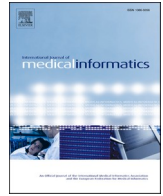


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Review article

## The effectiveness of clinical pathway software in inpatient settings: A systematic review

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## ABSTRACT

**Background:** Various studies have assessed the effectiveness of clinical pathways (CPs) in inpatient settings and provided systematic evidence that they positively affect patient outcomes and efficiency of care, thus lowering costs. In recent years, CP implementation is often combined or extended with clinical pathway software (CPS). Until now, no systematic literature review appears to exist which synthesizes the evidence on the effectiveness of CPS in inpatient settings, in relation to the CPs they support.

**Objectives:** The purpose of this study was to systematically review evidence on (perceived) effectiveness of clinical pathway software (CPS) and investigate mechanisms explaining the effects of CPS implementation on outcomes.

**Methods:** We searched MEDLINE via PubMed and Scopus, for English-language original articles. Articles were included if they examined the effectiveness and/or the perceived effectiveness of CPS in the inpatient setting. They were analyzed for evidence on structure, process and outcome effects, as well as for mechanisms explaining such effects in relation to contextual factors.

**Results:** From 2904 articles, 12 studies met our inclusion criteria. The seven studies reporting on adherence provide conclusive evidence that CPSs can improve adherence. We also found conclusive evidence of improvement of process related measures regarding appropriate diagnostics, timeliness of care, and length of stay (LOS). Evidence on costs and outcomes is weak and/or less conclusive. This holds true both for patient outcomes (e.g. mortality/patient satisfaction) and caregiver outcomes (e.g. user satisfaction). The studies presented no direct evidence on mechanisms explaining how CPS relate to process and outcome improvements.

**Conclusions:** The primary effects of CPS to increase adherence may in turn positively impact other process indicators such as LOS, timeliness of care, and diagnostic effectiveness. Subsequent effects on costs, outcomes for patients, physicians and nurses remain inconclusive and call for further research. Further research should explicitly take context into account. The scarce and weak evidence-base relating CPS implementation to process and outcome effects needs development along the same lines.

## 1. Introduction

Worldwide, healthcare providers seek to ensure safety, effectiveness and efficiency of care [1]. Many instruments and technologies have been developed to this purpose [2–4]. Clinical pathways form one of these tools. A clinical pathway is ‘a complex intervention for the mutual decision making and organisation of care processes for a well-defined group of patients during a well-defined period’ [5]. It defines essential steps in the care plan that a patient with a specific medical condition can undertake [6]. Clinical pathways have been implemented in hospitals across the globe [7,8]. Various studies provide evidence that clinical

pathways positively affect patient outcomes and efficiency of care, thus lowering costs [7,9,10]. According to the systematic review conducted by Allen et al. [11], clinical pathways can beneficially impact timeliness of clinical interventions, standardization of guidelines, documentation of care, inter- and intra-professional consensus, and variance of care.

Clinical pathways can be either paper- or software-based [12]. The paper-based method typically relies on manuals and forms on paper sheets, in addition to the patient records being kept [13]. Consequently, paper-based clinical pathways can result in more paperwork instead of simplifying daily routines for hospital staff, eventually hampering adherence and impact on effectiveness and efficiency of care [14,15]. As

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a remedy to such shortcomings, and as a natural development in the progression of Health IT, clinical pathway software has been developed to support clinical pathways and promote their benefits [16,17].

While the effects of clinical pathways in inpatient settings have been thoroughly reviewed [7] this is not the case for clinical pathway software. Recent reviews have addressed more general topics such as decision support systems for inpatients [18,19] and health information technology to support clinical pathways [20]. Thus, the evidence base on clinical pathway software effectiveness for inpatient care presently consists of a variety of results from case studies in different settings [16, 20–22]. Moreover, there is little understanding of the corresponding mechanisms that explain (lack of) effectiveness of clinical pathway software implementation. The purpose of this review is therefore to systematically synthesize the (perceived) effectiveness of clinical pathway software in inpatient settings and the underlying mechanisms.

## 2. Methods

### 2.1. Data sources and search query

Studies were identified by systematically searching MEDLINE (via Scopus and Pubmed) by using the following search query: (Critical OR clinical OR collaborative OR care OR integrated) AND (pathway\*) AND (software OR app\*) AND (inpatient OR hospital), and from the studies included in the review of the closely related review by Neame et al. [20].

### 2.2. Study selection and data extraction

For quality purposes, we only included peer reviewed international (English) journal articles as identified by the data sources and query above, published between January 2000 and January 2018. The review by Neame et al. [20] had a wider search focus and additionally searched Embase.

Further selection consisted of two rounds. In the first round, the search results were critically examined by reading the title and abstract, using the criteria depicted in Table 1. The full texts of the remaining studies were examined in the second round using the same exclusion criteria from Table 1. To further reduce the likelihood of missing relevant peer reviewed literature, the references of the included articles were screened to identify additional candidate articles (snowballing). The conducted systematic search, inclusion of articles from a recent review with a broader scope, and the snowballing, together with the peer review requirement reduce risks of not including relevant publications and of including publications which fall short of scientific standards. Consensus was reached in case of doubt by consulting a third author. Inter-rater agreement was measured by Cohen's kappa to determine the extent of agreement between two reviewers [23].

Using a structured extraction form, study characteristics (such as author, year, type of study, setting, number of patients, outcomes, and objectives) were extracted. Moreover, we collected data on the

**Table 1**

Exclusion criteria.

Not a scientific peer reviewed journal paper (no conference papers, abstracts, posters, book chapters, no grey literature).
Not in English.
Not a primary study (e.g. systematic reviews).
Not reporting outcomes (e.g. implementation studies).
Intervention is not restricted to implementation of (Clinical Pathway and) Clinical Pathway Software (e.g. studies which include other concurrent quality improvement interventions, as is the case when software is used to measure effects of other interventions).
Studies on software implementation for processes intentionally only covering part of 'the mutual decision making and organization of care processes for a well-defined group of patients during a well-defined period' (e.g. implementation of a safety bundle or a surgery checklist).

mechanisms explaining the results, to synthesis how clinical pathway software (henceforth also referred to as CPS) interacts with the clinical pathways (henceforth also CPs). An Excel file with all extracted data is available as an online Appendix.

### 2.3. Data extraction, analysis and synthesis

To gain a first understanding of the effectiveness of CPS, the results and conclusions of the included articles were evaluated. The studies were categorized by objectives and primary outcomes. To enable further understanding, we also collected information on the structures and processes – in particular the underlying CPs – in which the CPS was implemented.

The Structure-Process-Outcome (SPO) model of Donabedian [24] posits that the quality of the structure of the organization in which care is provided impacts the quality of the processes, and that each of these two impacts the quality of the outcomes. 'Structure' refers firstly to structural characteristics of the organization in which the CPS is implemented, such as the type of hospital, the existing IT infrastructure and the organizational structure. It may more widely refer to the health system context, e.g. in relation to financing or integration with primary care. 'Process' firstly refers to the patient and provider (inter)actions which form the health service delivery. Obviously, this process may be importantly defined by a CP. 'Outcome' explains the effects of care on patient health as well as outcomes for other stakeholders, in particular staff.

Through the lens of the SPO model, CPS implementation is an intervention in the information systems and hence in the structure of an organization. The objectives of this intervention are to improve the process of care (e.g. in terms of guideline adherence or costs) and subsequently the outcomes for patients (e.g. mortality) and staff (e.g. user satisfaction). The first part of the results section synthesizes effects on processes and outcomes resulting from CPS implementation. These results are organized using the high level SPO model. Given the current lack of understanding and evidence on clinical pathway software effectiveness, no further predefined models on measurement – for instance on outcome categories – were imposed. Instead data collection and synthesis proceeded inductively: we firstly extracted data as completely as possible, and then synthesized and structured findings when possible. Throughout, the study and context specifics are explicitly analyzed and reported, to prevent study biases from implicitly impacting synthesized results. Possible publication bias is addressed in the discussion section.

The second part of the methods and results are devoted to advancing understanding of the mechanisms explaining the outcome effects. These mechanisms (M) are important as it is well known that the effects (or Outcomes (O)) of intervention (I) vary with the context (C) in which they are deployed. The conceptual model relating these constructs is acronomously known as the CIMO model [25,26]. For instance, the effect of introducing a CPS may importantly depend on the presence of a pre-existing paper-based CP. We therefore collected data in the form of hypothesized and evidenced mechanisms from the introduction, results, discussion and conclusion sections of the included articles and synthesized the evidence on mechanisms found. This review is the first to explicitly consider pre-existing CPs as a contextual factor in the analysis.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist (PRISMA framework) was used as a guideline for the systematic review to ensure transparency and completeness of the report [27].

## 3. Results

The searches resulted in 2904 articles. After removal of duplicate articles, and title and abstract screening, 65 of these remained for full-text review, 6 of which were from the studies in Neame et al. [20]. After full-text review, 12 articles were ultimately included [15,22,

28–37]. The reasons of exclusion are mentioned in Fig. 1. Inter-rater agreement was substantial with a Kappa of 0.66 (P = 0.009).

The remainder of this section is organized as follows. First we describe reported results on processes for contexts with and without pre-existing pathways, and then on outcomes. Next we present results on mechanisms explaining the results for both contexts.

### 3.1. Study characteristics

Of the 12 included studies, six (50 %) [28–30,35–37] were published in 2015 or later, five (42 %) [15,31–34] from 2010 to 2014, and one (8%) [22] in 2006. From a geographical perspective, we found that six (50 %) were conducted in the United States [29,32,33,35–37], three (25 %) in Europe (Germany, The Netherlands and Italy) [15,22,34], two (17 %) in Asia (China and Korea) [28,31], and one (8%) in Canada [30]. The medical conditions considered range from diagnosis and treatment of acute conditions (stroke, pneumonia) to (end-stage) treatment of chronic conditions (heart failure, oncological conditions). Ten included hospitals were tertiary, university or teaching hospitals, one study was performed at oncological centers [35] and one study included a network of community and university hospitals [37]. Hence, there is considerable heterogeneity among the included studies, as also expressed in the number of cases/patients/participants which varies from 34 to 4700.

There were also differences in the Hospital Information Systems already in place, the use of EMRs, other related software, and implementation approaches. Only one study (Schuld) [15] reported on implementation of a CPS within already available standard software. Four studies evaluated the introduction of software in a context where a (paper-based) CPs was already in place [15,28,30,34]. The remaining eight studied interventions which simultaneously introduced a CP and supporting software [22,29,31–33,35–37]. In the latter studies, it is difficult to separate the effects of introducing the CP from the effect of introducing the CPS – if at all desirable. Hence, there are essential differences in the contexts and the interventions among the twelve studies

(see Table 2).

Below we present results following the SPO framework, while continuously bearing the heterogeneity in mind, in particular regarding pre-existing CPs.

Ten (83 %) [22,28–34,36,37] articles used before-after comparison. The before measures were often acquired retrospectively instead of being collected for the purpose of the study. The other studies were a cohort study and a cross-sectional study [15,35]. None of the studies adopted a randomized design.

There was also considerable heterogeneity among the research objectives and hence among the reported process and outcome indicators. Ten studies present quantitative results on process indicators (e.g. length of stay) [22,28–31,33–37]. Five report on patient outcomes (e.g. mortality) [22,29,30,33,36]. One study presents quantitative results on patient satisfaction [34]. Three studies present quantitative results on user satisfaction [15,31,32] (see Table 3). Taken together, all these forms of heterogeneity prohibit meaningful aggregation of quantitative results other than categorizing them, and we report accordingly below.

### 3.2. Evidence on process

#### 3.2.1. Adherence

Seven studies report on the process indicator adherence. All of the five studies reporting from a context without pre-existing CP report adherence to be high(er) after CPS implementation, however not necessarily in full. Brignole et al. [22] report that guideline adherence increased. Wilde et al. [33] report that adherence in the form of appropriate antibiotic therapy and de-escalating from unnecessary medication improved when CPS use was mandatory, yet reduced again when changed to be voluntary. Katzan et al. [29] report that already high guideline adherence was not significantly affected by CPS implementation. Gebhardt et al. [37] found differences in adherence between community and university hospitals, where the latter shows significantly more adherence improvement. Ellis et al. [35] simply report high

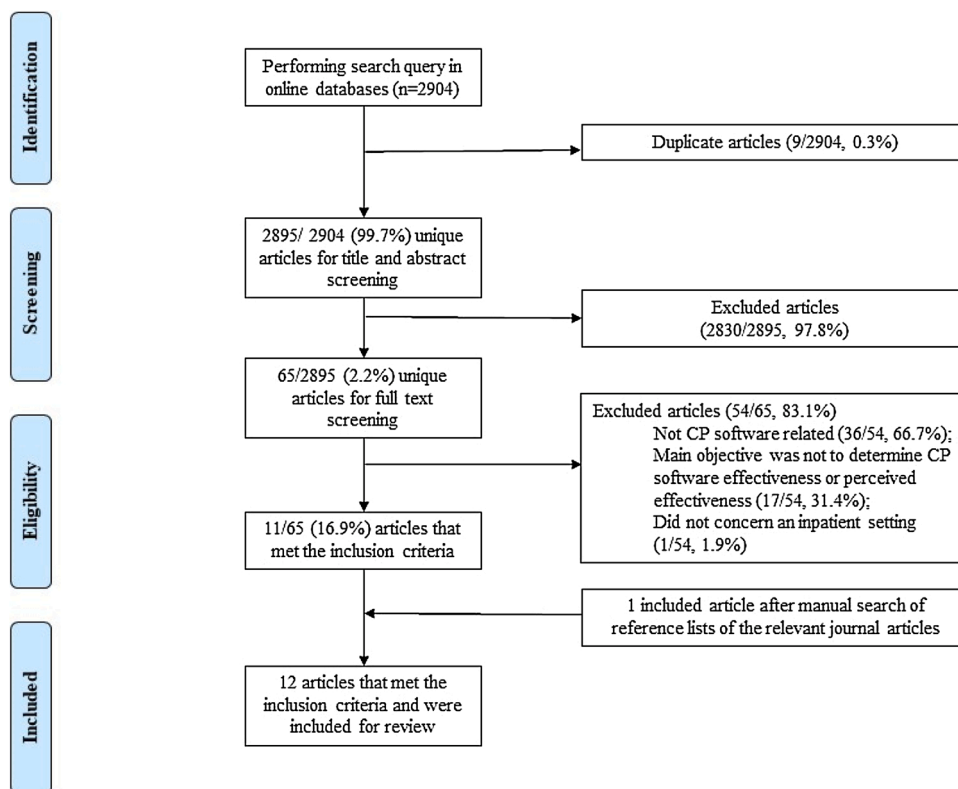


Fig. 1. Article selection flow diagram.

**Table 2**  
Study characteristics of included articles. LOS = Length of Stay, <sup>a</sup> = Pre: mandatory use of CPS, Post: voluntary use of CPS.

Author	Country	Study type	Department / medical condition(s) / participants	# of patients/ cases/ participants	Primary outcomes
Jackman et al. 2017 [36]	USA	Before-after	Stage IV non-small-cell lung cancer	370 (160 pre vs. 210 post)	Decrease in hospital charges after implementation of pathways; chemotherapy was the single largest contributor to these savings. Clinical outcomes remained consistent, with no significant difference in median overall survival.
Ellis et al. 2016 [35]	USA	Retrospective EMR review	Breast cancer	643	Adherence rates for included patients are 92.6 %, 96.4 %, and 87.5 % in the low-, intermediate-, and high-risk categories, respectively.
Wang et al. 2016 [28]	China	Before-after	Breast carcinoma, cataract, inguinal hernia, Diabetes Mellitus type 2	1773 (901 pre vs. 872 post)	After CPS implementation, the median total LOS decreased with 1–3 days. Total hospital costs decreased.
Gebhardt et al. 2015 [37]	USA	Retrospective interrupted time series trial	Bone metastasis	12,678 treatment courses	The overall rate of single-fraction treatment, as encouraged by the guideline, increased.
Katzan et al. 2015 [29]	USA	Before-after	Stroke	1106	Significant reduction in inpatient mortality as well as LOS in patients with ischemic stroke, but not in the control patients with intracerebral hemorrhage or subarachnoid hemorrhage.
O'Connell et al. 2015 [30]	Canada	Before-after	Head and neck free flap patients	256 (99 pre vs. 157 post)	No significant difference in LOS. Rate of major complications was significantly higher in the pre-phase, no significant difference in rate of minor complications.
Sung et al. 2013 [31]	Korea	Before-after	Supracondylar fracture of the humerus	122 (90 pre vs. 32 post)	Decrease in LOS and hospital costs. Significant increase in the satisfaction score of doctors, but no change in satisfaction of nurses.
Hyde et al. 2012 [32]	USA	Before- after	Medical-surgical department	34	Improvements in pathway documentation and staff satisfaction (regarding education patient, communicating patient information, documentation).
Wilde et al. 2012 [33]	USA	Before-after	Intensive care units (medical, surgical, neurotrauma)	136 (72 pre vs. 64 post) <sup>a</sup>	Proportion of patients with appropriate antibiotics within 24 h of diagnose was not significantly different when comparing mandatory use to voluntary use. Time to appropriate therapy was shorter for patients treated with CPS. Mortality was not significantly different.
Schuld et al. 2011 [15]	Germany	Retrospective survey	Surgical department staff	4700	After CPS implementation, knowledge of the aims increased significantly under nursing staff, whereas doctor's knowledge remained high. High satisfaction level on usability and graphical layout. Acceptability of CPS is independent from staff's computer knowledge.
Valente et al. 2010 [34]	The Netherlands	Before-after	Atrial fibrillation	600	Patient satisfaction rose significantly. Reduced walk-through times. Risk calculator and drug therapy recommendations were completed significantly better.
Brignole et al. 2006 [22]	Italy	Before-after	Syncope	1674 (929 pre vs. 745 post)	Significantly lower hospitalization rate, shorter LOS, fewer tests performed per patient. The mean cost per patient and per diagnoses were significantly lower.

**Table 3**  
Summary of process and outcome measures per study.

Author	Pre-existing CP / CPS	LOS Reduction	Cost Reduction	Time until treatment (waiting time)	Fewer Diagnostics	Adherence Improvement	Mortality Reduced	User satisfaction Improvement	Patient satisfaction Improvement	
		<b>Process</b>					<b>Outcome</b>			
Brignole [22]	No	Yes	Yes		Yes	Yes	No			
Sung [31]	No	Yes	Yes	For some treatment steps	Yes			For doctors		
Katzan [29]	No	Yes					Yes			
Wang [28]	No	Yes	For some conditions		Yes					
Hyde [33]	Yes									
Schuld [15]	Yes									
O'Connell [30]	Yes	No	Yes			Yes				
Wilde [33]	Yes	No		For some treatments		Yes	Yes			
Valente [34]	Yes			Yes		Yes			Yes	
Jackman [36]	No		Yes				No			
Gebhardt [37]	No					Yes				
Ellis [35]	No					Yes (without control)				

adherence after implementation without control.

From contexts with pre-existing paper-based CPs, Valente et al. [34] report an improved adherence, mostly in relation to timeliness of treatment steps, and Wang et al. [28] report improved guideline adherence with regard to pre- and peri-operative processes and drugs prescription.

### 3.2.2. Diagnostics

All three studies (100 %) which considered effects on diagnostics, such as laboratory tests and radiology examinations [22,28,31], reported a reduction in diagnostic testing in a context without pre-existing CP. These studies report the reduction to be related to improved adherence to guidelines in the pre-intervention situation and/or the avoidance of unnecessary and inappropriate diagnostics.

### 3.2.3. Length of stay

Six studies examined whether the implementation of CPS led to a difference in total length of stay (LOS) in the hospital [22,28–31,33]. O’Connell et al. [30] and Wilde et al. [33], who report from contexts where a CP was already in place and the interventions consisted of transitioning from paper based to electronic, did not find a significant change in LOS. It may be noted that both these studies report on relatively complex medical conditions. Wang et al. [28] found a significant decrease in LOS after the implementation of a CPS, as did the three studies [22,31,33] reporting from contexts in which no CP was implemented a priori. Sung et al. [31] found that pre-operative LOS increased, but post-operative LOS did not. Wang et al. [28] report a significant decrease in both.

### 3.2.4. Timeliness of care

Two studies assessed effects on timeliness [33,34]. Valente et al. [34] found significant improvements in timeliness of care for a pre-existing CP which includes outpatient episodes. Wilde et al. [33] report that the time to appropriate therapy was shorter for ICU patients with ventilator associated pneumonia following the CP supported by the CPS.

### 3.2.5. Costs

Four studies assessed the impact CPS implementation had on total costs of hospitalization [22,28,31,36]. Brignole et al. [22], Sung et al. [31], Wang et al. [28] and Jackman et al. [36] report that the total costs decreased after the implementation of a CPS. According to Wang et al. [28], this result was especially due to the LOS reduction. Brignole et al. [22] state that the lower costs were due to the lower admissions caused by CPS use and 24 % reduction in tests. Sung et al. [31] also reported that the laboratory and radiologic costs decreased significantly, which indicates a reduction of unnecessary medical practice. However, they found cost of materials to have increased significantly. By contrast, Jackman et al. [36] did not find a significant effect on cost of diagnostics, radiology (and a variety of other categories), yet reported a significant reduction in treatment cost (antineoplastics, radiation therapy). All of these studies regarded a context without pre-existing CP. Katzan et al. [29] are the only authors to mention the considerable investment required for the CPS development and implementation, without providing a specific amount.

## 3.3. Evidence on outcomes

### 3.3.1. Clinical and functional outcomes

Of the four studies which considered mortality, three are from a context without pre-existing CP. One of these three [29] report a significant decrease in mortality rate. The other two studies [22,36] found no significant effect. The fourth study [33] report a non-significant ( $P = 0.112$ ) increase resulting from switching from mandatory to voluntary use of the CP(S), while mentioning that the mortality originally decreased significantly when the CPS was introduced.

O’Connell et al. [30] report a significant reduction in major

complications but not in minor complications from a context with pre-existing CP. Katzan et al. [29] found no significant effect on functional outcomes such as activities of daily living (ADL) and physical activity in a context without pre-existing CP.

### 3.3.2. Patient satisfaction & experience

Valente et al. [34] reports an increase in patient satisfaction from 86 % to 91 % in the implementation phase compared to the development phase of the CPS in a context in which a care program was already in place, without reporting significance. According to the patients, the improved scheduling culture and the information provided about the care process were the major areas of improvement since the implementation of the CPS.

### 3.3.3. User satisfaction & experience

Katzan et al. [29] report that the perceived workload concerning the electronic medical record decreased in a context without pre-existing CP. Schuld et al. [15] and Hyde [33] evaluate the introduction of a CPS in a context of a pre-existing CP and report that the administrative workload remains time consuming but was expected to go down, resp. that nurses were more likely to experience an increased workload than physicians. From a context without pre-existing CP, Sung et al. [31] report likewise that user satisfaction among physicians increased significantly, while it did not for nurses. They report process facilitation to be an important perceived user benefit. The most important benefits of CPS as perceived by users from contexts with pre-existing CPs are standardization [15], process facilitation [15,32], cost-effectiveness [15] and prompting patient education [32].

## 3.4. Mechanisms

### 3.4.1. From structure to process to outcome

The introductions and discussions of the included studies present a wide variety of mechanisms explaining the effects the CPS implementation may have on care processes and outcomes. For instance, Hyde et al. [32] mention that ‘automating the patient care plan can promote collaboration among healthcare disciplines...promote continuity of care...and ultimately the patient and family’.

While all included studies refer to corresponding evidence when hypothesizing effects of CPS implementation, none appraise the validity of the evidence in their own context. Hence, the validity of proposed mechanisms remains unclear. Below we overview hypothesized mechanisms and synthesized indirect evidence.

The findings of Katzan et al. [29] suggest that CPS may not further improve already high adherence resulting from previous CP implementation. Conversely, Brignole et al. [22] consider prior diagnosis and treatment haphazard and unstratified, and (therefore) did find significant improvement in adherence. Like Gebhardt et al. [37] conclude that the existence of a guideline is not enough, because it may not be disseminated or implemented. Valente et al. [34] claim adherence improved because of the CPS implementation, which in their case involved provisioning of documents with guidelines and latest evidence.

The relevance of context in the relationship between the CPS intervention and the outcome adherence is illustrated by Gebhardt et al. [37], who found that the same CPS intervention that improved adherence significantly in academic hospitals, did not do so in community hospitals. Wilde et al. [33] provide interesting insight into potential lack of subsequent effects of processes on outcomes when reporting that adherence is significantly and positively associated with proper medication (process) yet not significantly with mortality (outcome).

Sung et al. [31] explore another commonly hypothesized mechanism regarding the care provided (process) and the corresponding cost. They relate a decrease in diagnostics and lab tests to a decrease in corresponding costs and an increase in material use and costs. Their evidence on costs is not empirical as costs are derived from the process measurements rather than being independently measured. O’Connell et al.



[30] report a reduction in major complications, which they propose to cause a reduction in LOS and subsequently of costs, without presenting data on LOS or costs. The cost reductions reported by Jackman et al. [36] are reductions in charges.

On satisfaction with using the CPS, Sung et al. [31] report that the increase observed for physicians may be caused by the standardization the CPS implementation brought among a number of participating hospitals, making the systems easier to use for residents. This mechanism does not apply to nurses, whose satisfaction did not increase.

Hyde et al. [32] and Valente et al. [34] both propose that the CPS may cause an increase in patient satisfaction as it reduces duplication of patient data provisioning, resulting in more time for personalized care.

### 3.4.2. Implementation

A technological organizational intervention such as CPS implementation is complex and may easily fail to achieve its objectives. Hence the results obtained not only depend on the intervention and the context, but also on the implementation. Valente et al. [34] point at the importance of communication skills for the project leader. Hyde et al. [32] emphasize that leadership buy-in is essential and that continued collaboration with clinical ancillary staff was of importance for their understanding. They posit that piloting helps to garnish such buy-in and support. They also discuss how, alternatively, the CPS may become a 'nursing document', instead of promoting integrated, patient-focused, multidisciplinary care.

O'Connell et al. [30] consider the acceptance by physicians to be the biggest challenge which can be addressed through user friendliness and perceived usefulness. Likewise, Jackman et al. [36] propose that unfriendly alerts may reduce adherence. They provide evidence that adherence improved when the software did not offer the option to deviate, or made deviations subject to peer review. Wilde et al. [33] find that adherence decreased when CPS use ceased to be mandatory and stewardship is undone. Lastly, Jackman et al. [36] conjecture that financial incentives may reduce effectiveness when adherence reduces provider income.

Schuld et al. [15] consider a stepwise implementation approach which involves key users and a steering committee, frequent interpersonal feedback and staff education as success factors. Jackman et al. [36] stress the importance of active physician collaboration. Valente et al. [34] supplement this view stating that it is important to communicate, evaluate, and keep everyone updated, and to remain firmly rooted in daily practice. A complication of piloting and stepwise approaches is pointed out by Hyde et al. [32]. They report that simultaneous reliance on paper and electronic forms of documentation during pilots can interfere with staff communication and workflow. Valente et al. [34] propose engagement of nurses as a success factor. Schuld et al. [15] emphasize that all professional groups must be involved in the implementation process and find the impact of nurses on success to be much larger than assumed.

## 4. Discussion

This systematic review relies on 12 publications to assess the effectiveness of clinical pathway software for inpatient treatment. The evidence base can therefore be characterized as scarce and it includes studies from very different contexts and from over a decade of technology advancement.

Ten of the included studies present results on process indicators: adherence, diagnostics, length of stay, timeliness, and costs [22,28–31,33–37]. Five studies report on patient outcomes: functional outcomes, clinical outcomes (such as mortality), and on patient/user satisfaction and experience [22,29,30,33,36]. None of the studies present direct evidence on mechanisms explaining how clinical pathway software implementation have produced these results within their various contexts.

Five studies addressing effects on adherence report improvements

[22,28,33,34,37]. The other two studies [29,35] report adherence to remain high after implementation. The improvements have been reported to depend on the clinical pathway software use being mandatory and to vary between academic and community hospitals.

Some authors propose that the access to and dissemination of guidelines and the latest evidence clinical pathway software provides, as well as transparency on adoption, positively impacted acceptance and adherence among physicians. Such findings however are just beginning to address the mechanisms explaining how clinical pathway software might impact adherence and by whom.

Adherence improvement is subsequently mentioned as a mechanism to drive further process improvement, as supported by evidenced on all process indicators which have been reported. Three studies reporting effects on diagnostics found reductions in diagnostic testing which closely relate to improved adherence [22,28,31]. Four studies reporting from a context in which no prior clinical pathway was implemented found a length of stay reduction [22,28,29,31], whereas the two studies reporting from a context with a pre-existing pathway did not find a significant effect [30,33]. The two studies reporting on timeliness of care also both report improvements [33,34].

The evidence on cost reduction is weak as the cost reductions presented are obtained via mechanistic reasoning. Moreover, none of the studies report on actual cost of clinical pathway software implementation. The importance of cost-effectiveness in today's healthcare warrants further research into costs effects and cost of software and implementation.

Effects on health outcome indicators regard the clinical outcomes mortality, major complications, minor complications, and the functional outcomes ADL and physical activities. Mortality is reported by four studies [22,29,33,36], only one of which found a significant improvement [29]. As improvement of health outcomes is often an important goal of clinical pathway software adoption, more and stronger evidence on health effects is called for, including the relevant mechanisms which explain how differences in software and context relate to outcomes obtained.

Evidence on patient and user experience is also scarce. Our synthesis may provide initial evidence that physicians experience clinical pathway software to be more beneficial than nurses, perhaps explained by a workload mechanism: nurses are more likely to end up with administrative burden increases [21].

Lastly, several authors make claims about the importance of the clinical pathway software implementation project being properly led and managed as a mechanism to explain achieving desired outcomes. The adopted research designs cannot produce evidence on these matters. For now the relevance of leadership styles, communication, engaging physicians and others, and taking a stepwise approach remain topics for further research.

Our study has some limitations: although our search was extensive and considered references checks, we may still have missed articles. Weakness of research designs of included studies forms a limitation that was also observed in a previous review with a broader pathway definition and technology scope [20]. Our narrowing of the scope enabled more specific and conclusive findings which distinguish between contexts with and without pre-existing clinical pathways. While our search identified additional literature, the resulting evidence base is small. The heterogeneity of the studies prohibited quantitative synthesis (e.g., in the form of meta-analysis). Lastly, it is likely that reported studies are biased towards successful implementations.

## 5. Conclusion

Our study provides evidence that a primary effect of clinical pathway software is to increase adherence towards higher levels. Increased adherence in turn positively impacts other process indicators such as length of stay, timeliness of care, and diagnostic effectiveness. Effects on costs remain unclear. Evidence on subsequent effects of process

improvements on outcomes for patients, physicians and nurses is inconclusive and calls for further research on mechanisms explaining how process effects relate to outcome effects. Likewise, the evidence-base on (mechanisms explaining how) implementation project characteristics relate to effects on process and outcome indicators is very scarce and needs development to promote effective implementation.

#### Summary Table

What was already known on the topic?

- a Software-based clinical pathways increase in popularity and are known to lead to several benefits in the hospital environment such as enhancing the efficiency on the work floor and providing better overview of tasks.
- b Insufficient research has been conducted on the effectiveness of software-based CPs in inpatient settings.
- c There is no understanding of the corresponding mechanisms that explain (lack of) effectiveness of clinical pathway software implementation.

What this study added to our knowledge

- a Our study provides evidence that clinical pathway software increases adherence and improves other process indicators such as length of stay, timeliness of care, and diagnostic effectiveness.
- b Evidence on subsequent effects of process improvements on outcomes for patients, physicians and nurses is inconclusive.
- c The evidence-base on (mechanisms explaining how) CPS implementation project characteristics relate to effects on process and outcome indicators is very scarce.

#### Author contribution

MA and JVDK designed the study. All the authors gathered the data. MA and JVDK drafted the paper. All authors revised the paper critically, and helped interpreting the results.

#### Transparency document

The [Transparency document](#) associated with this article can be found in the online version.

#### Declaration of Competing Interest

The authors report no declarations of interest.

#### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ijmedinf.2020.104374>.

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