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Computerized Decision Support Systems for Nursing Homes: A Scoping Review

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► **To cite this version:**

Abir Abdellatif, Jacques Bouaud, Carmelo Lafuente-Lafuente, Joël Belmin, B. Séroussi. Computerized Decision Support Systems for Nursing Homes: A Scoping Review. Journal of the American Medical Directors Association, 2021, 22 (5), pp.984-994. 10.1016/j.jamda.2021.01.080 . hal-03648850

HAL Id: hal-03648850

<https://hal.science/hal-03648850v1>

Submitted on 9 May 2023

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Title: A complete scoping review of computerized decision support systems designed for nursing homes

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Running title: Scoping review of CDSSs designed for NHs

Key words: Computerized decision support systems, Nursing homes, Geriatrics, Outcome assessment

Funding sources:

- This research was supported by the French National Association for Research in Technology (ANRT) - CIFRE- Industrial Agreements for Research Training under (Grant n° 2018/0307) for Abir ABDELLATIF.

Word, references and graphics count:

- Word count: main text: 4513 ; abstract: 178.
- Reference count : 54
- Graphics count : 4 Tables, 1 Figure
- Supplemental material: 2 Tables

Brief summary: We reviewed 24 articles analyzing computerized decision support systems (CDSSs) used in nursing homes. CDSS use was associated with improved process/health outcomes in several studies. It might contribute to the quality of care and the health of residents.

Acknowledgments: none.

Sponsor's role in the design, methods, data collection, analysis and preparation of the paper: none.

1 **TITLE: A complete scoping review of computerized decision support systems designed for**
2 **nursing homes**

3

4 **ABSTRACT**

5 **Objectives:** To summarize the research literature describing the outcomes of computerized
6 decision support systems (CDSSs) implemented in nursing homes (NHs).

7 **Design:** Scoping review

8 **Methods:** Search of relevant articles published in English language between January 1, 2000,
9 and February 29, 2020 in the Medline database. The quality of the selected studies was
10 assessed according to PRISMA guidelines and the Mixed Method Appraisal Tool (MMAT).

11 **Results:** From 1828 articles retrieved, 24 studies were selected for review, among which only
12 six were randomized controlled trials. Although clinical outcomes are seldom studied, some
13 studies show that CDSSs have the potential to decrease pressure ulcer incidence and
14 malnutrition prevalence. Improvement of process outcomes such as increased compliance
15 with practice guidelines, better documentation of nursing assessment, improved teamwork
16 and communication, and cost saving, are also reported.

17 **Conclusions and implications:** Overall, the use of CDSSs in NHs may be effective to improve
18 patient clinical outcomes and healthcare delivery. However, most of the retrieved studies
19 were observational studies, which significantly weakens the evidence. High quality studies
20 are needed to investigate CDSS effects and limitations in NHs.

21 INTRODUCTION

22 With aging, people are suffering from multiple chronic diseases leading to a high prevalence
23 of dependency, and a high number of older adults living in nursing homes (NHs) despite the
24 improvement of care at home.^{1,2} Because they are suffering from multiple chronic diseases,
25 older adults are subject to polypharmacy which put them at risk of taking potentially
26 inappropriate drugs and experiencing adverse drug events (ADEs). Thus, NH residents are a
27 highly vulnerable population with severe medical issues that require complex management
28 with a high level of geriatric and nursing expertise.³ However, nurses' expertise is often
29 lacking due to insufficient knowledge and limited staff training efforts because of high staff
30 turnover. Missed nursing care is common in NHs due to inadequate time or resources.⁴
31 Besides, health professionals are involved in high regulatory requirement that may conflict
32 with or distract from clinical practice guideline implementation.⁵ Thus, studies have reported
33 that NH residents may experience several potentially preventable clinical complications,
34 such as pressure ulcers, falls, malnutrition, or ADEs.⁶⁻⁸ Defined as information systems
35 where characteristics of individual patients are matched to a computerized knowledge base
36 to generate patient-specific recommendations,⁹ computerized decision support systems
37 (CDSSs) have proven to be efficient in detecting medical errors and improving care quality in
38 both hospital settings and primary care centers.^{10,11} However, it is not clear whether CDSSs
39 have the same efficiency in NHs and little is known about their impact on nursing practices
40 and NH resident clinical outcomes.¹²

41 In the perspective of enriching the NetSoins EHR system, currently implemented in nearly
42 half of the French NHs nationwide, with the development of a CDSS module to support the
43 prevention and management of malnutrition, pressure ulcers, osteoporotic fractures, and

44 drug prescription errors, we conducted a scoping review to identify published CDSSs
45 implemented in NHs and assess the factors that contributed to their effectiveness regarding
46 NH resident clinical outcomes and care delivery. Another objective was to study NH
47 healthcare professional satisfaction when using a CDSS and their level of adoption of CDSSs
48 in routine practice. Beyond preliminary results previously reported,¹³ the objective of this
49 paper is to present the complete methods, results, and discussion of the scoping review.

50

51 **METHODS**

52 **Search strategy**

53 We searched PubMed/MEDLINE for papers written in English language and published
54 between January 2000 and February 2020. Search terms were selected to cover the two
55 dimensions of interest, i.e., decision support systems and nursing homes. The query used
56 MeSH terms, e.g., “decision support systems, clinical”, “reminder systems”, “expert
57 systems”, “geriatric nursing”, “homes for the aged”, “nursing homes”, “residential facilities”,
58 and key words, e.g., clinical decision support tool, computer-based decision support, long-
59 term care homes, care home, etc. Two of the authors (AA and CL) independently screened
60 the titles and abstracts of the retrieved articles to assess their relevance based on eligibility
61 criteria. Backward citation tracking was also performed to identify additional relevant
62 articles. Full text papers were reviewed for articles that both reviewers finally considered
63 relevant.

64 **Study eligibility criteria**

65 The following inclusion criteria were used for the selection of relevant studies: (i) the study
66 had to evaluate the implementation of a CDSS in NHs, (ii) the CDSS used should have to

67 provide patient-specific recommendations to be considered by a healthcare practitioner
68 (e.g., physicians, pharmacists, nurses), (iii) the CDSS impact defined in terms of resident
69 clinical outcomes or NH care delivery had to be assessed. Studies were excluded when (i) the
70 described CDSS was used in hospitals or primary health care settings but not in NHs, (ii) the
71 study described the use of a non-computerized CDSS, (iii) there was no assessment of the
72 CDSS implementation.

73 **Study appraisal and synthesis methods**

74 We assessed the quality of selected studies using the Mixed Method Appraisal Tool
75 (MMAT),¹⁴ version 2018, a qualitative scale that yields a 5-value score (0%, 25%, 50%, 75%,
76 or 100%). The tool evaluates the aim of a study, its adequacy to the research question, the
77 methodology used, the study design, participant recruitment, data collection, data analysis,
78 presentation of findings, and the discussion and conclusion sections of the article. Studies
79 were considered to be of “Low quality”, “Medium quality”, and “High quality” when the
80 MMAT score was resp. 0 or 25%, 50% or 75%, and 100%.

81 Selected papers were first manually characterized using the following criteria: design of the
82 study, type of the study, MMAT score, CDSS recipients (number of residents, number of
83 facilities, patient characteristics), CDSS target users (nurses, pharmacists, physicians), CDSS
84 features, and CDSS outcomes (including clinical outcomes and process outcomes). Inter-rater
85 disagreements were solved by consensus.

86 Since we didn't retrieve enough studies reporting the same outcome in a similar way and
87 because studies were not sufficiently homogeneous regarding the patients and the CDSSs
88 studied, we didn't pool data in a random-effects meta-analysis. However, we narratively
89 described the findings of included studies, organizing them according to the special issue

90 addressed by the CDSS and presenting their results on: a) clinical outcomes, b) care delivery,
91 and c) other criteria including users' satisfaction and adoption.

92

93 **RESULTS**

94 **Article selection**

95 The search query returned 1,809 references. Analysis of titles and abstracts discarded 1,747
96 references that were not relevant to the research question. A manual analysis of the
97 citations of the remaining 62 articles was performed and identified an additional set of 19
98 references. We finally reviewed 81 full-text articles among which we excluded 57 papers
99 that did not satisfy eligibility criteria, e.g., five studies¹⁵⁻¹⁹ were removed because
100 information was missing to assess CDSSs. Finally, 24 articles were included for the final
101 analysis. The corresponding PRISMA flow diagram is depicted in Figure 1.

102 **General overview**

103 Included studies (n=24) describe 20 different unique CDSSs implemented to support NH
104 resident care quality. We have classified the papers according to the issue addressed by the
105 CDSS as follows: malnutrition and pressure ulcer prevention and management (n=7),^{12,20-25}
106 drug prescription (n=8),²⁶⁻³³ medication review (n=6),³⁴⁻³⁹ and disease management (n=3).⁴⁰⁻
107 ⁴² Studies were primarily conducted in the United States (n=12),^{20-22,29-34,40-42} in European
108 countries (n=9),^{12,23-25,35-39} namely Sweden (n=4),³⁵⁻³⁸ Norway (n=3),^{12,23,24} Belgium (n=1),²⁵
109 and the Netherlands (n=1).³⁹ Three studies were conducted in Canada.²⁶⁻²⁸ Studies follow
110 different designs, with six cluster randomized controlled trials (RCTs)^{25,26,29-31,34}, four non-
111 randomized controlled trials,^{12,21,24,37} 13 observational studies,^{20,22,23,27,28,32,35,36,38-42} and one

112 ancillary study.³³ According to the MMAT score, a majority of the study are of high²⁰⁻
113 ^{23,26,30,36,37,42} or of medium quality (i.e., MMAT score of 75%^{12,24,25,27,31,32,35,38} or 50%^{28,29,39-41}).
114 Only two studies^{33,41} are scored of low quality, both with a MMAT score of 25%. None was
115 excluded from the analysis based on the MMAT score. Full details of quality and bias risk
116 assessment are provided for each study in the supplementary material (Table s1, Table s2).

117 **Description of the studied CDSSs**

118 In all cases, CDSSs are computerized, knowledge-based systems providing decision support
119 generated from clinical practice guidelines or experts' recommendations. Fourteen CDSSs
120 are developed as software either embedded within EHRs (n=8),^{20-23,34,37,40,41} or connected to
121 computerized provider order entry (CPOE) systems (n=6),^{26,29-31,33,42} leading to decision
122 support automatically triggered from data input in EHR or CPOE systems. The remaining six
123 CDSS^{25,27,28,32,35,39} are standalone systems requiring users to re-enter patient data in a
124 separate software.

125 CDSSs applied to malnutrition and pressure ulcer prevention and management aim at
126 supporting nurses in the implementation of clinical practice guidelines, e.g., repositioning
127 standards of care. Three out of seven CDSSs^{12,23,24} display alerts automatically triggered from
128 risk assessment instruments, e.g., the Risk Assessment Pressure Scale for pressure ulcer risk
129 screening, or the Mini Nutritional Assessment (MNA) scale to assess the nutritional status.
130 Risk assessment is continuously updated from new input data, which triggers alerts when
131 the computed risk exceeds a certain threshold. More recently, based on connected devices,
132 Yap et al.²² developed a CDSS operating from data on the frequency and position of
133 residents, wirelessly transferred from sensors to estimate nurse practices before and after
134 visual monitors were activated.

135 CDSSs applied to drug prescription and medication review are usually implemented as CPOE
136 systems identified as a means to improve medication safety.⁴³ They usually display warning
137 messages to alert physicians on non-compliant drug prescription. Subramanian et al.³³
138 proposed a system for NH residents with renal insufficiency able to display four categories of
139 alerts to show the recommended doses, the recommended frequencies, the drugs to be
140 avoided, and when additional information was needed to compute creatinine clearance.
141 Colón-Emeric et al.⁴² developed an alert-based CPOE system based on clinical practice
142 guidelines to manage geriatric problems in NHs, e.g., falls, fever, pneumonia, urinary tract
143 infection, and osteoporosis. Alexander⁴⁰ developed a CDSS to alert clinicians about changes
144 in resident condition either based on episodic events (e.g., a dehydration alert is sent to a
145 provider if an episode of bowel incontinence is reported within a 24-hour period) or
146 successive clinical assessments (e.g., a decline in condition alert is sent when the resident
147 ability to make decisions declines over two successive systematic evaluations).

148 CDSSs alerts are usually displayed at the moment of the prescription,^{26,29-32} but they could
149 also be sent as emails, or used in phone calls between pharmacists and physicians. For
150 instance, de Wit et al.³⁹ developed a standalone pharmacy CDSS for medication review that
151 automatically triggers alerts to the pharmacist who then had to contact the prescriber
152 physician to indicate how to revise the mis-prescription. Johansson-Pajala et al,³⁶⁻³⁸
153 proposed a CDSS as a web application connected to the NH EHR system. When using the
154 CDSS, registered nurses could assess patient symptoms and initiate the medication review to
155 be sent to the physician who then could make the final decision. Zhu et al.⁴¹ developed a
156 CDSS applied to heart failure management which includes various reporting tools to help
157 data tracking and analysis to be used by physicians (tabular view of medications, interactive

158 trending graphs for weight tracking over time, and charts to support visual symptom
159 analysis).

160

161 **Effects of CDSSs on malnutrition and pressure ulcer prevention and management**

162 Seven articles^{12,20–25} assessed the implementation of five different CDSSs to support pressure
163 ulcer and malnutrition prevention and management (see Table 1). There is only one cluster
164 RCT²⁵ including 464 residents and 118 NH staff. The aim of the intervention is to assess the
165 impact of the CDSS on nursing practice compliance with pressure ulcer prevention in NHs. A
166 significantly increased number of patients (from 13.2 % to 60.0 % within 120 days, p=0.003)
167 actually received the recommended pressure ulcer prevention when there were seating in a
168 chair. However, no effect was found on the allocation of preventive measures when
169 residents at risk were lying in bed.²⁵ This study also reports a significant improvement in the
170 attitude of healthcare professionals towards pressure ulcer prevention (from 74.3% to
171 83.5%, p=0.001).²⁵ However, no clinical outcome related to the decrease of pressure ulcer
172 prevalence was found and no significant improvement was observed in healthcare
173 professional knowledge,²⁵ as assessed by a validated pressure ulcer Knowledge Assessment
174 Tool.⁴⁴

175 Three studies are non-randomized controlled trials,^{12,21,24} cumulating 7,623 residents and 28
176 nurses. Clinical outcomes are assessed in two studies. In these studies, using the CDSS
177 significantly lowered the prevalence of malnutrition among NH residents (from 28.8% to
178 19.8%, p=0.05)¹² and significantly decreased pressure ulcer incidence (59% reduction in a
179 month, p=0.035).²¹ Cost reduction (approximately US\$208 saved per month and per
180 resident) was also observed.²¹ The third study concludes on the better documentation of

181 nurse assessment of pressure ulcers (from 25 % to 88 %, $p < 0.05$) and nutritional issues (from
182 20% to 100%, $p = 0.007$)²⁴ in patient records when using the CDSS.

183 The three remaining studies are observational studies,^{20,22,23} involving 2,146 residents and 63
184 nurses in total. The use of the CDSS was associated with an improvement of care delivery,
185 e.g., a better compliance of nursing care with repositioning clinical practice guidelines (from
186 7.0 % to 100 % during a 3-day baseline period and from 50.6 % to 100 % during the 18-day
187 intervention $p = 0.0003$).²² However, no significant change in nursing culture (assessed by the
188 Nursing Culture assessment tool⁴⁵) was reported.²²

189

190 **Effects of CDSSs on drug prescription and medication review**

191 *Drug prescription*

192 The implementation of CDSSs supporting daily drug prescription is described in eight
193 studies,^{26–33} that report the results of the assessment of eight different CDSSs (see Table 2).
194 Six studies enroll physicians as primary users of the CDSS.^{26–33} Pharmacists are the principal
195 users in the two other studies.^{27,30}

196 Four studies are cluster RCTs,^{26,29–31} cumulating 3,209 resident with physicians and
197 pharmacists as users. No clinical outcomes are reported in these studies. Gurwitz et al.,³⁰
198 observed no significant reduction of adverse drug events (ADEs) or preventable ADEs. The
199 other cluster RCTs reported an improvement of drug prescribing in response to alerts
200 generated by the CDSS. Judge et al.,³¹ observed that alerts were most likely to generate
201 appropriate action, e.g., ordering a recommended laboratory test or canceling an
202 inappropriate ordered drug (25 % with the CDSS vs 7% in the control unit, relative risk 1.11,

203 95% confidence interval [1.00, 1.22]). Donovan et al.,²⁹ reported that psychotropic
204 medication orders, modified in response to alerts, were significantly improved. Final drug
205 orders were appropriate significantly more often in the intervention units as reported by
206 Field et al.²⁶ (increase of recommended administration frequencies, but no improvement of
207 the appropriate doses, and decrease of drugs that were recommended to avoid in NHs).
208 However, Donovan et al.,²⁹ found no overall improvement of the quality of psychotropic
209 medication prescriptions with the use of a CDSS.

210 Three studies are observational studies,^{27,28,32} including 1,598 residents and 17 users.
211 Papaioannou et al.,²⁷ reported no significant increase of the percentage of INR in the
212 therapeutic range for resident on warfarin. However, CDSSs supporting daily drug
213 prescription showed an impact on practices beyond clinical outcomes. Handler et al.,³²
214 implemented a clinical event monitoring system using signals to detect potential ADEs that
215 allowed to improve the detection of ADEs at levels that are substantially higher than the
216 rates reported in the literature (53% for antidote signals and 96% for laboratory/medication
217 signals). Papaioannou et al.²⁷ showed that using a CDSS significantly decreased the average
218 number of INR tests performed per month (from 4.2 to 3.1 per resident, $p < 0.0001$), while at
219 the same time either maintaining or improving the quality of Warfarin management.
220 Similarly, Kennedy et al.²⁸ reported that physicians responded to 70% of the alerts with an
221 appropriate dose change or medication discontinuation when using the CDSS.

222 The last study is an ancillary study performed in a cluster-randomized trial³³ studying 10
223 users that concluded on a modest reduction of costs (US\$4.71 per resident and per year)
224 partially offset by an increase in laboratory-related costs.³³

225 *Medication review*

226 Six studies,^{34–39} evaluate the role of CDSSs to improve medication review (see Table 3). None
227 of them evaluate CDSS clinical outcomes. One cluster RCT,³⁴ including 141 residents and 60
228 pharmacists and physicians showed an improved physicians' assessment of the importance
229 and performance of consultant pharmacists services. In this study, importance rating
230 increased for all 24 survey questions, and five of the changes were statistically significant
231 ($p < 0.05$).

232 One non-randomized trial,³⁷ including 54 residents and 14 nurses describes a CDSS to be
233 used by nurses to initiate and prepare medication reviews.³⁷ CDSS detected significantly
234 more drug-related issues ($p = 0.008$) than nurses, but nurses detected additional relevant
235 problems that were outside the scope of the CDSS, e.g., the lack of adherence. In addition,
236 CDSS allowed to improve the quality of prescriptions with a decreased number of renally
237 excreted drug orders in residents with reduced renal function.

238 The four remaining studies are observational studies,^{35,36,38,39} cumulating 1,425 residents
239 and 36 users (12 physicians and pharmacist and 24 nurses). Using a CDSS evidenced some
240 positive outcomes on care delivery processes. Ulfvarson et al.,³⁵ reported that the CDSS
241 improved the quality of drug use with the reduction or the elimination of dangerous or
242 improper prescriptions (reduction of anticholinergic drugs by 40%, of long-acting
243 benzodiazepines by 17%, correction of drug duplication by 30%). When using the system to
244 support medication review, the number of drugs used decreased from 10.4 to 9.5 drugs per
245 patient, resulting in a more cost-effective drug therapy (decreased drug costs of 149 euros
246 per patient over a 10-month period), while preserving the same level of care quality. De Wit
247 et al.,³⁹ studied the relevance of alerts generated by the CDSS and reported that only 3.6% of

248 alerts were considered as clinically relevant, with non-relevant alerts related to care already
249 delivered.

250

251 **Effects of CDSSs on disease management**

252 Disease management was applied to heart failure, falls, and chronic diseases, e.g., Alzheimer
253 disease. Results are displayed in Table 4. Three studies assess the use of a CDSS for disease
254 management in NHs.⁴⁰⁻⁴² All three studies are observational studies and describe three
255 different systems cumulating 783 residents and 47 NH staff.

256 No study involving the use of a CDSS for disease management evaluate the impact of the
257 system on patient clinical outcomes. However, the OneTouch system⁴⁰ that automatically
258 triggers clinical alerts to support identifying when a resident might be experiencing some
259 change in condition, e.g., constipation, dehydration, skin integrity change, weight loss,
260 weight gain, was beneficial in decreasing pressure ulcer prevalence (from 20% to 9%) and
261 pain (from 14% to 6%) as a side effect. Process outcomes were assessed in the two other
262 studies.^{41,42} Colón-Emeric et al.⁴² showed that using a guideline-based CDSS applied to the
263 management of five common problems in NHs (falls, fever, pneumonia, urinary tract
264 infection, and osteoporosis) could improve the collection of quality measures for blood
265 pressure (from 17.5% to 30.0%, $p=0.29$), neuroleptic prescription (from 53.8% to 75%,
266 $p=0.27$), sedative-hypnotics prescription (from 16.7% to 50.0%, $p=0.50$), calcium prescription
267 (from 22.5% to 32.5%, $p=0.45$), vitamin D prescription (from 20.0% to 35.0%, $p=0.21$), and
268 external hip protectors (from 25.0% to 47.5%, $p=0.06$). Zhu et al.⁴¹ developed a CDSS
269 following the Heart Failure national guidelines for the weekly monitoring, evaluation, and
270 management of care for patients suffering from heart failure. This included documentation

271 of left ventricular function, weight changes and specific symptoms tracking, medication
272 titration, discharge instructions, 7-day follow up appointment post NH discharge, and
273 patient education. Using the CDSS showed to have beneficial process outcomes, e.g., the
274 authors observed that data capture was improved as compared to paper-based practices,
275 and order input was enhanced (auto completion of medication name, easy retrieval of
276 medication history, easy medication modification).⁴¹ Besides, Zhu et al.,⁴¹ reported that real
277 time data capture when using the CDSS was beneficial to avoid errors and allowed to save
278 time by the automatic computation of clinical scores.

279 **CDSS users' acceptance**

280 Users' acceptance of CDSSs was rarely investigated in the retrieved studies,^{22,23,27-29,35,39-42}
281 and when investigated, results were controversial.

282 A good acceptance of the CDSS was reported in six studies^{22,23,27,28,35,40} where users
283 considered that the CDSS was a supportive work environment tool, easy to use, and
284 useful.^{23,28} In a survey, Papaioannou et al.²⁷ reported CDSS users thought the CDSS decreased
285 workload (75% of participants), improved healthcare professional confidence in patient
286 management and drug decisions (80% of participants), enhanced teamwork (67% of
287 participants) and communication (92% of participants). Ulfvarson et al.,³⁵ reported the same
288 conclusion that users considered the CDSS was successful to improve teamwork between
289 healthcare professionals.

290 However, five studies^{23,29,39,40,42} reported a poor acceptance of CDSS users. Fossum et al.,²³
291 observed some resistance to using computers and a limited integration of the CDSS within
292 the facility's EHR. Alexander et al.,⁴⁰ reported multiple unnecessary alerts due to the non-
293 documentation of actually given care, criticism expressed towards the lack of

294 standardization in terminologies,⁴⁰ a poor use of the CDSS by NH staff except for the
295 management of falls (in 73% of the cases) although the system was recognized as a means to
296 improve the training of new staff.⁴² Similarly, de Wit et al.,³⁹ highlighted the alert fatigue
297 phenomenon with only 3.6% of alerts considered as actually clinically relevant.

298 Qualitative methods have been used to assess nurses' position towards the use of CDSSs.
299 Nurses' expectations stated that the CDSS should help saving time, provide some clinical
300 work standardization, support knowledge acquisition, and contribute to a better division of
301 responsibilities between nurses and physicians.³⁶ Nurses' recommendations for a successful
302 CDSS implementation were that the CDSS should allow saving time, curbing administrative
303 hassle, improving collaboration at all levels, and identifying responsibilities and roles. There
304 should also be a strong governance involvement.³⁸

305 The use of CDSSs in routine practice was not described in the selected papers, thus CDSS
306 adoption beyond the intervention study period is not discussed in this paper.

307

308 **DISCUSSION**

309 Despite an exhaustive search, the scoping review identified only 24 studies reporting on the
310 use of a CDSS in NHs, among which only six are controlled trials. This low number contrasts
311 with those of literature reviews on CDSSs that did not restrict to NHs. For instance, with
312 respect to CDSS impact, Bright et al.,⁴⁶ in 2012 included 148 RCTs, Roshanov et al.,¹⁰ in 2013
313 included 162 RCTs, and more recently in 2020, Kwan et al.,⁴⁷ analyzed 108 randomized or
314 quasi-randomized trials. Such an imbalance confirms that NH CDSSs have been poorly
315 investigated yet, meaning that probably CDSSs are less implemented in NHs than in other

316 healthcare settings, and that evidence regarding current CDSS impact in NHs would be less
317 robust. In our study, only four RCTs reported a positive impact of the CDSS on care delivery
318 concerning the prevention of pressure ulcers and adverse drug events.

319 Besides, included papers are rather old, published before 2015, except those used to
320 support medication review. Most of the selected articles (58%) are applied to drug
321 prescription and reviewing. This can be explained by the fact that older adults are subject to
322 multimorbidities and polymedication, and consequently very likely to experience adverse
323 drug events.⁴⁸ The other studies are mainly applied to the management of pressure ulcers
324 and malnutrition, with a few of them applied to disease management.

325 These findings about the relatively scarce literature and the focus on medication are broadly
326 consistent with those of other published reviews on the subject. Thus, a recent systematic
327 review and meta-analysis of RCTs assessing interventions that increase the appropriateness
328 of medications used in NHs only retrieved two interventions including a CDSS.⁴⁹ In 2015,
329 Marasinghe⁵⁰ published a systematic review on CDSSs in long-term care homes, but the
330 focus, restricted to medication safety, was not as broad as in this scoping review. Only seven
331 papers met the inclusion criteria, leading the author to the conclusion of limited literature
332 on the subject. It is of note that among the seven studies selected by Marasinghe, six
333 reported on CDSSs for daily drug prescription^{26,28-32} that we also retrieved and included
334 within our review. The seventh paper was not related to NHs but to adults aged 65 and
335 older.

336 The impact of CDSSs in terms of clinical outcomes for NH residents was assessed in only one
337 quarter of all studies.^{12,21,25,27,30,40} Three of them reported positive effects: a decrease in
338 malnutrition prevalence,¹² a decrease in pressure ulcer incidence,²¹ and a decrease of pain
339 prevalence.⁴⁰ Two studies reported no impact of the CDSS on pressure ulcer prevalence,^{12,25}

340 and one study showed no impact on the reduction of adverse drug events.³⁰ From this
341 limited number of studies, the impact of CDSSs on residents' clinical outcomes appears to be
342 poorly studied and, when studied, it remains limited.⁹ Otherwise, improvements of care
343 delivery were observed in almost all included studies.^{22,24–29,31,32,35,37,41,42} The benefits
344 reported are similar to those already observed in hospital settings,⁵¹ e.g., improvement of
345 drug order quality, better compliance with guidelines (for pressure ulcer prevention), and
346 enhanced documentation of care records. In addition, studies showed that CDSSs were
347 useful and cost effective; ^{21,33,35} they allowed for time saving, they improved communication
348 and healthcare professional commitment,²² they increased teamwork.^{33,35} However, no
349 improvement of healthcare professional knowledge²⁵ or nursing culture²² was reported.

350 It should be noticed that almost all systems were evaluated by their own developers and it
351 has been reported that such evaluations are more likely to show benefit than evaluations
352 conducted by third parties.¹⁰ Moreover, most CDSSs were embedded within an EHR or a
353 CPOE system. This allows for system interoperability, unique data entry, multiple data reuse,
354 and enables workflow integration, characteristics which are known to increase users'
355 acceptance and CDSS use as compared to standalone CDSSs.¹⁰

356 CDSSs are generally poorly described in the studies retrieved by the scoping review and it is
357 difficult to know how these systems were developed (guideline modeling, knowledge base
358 implementation, data processing, user's interfaces, etc.) and how they were operating.
359 Kawamoto et al.,¹¹ attempted to address the question of which CDSS features contribute to
360 making them more effective in a meta-analysis of 70 studies. In particular, they stressed the
361 importance of a decision-support recommendation accompanying warnings rather than a
362 simple assessment or alert. Lobach et al.,⁵² pointed out that when CDSSs did not require the

363 entry of new information, they were more likely to be adopted. However, CDSS limits such
364 as alert fatigue, distraction, or user hostility have been reported.⁵³ The main pitfalls of
365 issuing too many clinically-non-relevant alerts are a systematic overriding, CDSS
366 disconnection, or clinician burnout.⁵⁴ In our work, NH users' acceptance, when assessed, was
367 judged satisfactory though alert fatigue was explicitly reported in two studies.^{39,40} Finally,
368 the small number of studies and the diversity of CDSSs and of study designs made difficult
369 the identification of factors contributing to the adoption of CDSSs specifically designed for
370 NHs.

371 As with any literature review, this scoping review presents some limitations related to
372 publication bias: some studies reporting on the implementation of a CDSS in NHs may have
373 not been published, especially if the results were negative. Another potential limitation is
374 that the studies we found are heterogeneous, and we have gathered them by type of clinical
375 application to identify general trends in their effects. The methodological design and quality
376 of the studies were also heterogeneous. We chose not to exclude any studies because of
377 poor methodological scores, as studies evaluating CDSS are much more difficult to conduct
378 than traditional double blind drug evaluation.

379

380 **Conclusions and implications**

381 We performed a scoping review of the literature to identify studies of CDSSs implemented in
382 NHs and assess CDSS factors impacting NH resident clinical outcomes and care delivery.
383 Whether embedded within an EHR or not, used by physicians, nurses, or pharmacists,
384 generating alerts or not, this review suggests CDSSs may improve healthcare professional
385 daily practice and resident clinical outcomes in several domains especially pressure ulcer

386 prevention and drug prescription improvement. However, we could not draw robust
387 conclusions from the evidence reported in the studies retrieved due to the variability in CDSS
388 design, intervention protocols, outcomes, and the limited number of included studies.
389 Therefore, more good quality studies are needed to assess further initiatives such as the
390 deployment of CDSSs able to detect critical conditions, alert practitioners during care
391 processing, provide recommendations to make decisions easier, or simply remind actions
392 not-to-be missed, all functionalities being rather promising in the NH context. Besides, CDSS
393 effects on residents' clinical outcomes should be more extensively investigated in future
394 studies.

395

396 **Conflicts of interest:** none for all the authors.

397 **Acknowledgments**

398 This research was supported by the French National Association for Research in Technology
399 (ANRT) CIFRE- Industrial Agreements for Research Training under the grant n° 2018/0307
400 and by Teranga Software, a French vendor of NH information systems.

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538 **Table 1: CDSSs for malnutrition and pressure ulcer prevention and management**

539

Reference	Study design	MMAT rating	Residents (R), Facilities (F), and End-Users (U)	Clinical Outcomes	Process Outcomes	Other outcomes
Olsho et al., 2014, USA ²¹	Non-randomized controlled trial	100%	- R = 3,463 + 2,698 - F = 12 + 13 - U = NA (Nurses)	- Significant reduction of pressure ulcer incidence (59% reduction in monthly incidence, p = 0.035)	- Not studied	- Cost saving (\$20,800 per month per NH, 100 residents)
*Fossum et al., 2011, Norway ¹²	Non-randomized controlled trial	75%	- R = 491 - F = 15 - U = 28 (Nurses)	- Significant decrease of malnutrition prevalence (from 28.8% to 19.8%, p=0.05) - No significant decrease of pressure ulcer prevalence	- Not studied	- Not studied
Beeckman et al., 2013, Belgium ²⁵	Cluster-randomized controlled trial	75%	- R = 464 - F = 4 - U = 118 (NH staff)	- No significant decrease of pressure ulcer prevalence	- Improved pressure ulcer prevention when residents are seated in a chair (p=0.003) - No significant increase of pressure ulcer prevention when residents are lying in bed	- Significant improvement of the attitude of healthcare professionals towards pressure ulcer prevention (p=0.001) - No significant improvement of healthcare professional knowledge
*Fossum et al., 2013, Norway ²⁴	Non-randomized controlled trial	75%	- R = 971 - F = 15 - U = NA (Nurses)	- Not studied	- Improved documentation of pressure ulcer (from 25% to 88%) and nutritional status nursing assessment (from 20% to 100%)	- Not studied
Yap et al., 2019, USA ²²	Observational study (pre/post design)	100%	- R = 44 - F = 1 - U = 38 (Nurses)	- Not studied	- Significant improvement of compliance with repositioning clinical practice guidelines (p=0.0003)	- Improved communication and professional commitment (p=0.035) - Satisfaction with the CDSS implementation (focus groups) - No improvement of nursing culture
*Fossum et al., 2011, Norway ²³	Observational study (cohort)	100%	- R = NA - F = 15 - U = 25 (Nurses)	- Not studied	- Not studied	- Ease of use, usefulness, and supportive work environment - Lack of training, resistance to using digital tools, limited integration of the CDSS within the EHR, poorly designed graphical user interfaces
Sharkey et al., 2013, USA ²⁰	Observational study (cross-sectional)	100%	- R = 2,102 - F = 14 - U = NA (NH staff)	- Not studied	- Not studied	- High level of CDSS use for pressure ulcer prevention in 36% of NHs - Significant involvement of NH directors and high participation of nurse managers

* The three studies by Fossum et al. used the same CDSS but were focused on different assessment facets.

540 **Table 2:** CDSSs for daily drug prescription

Reference	Study design	MMAT rating	Residents (R), Facilities (F), and End-Users (U)	Clinical Outcomes	Process Outcomes	Other outcomes
Papaioannou et al., 2010, Canada ²⁷	Observational study (pre/post design and focus groups)	75%	- R = 128 - F = 6 - U = 12 (NH staff, pharmacist)	- No significant increase of the percentage of INR in the therapeutic range	- Significant decrease of the average number of INR tests per month ($p < 0.0001$)	- Decreased workload, improved healthcare professional confidence in patient management and drug decisions, improved teamwork, improved communication
Gurwitz et al., 2008, USA ³⁰	Cluster-randomized controlled trial	100%	- R = 1,118 - F = 2 - U = NA (Pharmacists, physicians)	- No significant decrease of ADEs and preventable ADEs	- Not studied	- Not studied
Judge et al., 2006, USA ³¹	Cluster-randomized controlled trial	75%	- R = 445 - F = 1 - U = NA (Physicians)	- Not studied	- Alerts were more likely to engender an appropriate action such as ordering a recommended laboratory test or canceling an ordered drug (RR=1.11, 95% CI = [1.00 ; 1.22])	- Not studied
Handler et al., 2008, USA ³²	Observational study (cohort)	75%	- R = 274 - F = 1 - U = NA (Physicians)	- Not studied	- ADEs detected in NHs with a high degree of accuracy using a clinical event monitor. - Overall PPV for all signals = 81% - Of the true positive findings, one-third of ADEs considered as preventable. - Of the preventable ADEs, 88% occurred at the monitoring and 69% at the prescribing stages.	- Not studied
Field et al., 2009, Canada ²⁶	Cluster-randomized controlled trial	100%	- R = 833 - F = 1 (22 units) - U = NA (Physicians)	- Not studied	- Higher proportions of final drug orders were appropriate in the intervention units (RR=2.4, 95% CI = [1.4, 4.4] for maximum frequency; RR=2.6, 95% CI = [1.4, 5.0] for drugs that should be avoided; and RR=1.8, 95% CI = [1.1, 3.4] for alerts to acquire missing information). - Final drug orders were appropriate significantly more often in the intervention units (RR=1.2, 95% CI = [1.0, 1.4]) - No improvement of drug orders with appropriate doses (e.g., no dose adaptation for residents with renal insufficiency)	- Not studied
Donovan et al., 2010, USA ²⁹	Cluster-randomized trial	50%	- R = 813 - F = NA - U = NA (Physicians)	- Not studied	- Significant improvement of psychotropic medication orders in response to alerts (8% in intervention unit vs. 2% in control unit, RR = 3.69, 95% CI = [1.08, 12.57]) - No overall improvement of prescribing quality	- Not studied
Kennedy et al., 2011, Canada ²⁸	Observational study (cohort)	50%	- R = 1,196 - F = 7	- Not studied	- Physicians responded to 70% of the alerts with a dose change or medication discontinuation.	- Alerts considered as helpful

			- U = 5 (Physicians)			
Subramanian et al., 2012, USA ³³	Ancillary study in a cluster-randomized trial	25%	- R = NA - F = 1 - U = 10 (Physicians)	- Not studied	- Not studied	- Modest reduction of direct costs by US\$1391.43, net 7.6% for 12 months

541 * The three studies by Johansson-Pajala et al. used the same CDSS but were focused on different assessment facets.

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543

544 **Table 3:** CDSSs for medication review

Reference	Study design	MMAT rating	Residents(R), Facilities (F), and End-Users (U)	Clinical Outcomes	Process outcomes	Other outcomes
Ulfvarson et al., 2010, Sweden ³⁵	Observational study (pre/post design)	75%	- R = 275 - F = 7 - U = 12 (Physicians)	- Not studied	- Improved quality of drug use: reduction of anticholinergic drugs (40%), long acting benzodiazepines (17%), drug duplication (30%), drugs that should be avoided in patients with impaired kidney function (17%), number of drugs per patient (from 10.4 to 9.5)	- Increased teamwork and awareness of the importance of detecting ADEs - Cost saving (143 € per patient/ 10 months)
*Johansson-Pajala et al., 2018, Sweden ³⁷	Non-randomized trial (pre/post design)	100%	- R = 54 - F = 4 - U = 14 (Nurses)	- Not studied	- Improved detection of ADEs such as adverse drug reactions (27 vs. 43, p=0.000) and drug-drug interaction (10 vs. 22, p=0.008) - Decreased use of renally excreted drugs in residents with reduced renal function (92.1% vs 86.8%)	- Not studied
De Wit et al., 2015, The Netherlands ³⁹	Observational study (cohort)	50%	- R = 900 - F = 1 - U = NA (Pharmacist, physicians)	- Not studied	- Not studied	- Alert fatigue due to non-clinically relevant alerts - Unnecessary alerts related to care already delivered but not documented in patient records
Kane-Gill et al., 2016, USA ³⁴	Cluster-randomized controlled trial	50%	- R = 141 - F = 4 - U = 60 (Pharmacists, physicians)	- Not studied	- Not studied	- Improved physicians' assessment of the importance and performance of consultant pharmacist services
*Johansson-Pajala et al., 2017, Sweden ³⁶	Observational study (qualitative method)	100%	- R = 250 - F = 4 - U = 16 (Nurses)	- Not studied	- Not studied	- Nurses' expectations from CDSSs include time saving, clinical work standardization, knowledge acquisition, and a better division of responsibilities between nurses and physicians
*Johansson-Pajala et al., 2019, Sweden ³⁸	Observational study (qualitative method)	75%	- R = NA - F = 2 - U = 8 (Nurses)	- Not studied	- Not studied	- Nurses' recommendations for a positive CDSS implementation include time saving, curbing administrative hassle, improved collaboration at all levels, identifying responsibilities and roles, and governance involvement

545 **Table 4:** CDSSs for disease management

Reference	Study design	MMAT rating	Residents (R), facilities (F) and End-users (U)	Clinical outcomes	Process outcomes	Other outcomes
Alexander, 2008, USA ⁴⁰	Observational study (pre/post design)	50%	- R = 518 - F = 3 - U = NA (NH Staff)	- Decreased prevalence of pressure ulcers (from 20% to 9%) and pain (from 14% to 6%)	- Not studied	- Moderate adoption of the CDSS - Unnecessary alerts related to care already delivered but not documented in patient records - Staff frustration because of the lack of standardization in terminologies
Colón-Emeric et al., 2009, USA ⁴²	Observational study (pre/post design)	100%	- R = 265 - F = 2 - U = 42 (NH staff)	- Not studied	- Improved collection of quality measures (from 17% to 30%)	- Easy training of new staff - CDSS infrequently used except for falls (73%)
Zhu et al., 2017, USA ⁴¹	Observational study (cohort)	25%	- R = NA - F = NA - U = 5 (NH staff)	- Not studied	- Improved data capture as compared to paper-based practices - Enhanced order input - Errors avoided and time saved (automatic computing of clinical scores)	- Not studied

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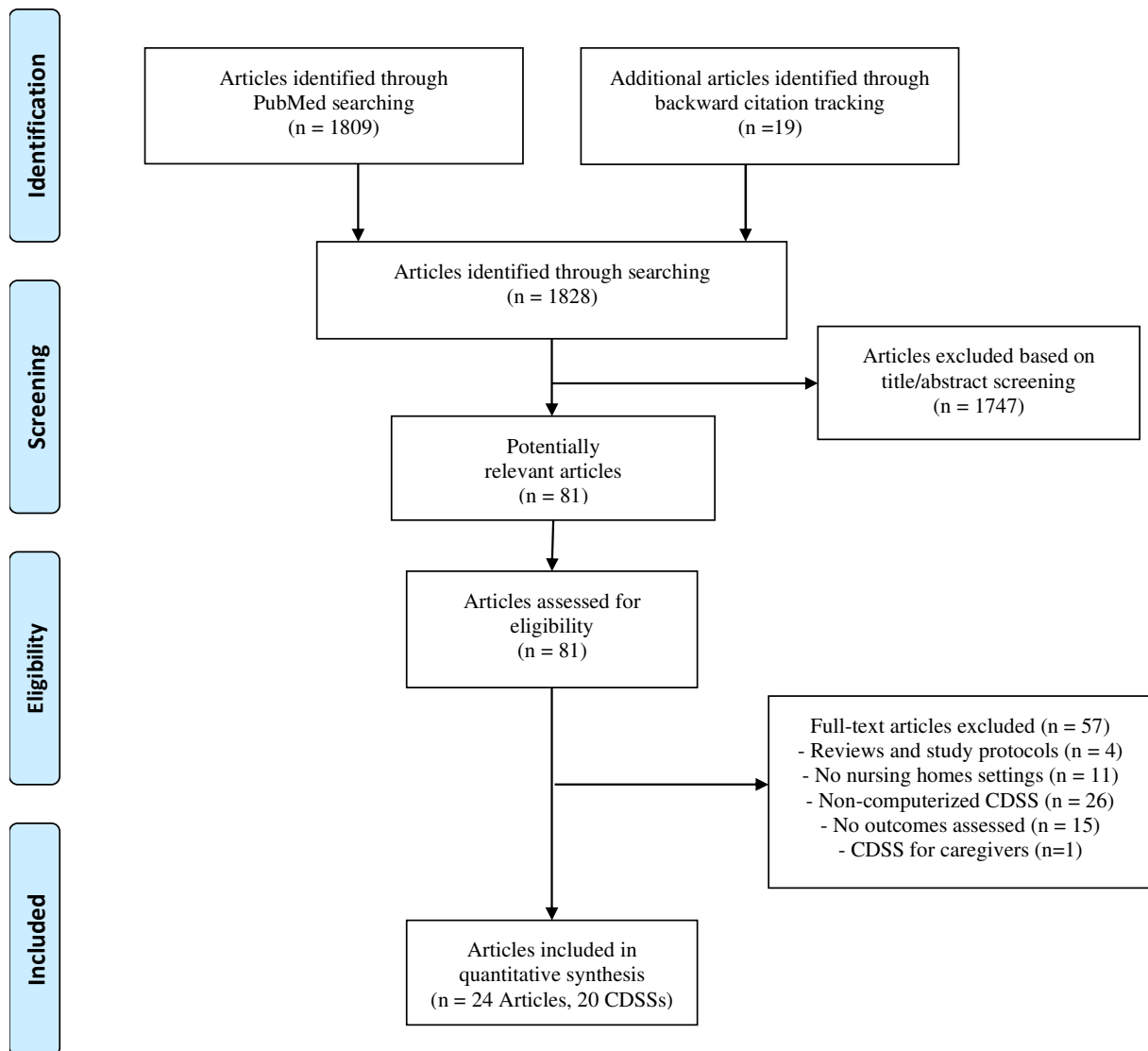


Figure 1: Prisma flow diagram