisco <sup>85</sup> attributed success in increasing rates of ACE inhibitor/ARB use and albuminuria quantification to promotion of a ‘team-based primary care approach’. The intervention included all primary care staff in the provision of audit data showing practice adherence to CKD management targets, and identifying patients not receiving recommended treatment.</p>
<p><b>Outcome</b></p>		
<p><i>Positive population health outcomes</i></p>	<p>Intended to summarize the combination of reduced cardiovascular risk, reduced burden of risk associated with CKD progression, reduced mortality, reduced RRT update, and associated improvements in quality of life</p>	