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Decision support in hospital care for older patients

Medication, falls and delirium

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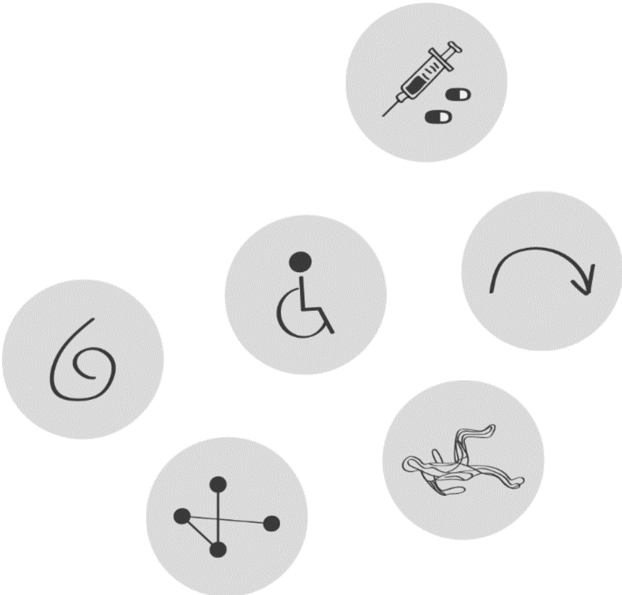
Discussion



The main objective of this thesis was to study and generate new evidence that contributes to the development of effective CDSSs in the care of older hospitalized patients. This thesis described different phases of developing CDSSs. The Dutch hospital population is aging.[8,9] Geriatric problems are complex due to multi-morbidity, frailty, communication difficulties and polypharmacy and all hospital clinicians should gain more geriatric knowledge to perform their tasks. Clinical Decision Support Systems (CDSSs) can support the implementation of geriatric knowledge to all clinicians. In this thesis, we primarily focused on developing CDSSs for medication review, fall prevention and delirium care.

In this final chapter, we summarize the main findings of this thesis. We discuss these in a wider context of the implementation science and CDSS literature. Finally, we discuss implications for clinical practice and future studies.

Main findings

Geriatric areas

Our modified Delphi study (*chapter 2*) identified nine causes for suboptimal care for older hospitalized patients. Six of these nine areas could potentially be improved by a CDSS as an implementation strategy. The six areas were “discharge and aftercare”, “medication review”, “fall prevention”, “delirium care”, “planning” and “communication with patients at discharge”. The highest-rated CDSS possibilities within these areas were “connecting in- and outpatient IT systems to re-use data in CDSS”, “support medication review at patient-level” and “support in selecting personalized (preventive) interventions”. Our systematic review (*chapter 7*) found 18 CDSS interventions studied in controlled trials. The CDSSs supported medication review, delirium care, fall prevention, functional decline, discharge/aftercare, and pressure ulcer. Of the 18 CDSS interventions, 72% were effective mostly on process-related outcomes. The effect on patient-related outcomes such as length of stay, adverse drug events (ADEs) and falls was limited. Three factors were described more often in articles on effective CDSSs, compared to ineffective CDSSs. Two were implementation factors: “multifaceted interventions” and “a priori problem or performance analyses”. One was a design factor: “consideration of the workflow”. The results in these chapters provided areas of geriatric care where clinicians saw the greatest opportunities for decision support to improve care and where evidence of CDSS effectiveness already exists.

Medication review

For developing a CDSS supporting medication review, our participants (*chapter 2*) suggested using the STOPP/START criteria v2 as the clinical knowledge base. Our analysis (*chapter 4*) in a retrospective cohort of EHR data showed that 56% of all admissions of patients >70 years had a potentially inappropriate medication (PIM) according to STOPP v2, and 58% had a potential prescribing omission (PPO) according to START v2. Six variables were independently associated with PIMs and PPOs. Over a period of 4 years, the absolute PIM prevalence stayed the same and the absolute PPO prevalence increased. However, when corrected for patient characteristics, both the PIM and the PPO prevalence decreased over the 4 years. Of the >16,000 admissions, 2.7% had at least one in-hospital fall. PIMs were independently associated with in-hospital falls (*chapter 5*). This effect was shown for PIMs according to three (de)prescribing tools. The strongest effect was seen for PIMs according to STOPP section K. In our scoping review *(chapter 7*), we found 30 articles assessing the clinical validation of CDSSs that support clinicians in conducting a medication review. Most of these articles focused on ADE, PIM, or drug-related problem (DRP) detection. Of these 30 articles, 21 assessed the clinical relevance of the alerts, 10 studies described the association with actual events and 10 studies compared the potential medication errors found by the CDSS with a medication/chart review in the total population. None of these studies described the use of a validation strategy. The results in these chapters provided insights into the clinical knowledge base and the relevance of CDSS's output supporting a medication review.

Falls prevention & delirium care

For fall prevention and delirium care, we successfully used the Functional Resonance Analysis Method (FRAM) and showed substantial differences (*chapter 3*) between guidelines (work-as-imagined) and actual care (work-as-done). In total, participants preferred a CDSS for 13 of the 25 barriers and 3 of 10 facilitators for (not) following the guidelines. Participants preferred a CDSS for fall and delirium risk screening, performing a risk assessment, and selecting multifactorial interventions (*chapter 2 and 3*). To assess the performance of the John Hopkins Fall Risk Assessment Tool (JHFRAT), we scrutinized its performance using a retrospective EHR dataset (*chapter 6*). The JHFRAT and all subcategories were associated with in-hospital falls. The overall AUC of JHFRAT was 0.67 and the AUC varied over the 5 years between 0.62 and 0.71. The PPV was, at 0.04, very low. This performance is in line with clinicians' sense that this is an area in need of improvement.

In the context of implementation science & CDSS literature

The Grol & Wensing implementation of change model, the GUIDES checklist and the Two-Stream Model include implementation science and CDSS literature.[35–37] These were used as backbone structures for the work in this thesis. Figure 9.1 shows the main findings of this thesis in the context of these models and the GUIDES checklist.

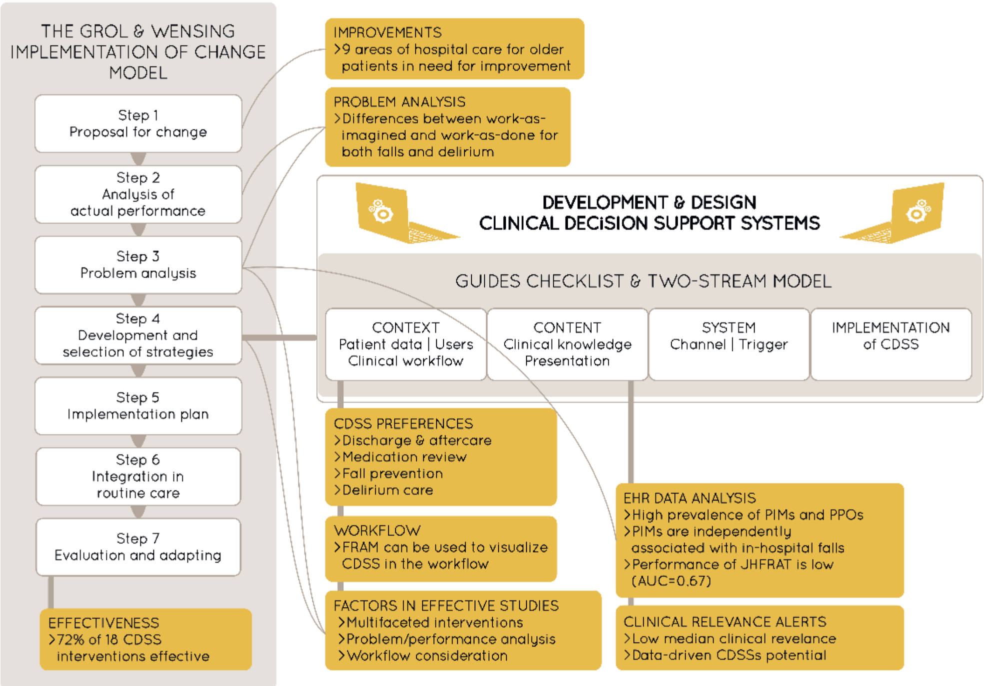


Figure 9.1. Main findings of this thesis in context of the Grol & Wensing implementation of change model, the GUIDES checklist and Two-Stream Model.[35–37] JHFRAT = John Hopkins Fall Risk Assessment Tool, PIMs = Potentially Inappropriate Medications, PPOs = Potential Prescribing Omissions

Implementation science

In step 1 of the Grol & Wensing implementation of change model, the desired healthcare improvements are determined.[35] This thesis concretized this step by identifying 9 areas of hospital care for older patients in need of improvement. Although most of the 9 areas might be already known to form a challenge, our study contributed by prioritizing these areas. Discharge & aftercare, admission, falls, and medication review were seen as the most important areas in need of improvement. Discharge & aftercare, medication review, falls and delirium were seen as the most important areas to be improved by CDSSs.

Consistent with our results, transfers (admission and discharge & aftercare) and availability of patient information were identified as problems by a Dutch position paper on care for vulnerable older patients.[22] Also consistent with our results, medication information was insufficiently transferred between the hospital and the next healthcare providers.[63,64] For example, in 27% of the drug withdrawals during hospital stay because of ADEs, unintentional re-prescriptions happened after discharge.[65]

In step 2 and 3 of the Grol & Wensing implementation of change model, actual care and barriers and facilitators to implementing the desired change are assessed.[35] As in Clay-Williams et al, we used FRAM to identify differences in work-as-done and work-as-imagined and the barriers & facilitators for guideline implementations.[85] FRAM was helpful in facilitating the discussion of why clinicians did not follow the geriatric knowledge in guidelines. “A priori problem or performance analyses” (step 2 and 3) were described more often in articles of effective interventions, compared to ineffective interventions in our systematic review.

In step 4 of the Grol & Wensing implementation of change model, implementation strategies are developed and selected. Implementation strategies are classified by the EPOC taxonomy and include for example a CDSS or audit and feedback.[246] In our systematic review, “multifaceted interventions” (interventions with >1 implementation strategy) were described more often in articles of effective interventions. Implementation literature is inconsistent on this factor and whether single or multifaceted interventions are more effective is not clear.[29] Previously published systematic reviews on fall prevention in hospitals showed inconsistent results from multifaceted interventions as well.[266,267]

<u>CDSS development</u>

Context – user preferences & workflow

CDSS best practices have shown that identifying user needs and preferences is a key step in developing an effective CDSS.[36,37,275,276] This thesis contributed by identifying user needs and preferences for CDSSs in hospital care for older patients. Consistent with our results, previous literature advised optimizing ADE documentation to minimize unintentional re-prescription of medications after discharge.[66] Also consistent with our results, previous studies already showed positive effects of CDSSs on the reduction of PIMs, reduction of the fall rate and on improving delirium care.[33,34,67–69]

This thesis showed that the scientific evidence on the factors influencing the success of CDSSs for older patients is sparse. Only one design factor (consideration of the workflow) was described more often in articles of effective interventions. This factor is in accordance with best practices in which workflow is seen as important factor for a potentially successful CDSS.[47,82,83] Other published reviews found more design factors.[38,42] The fact that we only found 1 design factor could be due to the relatively small number of 18 CDSS interventions supporting hospital care for older patients. We showed that FRAM is a useful tool to consider the workflow in the development of a CDSS. CDSSs fitting in the clinical workflow are more likely to be effective and more frequently used.[199,276]

Content - clinical knowledge

The quality of the clinical knowledge underlying a CDSS (knowledge base) is important for users and thus for the potential success and impact of a CDSS.[36,47,82,83,269] CDSSs should include “trustworthy evidence-based information” and “relevant and accurate decision support”.[37]

This thesis contributed to assessing the quality of clinical knowledge in a large Dutch observational dataset of older hospitalized patients (70 years and older). We identified 1) a high prevalence of potentially inappropriate prescribing (for both PIMs and PPOs), 2) an independent association between PIMs (according to two fall-risk specific and one general (de)prescribing tool) and in-hospital falls and 3) a performance of JHFRAT with a low AUC but stable over time. The PIM and PPO prevalence in our population were similar to the prevalence in other hospital settings. A systematic review described a PIM prevalence of 52% and PPO prevalence of 64% for 3,964 hospitalized patients (in 15 studies) using the STOPP/START v2.[120] Previous studies did show a relationship PIMs and falls during hospital stay, but were underpowered to assess an independent association.[153,277] Our results show that the association with inpatient falls was stronger for PIMs according to STOPP section K, compared to PIMs according to STOPPFall. This is reasonable as STOPP section K contains only high-risk medications and the STOPPFall is more comprehensive with medium- and high-risk medications. In our population, 2.7% of the hospital admissions had ≥1 fall. This prevalence is lower compared to the 5.9% - 6.4% observed in older inpatients in other studies.[15,16] We used real-world data from the EHR and possibly not all falls were recorded in the free text and/or our free-text search did not identify all falls. In studying the JHFRAT, one previous study reported a lower AUC (0.58) and four studies reported a higher AUC (0.69, 0.70, and 0.71), compared to our AUC (0.67).[170–172,183,188]

One of these studies conducted a sub-analysis for patients ≥65 years and reported a lower AUC of 0.61.[183] Differences in these AUCs might be explained for example by differences in timing of JHFRAT recording (we used the first score during admission, while others used the last score before the fall/before discharge) and differences in populations. Klinkenberg et al found a similar PPV of 4%.[171]

Content - relevant alerts

A systematic review on medication-related CDSSs stated that irrelevant alerts and information being not trustworthy were barriers of uptake of CDSSs.[238] A high clinical relevance of alerts could positively influence the effectiveness of a CDSS.[36,207,212] Our scoping review showed that most of the studies assessing quality of alerts reported outcomes describing the clinical relevance. The median clinical relevance of 13% (range 4-80%) found in our review is lower than the desired threshold of ≥89% described in the framework of Scheepers-Hoeks et al.[41] Two studies with machine learning as input reported a clinical relevance of 75% and 80%. In the literature it is stated that the clinical relevance improves with more patient characteristics, higher data quality and by selecting common clinical problems.[211,219,223,225,278]

Clinical implications & future research

<u>Geriatric areas</u>

(De)prescribing interventions

The high prevalence of potentially inappropriate prescribing (PIPs) in older hospitalized patients shows that this issue should be better addressed in clinical practice. Although prevalence decreased over 4 years after adjusting for patient characteristics, the prevalence was still high. A previous study showed relatively (in relation to the number of PIPs) infrequent deprescribing in a hospital setting.[279] Five clinical trials evaluated STOPP/START v1 interventions and described improvements in fall risk, medication appropriateness, costs and adverse drug reactions.[136] Studies demonstrating the added value of an electronic STOPP/START v2 on (de)prescribing are warranted. The next version of STOPP/START, version 3, is currently in development. Future studies and CDSS developers should incorporate this updated version and regularly update the content of CDSSs. We showed that PIMs are independently associated with in-hospital falls. Our results indicate that decreasing exposure to PIMs might benefit fall prevention. Future research should study the effect of an electronic (de)prescribing tool on in-hospital falls.

Automatic fall-risk screening

Clinical and administrative EHR data offer opportunities to automate fall-risk detection.[157,189] Currently, nurses screen all patients by manually filling in the JHFRAT. They prefer that information already known in the EHR would be automatically filled in.[160] Another possibility is to develop fall-risk prediction models based on EHR data. Previous studies described the validation of fall-risk prediction models, for example based on Bayesian networks, and demonstrated promising first results.[188,190,191] We recommend improving the fall-risk assessment tool, by automatically filling in information already known or by developing a fall-risk prediction model using EHR data. Improving the fall-risk assessment would limit the workload of nurses and increase the efficiency of fall prevention work processes.

<u>CDSS development</u>

FRAM for workflows

FRAM was very useful to identify and visualize preferred CDSSs in clinical workflows. We found that FRAM facilitated the discussion of user preferences and needs for CDSSs. Our study was innovative in showing how differences between work-as-done and work-as-imagined can impact CDSS design and how CDSSs could fit into the workflow. Previous research was done using process analysis methods such as UML activity diagrams.[101] We also used UML-activity diagrams but found FRAM to be more beneficial than UML-activity diagrams. These diagrams describe workflows only in a linear way, FRAM has more possibilities and can model non-linear healthcare processes. Future work has to be done to confirm whether FRAM is a useful tool for user-centered CDSS developments in other projects and to include patients in conducting a FRAM.

Quality of clinical knowledge

Evidence-based information in geriatrics often has a lower level of evidence due to underrepresentation of older patients in clinical trials and heterogeneous patient characteristics.[268,280] The clinical knowledge underlying a CDSS has therefore a lower level of evidence as well. More relatively healthy older people might be included in trials which can lead to population selection bias. EHR data is extensive and includes for example diagnoses, blood pressure, medications, and free text mentioning geriatric conditions. Using this routinely collected data, large populations and events can be studied without many research costs.[281]

Studies using EHR data might overcome the selection bias as all older patients admitted to the hospital are included. In this thesis, we showed that data from the EHR can be used to assess the quality of the clinical knowledge for a CDSS. Analyses using EHR data can identify common problems and patterns in the care for older hospitalized patients.

Data-driven CDSSs

It would be interesting to explore the possibilities of personalized (data-driven) CDSSs for older hospitalized patients. Data-driven methods, for example, machine learning or prediction models, typically analyze complex and large datasets and are promising as clinical knowledge for CDSSs.[272,273] Models based on these datasets may result in new findings and clinical patterns. CDSSs based on these models can potentially quantify the impact of patient characteristics, suggest individualized actions and make predictions on, for example, length of stay or treatment outcomes.[282–284] Data-driven CDSSs also have challenges, for example models as black boxes that hamper users' understanding.[272] Furthermore, the CDSSs do not integrate specific patients' concerns, life situations, or personalities and might impact the patient-physician relationship.[285] None of the clinical knowledge of the CDSSs included in the systematic review of chapter 8 was data-driven. Evidence regarding data-driven CDSSs is limited.[273] The two studies using machine learning as clinical knowledge in chapter 7 had however a relatively high clinical relevance. Cho et al reported a reduction on pressure ulcer prevalence and on ICU length of stay with a CDSS (not specifically for older patients) based on a Bayesian Network model.[274] More studies are needed on the development and possibilities of data-driven CDSSs in improving care for older hospitalized patients, taking the ethical considerations into account.

Relevance of CDSS's output

The assessment of this clinical relevance is important because high clinical relevance of alerts positively influence the effectiveness of a CDSS.[36,207,212] We showed that clinical relevance of alerts of CDSSs supporting medication review is generally low and that none of the studies reported the use of a CDSS validation strategy. The used methods and outcomes were heterogeneous. Future studies would benefit from following a systematic and comprehensive approach to assess clinical validation of CDSS's output.

CDSS effectiveness

Effect of CDSSs on geriatric conditions

This thesis showed that CDSS interventions have the potential to improve hospital care of older patients, mostly on process outcomes. Previous systematic reviews also reported sparse evidence on patient-related outcomes.[33,38,270,271] Possible reasons include logistical difficulties to conduct a RCT for CDSS interventions, indirect effect of CDSSs on patient-related outcomes, and short duration of studies.[38,245,271] However, another systematic review on CDSSs for inpatients did describe a relationship with patient-related outcomes.[269] Future studies assessing the effect on geriatric conditions should select outcomes directly affected by the intervention and include a large sample size. Geriatric problems are often complex and interventions to improve care of older patients can be complex as well. RCTs predominantly are used to study the effect of a (single) intervention such as a new drug. For a sustainable implementation, the Medical Research Council (MRC) framework for developing, piloting and evaluating complex intervention should preferably be applied to optimally develop and evaluate effectiveness of CDSSs in hospital care of older patients.[286]

Strengths and limitations

This thesis described the use of several methods. We used qualitative studies & surveys, etiological & prognostic research and systematic & scoping reviews.

The qualitative studies and surveys gave directions for which CDSSs were most wanted and needed as perceived by clinicians. These studies were time-consuming but prevented us from focusing on unwanted and therefore, by definition, ineffective CDSSs. By selecting FRAM as tool to study workflows, we added to the existing CDSS evidence and FRAM can quite easily be adopted to the development of CDSSs in clinical practice. A limitation was that patients were not involved. Patient participation and engagement could be beneficial for their perspectives on priorities and workflow. For example, previous literature showed that patient engagement was important in fall prevention.[102,103]

The clinicians wanted CDSSs supporting medication review and fall prevention. Evidence on the quality of the clinical knowledge to build these CDSSs were limited and partly expert-based. Data analyses gave us more insights into the quality of the clinical knowledge. This is a strength of this thesis as the quality of the clinical knowledge is important for potential CDSS effectiveness.

A major strength of our etiological and prognostic studies was the use of a very large (and growing) EHR dataset with hospital admissions and important confounders in the dataset. The limitations are related to the real-life EHR dataset and retrospective study designs. For example, we did not know whether clinicians did not STOPP or START potentially inappropriate prescriptions for clinical reasons such as side effects. Furthermore, the dataset included admissions of only one hospital. The results might, therefore, not necessarily be generalizable to other settings. For the development of CDSSs in other settings, it would be advisable to conduct similar data analyses.

By reviewing studies on CDSS effectiveness and on clinical validation of CDSSs, we could learn for our own CDSS development projects. A strength of the reviews was that we used broad and comprehensive search strategies. We used prior research on geriatric care, CDSS development, and implementation science to select geriatric topics, structure implementation and design factors and CDSS validation strategies. Limitations include that in both studies the extracted outcomes were heterogeneous and hence insufficiently comparable for quantitative analysis.

Conclusion

This thesis showed that CDSSs can improve hospital care for older patients, especially on process-related outcomes. Users and experts preferred CDSSs supporting discharge/aftercare, medication review, fall prevention and delirium care. Therefore, we focused on the development of CDSSs for the latter three domains and showed that 1) FRAM is very useful to identify differences between guidelines and actual care and visualize CDSSs in the workflow, 2) EHR data gives opportunities to assess the quality of clinical knowledge and identify common clinical problems, and 3) evidence of CDSSs on patient-related outcomes and of data-driven CDSSs is limited. We recommend exploring the use of FRAM, possibilities of EHR data and data-driven CDSSs in future developments of decision support in hospital care for older patients.