Developing a Workflow Composite Score to Measure Clinical Information Logistics*

A Top-down Approach

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Clinical workflows, IT support, clinical information logistics, workflow management, composite score, validation

Summary
Background: Availability and usage of individual IT applications have been studied intensively in the past years. Recently, IT support of clinical processes is attaining increasing attention. The underlying construct that describes the IT support of clinical workflows is clinical information logistics. This construct needs to be better understood, operationalised and measured.

Objectives: It is therefore the aim of this study to propose and develop a workflow composite score (WCS) for measuring clinical information logistics and to examine its quality based on reliability and validity analyses.

Methods: We largely followed the procedural model of MacKenzie and colleagues (2011) for defining and conceptualising the construct domain, for developing the measurement instrument, assessing the content validity, pre-testing the instrument, specifying the model, capturing the data and computing the WCS and testing the reliability and validity.

Results: Clinical information logistics was decomposed into the descriptors data and information, function, integration and distribution, which embraced the framework validated by an analysis of the international literature. This framework was refined selecting representative clinical processes. We chose ward rounds, pre- and post-surgery processes and discharge as sample processes that served as concrete instances for the measurements. They are sufficiently complex, represent core clinical processes and involve different professions, departments and settings. The score was computed on the basis of data from 183 hospitals of different size, ownership, location and teaching status. Testing the reliability and validity yielded encouraging results: the reliability was high with $r_{pbl-half} = 0.89$, the WCS discriminated between groups; the WCS correlated significantly and moderately with two EHR models and the WCS received good evaluation results by a sample of chief information officers ($n = 67$). These findings suggest the further utilisation of the WCS.

Conclusion: As the WCS does not assume ideal workflows as a gold standard but measures IT support of clinical workflows according to validated descriptors a high portability of the WCS to other hospitals in other countries is very likely. The WCS will contribute to a better understanding of the construct clinical information logistics.

1. Introduction

Studies in health IT adoption, usage and impact often focus on structural features of quality, i.e. the existence of a certain IT system with dedicated functions. These features may serve as dependent or independent variable. However, structure is only one dimension of quality [1], a notion that has been widely accepted throughout health care. The other dimensions, i.e. process quality and outcome quality, are now coming increasingly into the view of evaluation studies [2, 3]. The questions addressed are: How can health IT contribute to the quality of clinical processes and to care outcomes? Before being able to answer these questions properly the type and manner of IT supporting processes and outcomes has to be clarified. With regard to processes the question then narrows down to: How can IT support of clinical workflows be measured?

Investigating workflow support widens the scope from IT support of individual tasks performed by a single person to IT support of entire care processes spanning teams, units, departments and institutions⁴. In this light, it is not only the type and number of IT systems installed, let
alone individual applications, but a chain of integrated and interoperable systems [4] that accompany the clinical workflows. Integration and interoperability hereby do not only refer to the technology used but also to the data and the information that is stored in the various heterogeneous systems and that steers the processes in routine care as well as in unexpected events. Process-aware information systems in health care therefore strongly depend on the access to the data sources [5, 6]. Integration and interoperability seek to bring together data, information and functions in one place and are an important prerequisite for mobility which furthermore aims at distributing data, information and functions to different places [7].

The notion of information transported from one node to another by information systems is captured by the idea of information logistics, which was first proposed by Lange [8] and later utilised to describe process phenomena [9]. It is a construct that is defined and assessed by the degree with which the user obtains exactly and on time the information needed for arriving at the right decision. In the ideal case, information logistics is built from the interaction of different constituents. It thus can draw on other concepts such as IT automation [10], IT sophistication [11, 12], system, information and service quality [2], which overlap with the idea of information logistics and which can stimulate its operationalisation. Consequently, IT support of clinical processes and the underlying concept of information logistics demand a measure that reflects its different constituents and amalgamates them into a composite score.

Such a workflow composite score (WCS) could serve different purposes in empirical studies – both as independent and dependent variable, for example for showing the effect of IT’ workflow support on care quality and efficiency or for identifying factors that foster health IT supporting clinical processes. As composite score it would help aggregating information and allowing comparisons over time and benchmarks between institutions and countries [13 –16]. Although composite scores are common in condensing and measuring IT related characteristics in health care (e.g. [2, 10, 16]), there is no composite score to our knowledge that specialises on clinical workflows, operationalises clinical information logistics and makes the construct measurable on a large scale.

It is therefore the overall aim of this study to propose and develop a workflow composite score (WCS) and to examine its quality based on reliability and validity measures. In detail, this study seeks to answer the following questions:

1) What is a valid framework for the standardised measurement of IT support of clinical workflows that can lead to the construction of a workflow composite score (WCS) and what is a suitable WCS inventory, in the sense of a useful structure and useful IT related features (short: features) based on this framework?
2) How reliable and valid is this workflow composite score?

2. Materials and Methods

2.1 Overview

In order to construct a workflow composite score we chose a top down approach that is largely orientated on the procedure of MacKenzie and colleagues [18] for building valid constructs. MacKenzie’s procedure resembles other methods for constructing scales and scores [13], but differs from them with regard to extracting dimensions or subdimensions. Table 1 shows the individual steps of this procedure that were applied in this specific context. The steps deviate from the original procedure with regard to the rank order of the pretest, which we performed before specifying the final model. We included a separate step for examining the reliability and omitted the last step of the MacKenzie process, i.e. the development of norms for the scale, because this would have required additional work that is independent from constructing and examining the score.

2.2 Definition and Conceptualisation (Step 1)

An in-depth literature review was carried out to find standardised instruments that measure IT usage along the clinical processes. In both cases the literature was searched in the databases Pubmed, Medline, ACM and AISel. We searched for articles in the timespan 2000 until 2013 and combined one or more keywords that described the technical field of interest (e.g. EMR system) and one or more terms that related to relevant methods (e.g. inventory, composite score or validity). The following keywords were used: hospital information system, clinical information system, health information system, EMR/ EHR system, inventory, questionnaire, validity, reliability, evaluation, composite score, composite index, workflow, process, information logistic, information management.

As we chose only studies that provided full information on the questions of the measurement instrument, the review resulted in five studies. The constructs were information technology sophistication, hospital information system quality, clinical information technology capability, meaningful use and level of eHealth. These constructs were broken down into several crucial attributes and were associated to various workflows (see Table A1 of the electronic appendix). In conjunction with the literature review, experts were asked to define the crucial attributes of the construct domain. Two chief information officers (CIO) of hospitals, one clinician and four medical and health informatics scientists were involved in these group discussions (see Table A2 of the electronic appendix).

The target construct underlying the literature study and the expert group discussions was clinical information logistics in the sense of potential clinical workflow support through information technology. It embraces the demand for “right information”, “right amount”, “right quality”, “right time” and “right place” [8]. The construct domain was explored with regard to functions, data, information and knowledge, integration and interoperability, mobility and external availability as well as other poten-

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a “It has been shown that HIT produces strong externalities, and it is highly plausible that a significant portion of the value of HIT is not captured by the entity that makes the investment. The benefit from information exchange between hospitals and practices can be significant” [17].
Clinical information logistics was compared with other constructs describing IT behaviour, i.e. performance, and IT skills, i.e. interoperability, in a general meaning.

The literature review and the group discussions led to the recommendation of the experts to describe the construct from the perspective of

- the data and information that are required to perform the tasks in the selected workflows,
- the functions and applications providing and processing these data and information,
- the level of integration and the capacity of interoperability among these functions and applications,
- the ability to disseminate (distribution) the data and information to different points of care and to health care professionals outside the own institution.

### 2.3 Development of the Inventory (Step 2)

Step 1 resulted in a framework that was utilised to develop the structure and the content of the inventory\(^b\). This framework embraced the following workflow descriptors. These are availability of data and information along the workflows, availability of workflow relevant functions and applications, depth of integration and skill for interoperability and capacity of data and information distribution via mobile devices and exchange platforms.

This framework was further refined with regard to specific clinical processes that are representative for patient care and that fulfil the necessary requirements for measuring the status of clinical information logistics in an institution. These requirements were: The process must belong to the core processes of health care organisations. It must be sufficiently complex. It must either span professions, departments or institutions/settings \(^{19}\). We chose the following sample processes that met these
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2.4 Assessment of the Content Validity (Step 3)

Content validity was examined in two phases. In a first round, the framework of workflow descriptors was assessed by a group of experts who searched the relevant literature (result from step 1) for sets of IT related features and checked in dependencies from each other whether these features could be assigned to the workflow descriptors. In a second round, the questions and the features captured by the questions in the inventory were evaluated regarding their relevance and completeness by a mixed group of 10 experts (Table 3). This assessment was based on the refined framework of the 16-cell matrix (Figure 1). During this process, adaptations and changes were made to the questions, their features and their allocation to the descriptor-workflow combinations.

2.5 Pretest (Step 4)

Once the questions were stable (result of Step 3) the inventory was implemented in an electronic form using Unipark online survey tool and was given to a group of 15 experts with the request for assessing the comprehensibility of the questions and the IT related features captured by these questions. In addition, the experts should test whether the digital version of the inventory was consistent and the overall structure and length were acceptable. The experts could enter their comments on the comprehensibility and feasibility into the online survey tool.

2.6 Model Specification (Step 5)

The model specification rested on the assumption that all workflow descriptors contributed equally to the entire workflow composite score and that no difference in the importance of the sample workflows was made. In other words, information logistics in ward rounds for example was not considered more important than information logistics in discharges with regard to the workflow composite score. Similarly, the workflow descriptor information and data for instance was regarded as important as the workflow descriptor integration. Furthermore, all cells were weighted equally, e.g. the combination of integration and discharge received the same weight as function and discharge.

The specification comprised the calculation of the weights necessary to compute the WCS and further scores on the level of the individual workflow descriptors and the workflows. The model specification was performed top down by a mixed group of experts (Table 3) and was based on the refined framework (Figure 1) and on the results of the content validity assessment (results of Step 3).

As Figure 2 shows the sum of all weights equalled 1. This total weight was...
evenly distributed to the 16 cells with a value of 0.0625 per cell. This distribution resulted in a weight sum of 0.25 for each workflow descriptor and for each workflow. Weights were given to features (e.g. "PC", "tablet", "notebook") not to questions (e.g. "in- and output devices") because they were the lowest level of information. These feature weights were calculated per cell by dividing the cell weight (0.0625) by the number of features in this cell. If for example four features captured the content of a certain descriptor-workflow-combination each feature had a weight of 0.0625/4 = 0.015625 (see example shown in the lower left cell of ▶ Figure 2). As certain features related to different descriptor-workflow combinations (see 2.3) their weight was calculated by the sum of the cell-specific weights per feature. We arbitrarily defined 40 points for the work-flow composite score. Following the scheme of weights we computed common imputation methods, in particular substituting the missing value by the measures of central tendency (medians or the modal values).

2.8 Examination of the WCS Reliability (Step 7)

We applied the odd-even method for splitting the inventory in two halves so that features from each of the workflow descriptor combinations were included. Split-half reliabilities [23] were computed for the WCS and for the workflow scores and the workflow descriptor scores. The split-half reliabilities were corrected using the Spearman-Brown formula [24]. All computations were performed using SPSS Version 21.

2.9 Examination of the WCS Validity (Step 8)

We started examining the WCS validity by checking the overall distribution of the WCS and testing the arithmetic means for differences in known-groups comparisons [18]. We hereby distinguished between hospitals of different size, ownership and teaching status. These characteristics had been found to influence the number and type of IT applications [25–27]. Internal WCS validity was tested on the level of the workflows by correlating the workflow scores with the subjective ratings of the CIOs on how well IT supported the four workflows. To assess the external WCS validity we assumed that electronic health records (EHR) are instruments that are in principle built to support clinical workflows (e.g. [17]) – among others purposes.

We therefore used two external EHR models to describe the degree of EHR adoption, namely the European Electronic-Medical-Record-Adoption-Model (EMRAM) [21] and the Electronic-Health-Record-Adoption-Model by Jha and colleagues [20]. We approximated these models according to the published descriptions and to the relevance of the IT related features for the clinical practice in Germany. As none of them could be used without modifications and as no proper publication existed in the case of EMRAM we called the two models EHR model 1 (modified EMRAM [21]) and EHR model 2 (modified Jha model [20]). Based on this starting...
position we allocated the IT related features captured by the questions in our inventory to the two EHR models. As the questions in our inventory were primarily derived from the HIMSS leadership surveys and the Jha model the allocation was straightforward. In the case of the Jha model we did not use the categories proposed by Jha and colleagues [20] but counted the number of applications available that met the criterion of the comprehensive EHR in order to yield a metric variable.

The WCS validity was finally examined by testing its practical usefulness in the context of IT benchmarks. To this end, 183 German hospitals that participated in the IT Report Healthcare survey (see Step 6) were approached with the request to evaluate the WCS. They had been given comprehensive material on their individual results with regard to the global WCS and its decomposition down to the feature level. Furthermore, their results had been visualised in comparison to the results of their reference groups [14]. They were asked to assess the usefulness and comprehensibility of the WCS on a 4-point Likert scale and the expected result of the WCS on a 3-point Likert scale.

3. Results

3.1 Research Question 1

“What is a valid framework for the standardised measurement of IT support of clinical workflows that can lead to the construction of a workflow composite score (WCS) and what is a suitable WCS inventory, in the sense of a useful structure and useful IT related features (short: features) based on this framework?”

This was answered in the steps 1 to 5.

First of all, results from assessing the content validity of the framework are presented (Table 2). These results were obtained by assigning the IT related features, which had been described in the various studies, to the four proposed workflow descriptors. The three experts involved agreed on the fact that all features in these studies could be mapped to the descriptors without exceptions. Hereby, the experts decided to assign the single features to one descriptor only, the primary descriptor. Pursuant to these allocations, all instruments put the greatest importance on the descriptor function. All other descriptors assumed various ranks of importance without indicating any preponderance.

These results showed that other approaches could be successfully mapped to the workflow descriptors and hereby gave evidence of the content validity of the framework.

The four workflow descriptors were then operationalised on the ground of the refined framework of the 16 cells matrix and its selected clinical workflows (Figure 1). A total of 92 features were captured that could be related to the global WCS and its inventory after the pretests. The 92 features that were captured by these questions were either related to only one descriptor and one workflow (specific feature), to several descriptors and one workflow (mixed features A) or vice versa (mixed features B) or finally to several descriptors and several workflows (general feature) (see Table A3 of the electronic appendix).

Assessing the content validity on the level of the questions and the features yielded agreement in two discussion rounds among the experts (Table 3).
Their judgment included both the allocation to the workflow descriptor – workflow combinations and the completeness of the questions and the features.

Based on the allocation of the features to the descriptor-workflow combinations and the matrix of weights (Figure 2), weights for individual features could be computed of which Table 3 shows some examples.

<table>
<thead>
<tr>
<th>Group characteristics</th>
<th>WCS $\bar{x}$ ± SD</th>
<th>Percentage within sample (absolute value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td></td>
<td></td>
</tr>
<tr>
<td>private</td>
<td>22.3 ± 5.9</td>
<td>18.0% (33)</td>
</tr>
<tr>
<td>public</td>
<td>23.6 ± 5.5</td>
<td>82.0% (150)</td>
</tr>
<tr>
<td>Size (number of beds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 to 399</td>
<td>22.3 ± 5.6</td>
<td>53.6% (98)</td>
</tr>
<tr>
<td>400 to 799</td>
<td>23.7 ± 4.4</td>
<td>30.0% (55)</td>
</tr>
<tr>
<td>800 and more</td>
<td>26.5 ± 6.2</td>
<td>16.4% (30)</td>
</tr>
<tr>
<td>Teaching status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no teaching hospital</td>
<td>22.3 ± 5.9</td>
<td>32.2% (59)</td>
</tr>
<tr>
<td>teaching hospital</td>
<td>24.2 ± 5.3</td>
<td>67.8% (124)</td>
</tr>
</tbody>
</table>

Table 4 Arithmetic means and SDs of WCS in known-groups comparisons ($n = 183$)

After having shown the content validity of the inventory, it was disseminated electronically (Step 5) with an overall response rate of 19.7% and with 183 being eligible for the computation of the WCS, i.e. having a surgery and an ICU department. The 183 hospitals belonged to all types of size and ownership and hospitals in all federal states were represented (Table 4). Workflow composite scores were computed for each hospital and resulted in a symmetric distribution with an arithmetic mean of 23.4 ($\pm 5.6$ SD) out of the 40 points and a range of 9.2 (lowest) to 38.0 points (highest value) (Figure 3).

3.2 Research Question 2

“How reliable and valid is this workflow composite score?”

3.2.1 Data Capture and Score Computation

The results of steps 6 to 8 contributed to answering the second research question.

3.2.2 Reliability Testing

Analysis of the split-half reliability for the WCS and the workflow scores yielded rounded Spearman-Brown coefficients between 0.72 and 0.89 (Table 5). Reliability coefficients of the workflow descriptor scores data and information and function were rather high with 0.98 and 0.89 respectively. There were only low reliability values for the workflow descriptor scores integration and distribution (Table 5).

3.2.3 Validity Testing

Validity of the WCS was tested in the first instance computing the differences in known-groups comparisons (Table 4). Workflow composite scores differed between public and private hospitals and between teaching and non teaching hospitals with higher values for public and teaching hospitals. The score also rose with increasing number of beds.

Testing internal validity through correlations between workflow scores and the subjective rating of IT workflow support quality resulted in coefficients from 0.49 to 0.44 for ward rounds, pre- and post-surgery (Table 6) and a low coefficient of 0.18 for discharge. The WCS correlated with the EHR model 1 at $r = 0.42$ and with the EHR model 2 at $r = 0.36$ (Table 6).

3.2.4 Evaluation

Finally, the WCS was validated by evaluation. Out of the 183 participating CIOs of hospitals, 67 responded to the evaluation.

Figure 3 Distribution of the WCS ($n = 183$ hospitals)
questionnaire (34% response rate). Over 4 out of 5 of the CIOs found the scoring model at least comprehensible and three quarters of them reported the WCS to be at least useful. A very large majority either expected or assumed the individual WCS result for their institution (▶ Figure 4).

4. Discussion

This study aimed at measuring the construct clinical information logistics via a workflow composite score and to our knowledge it is the first dedicated approach to reach this goal. Clinical information logistics was decomposed into the descriptors data and information, function, integration and distribution, which embraced the initial framework. It was validated by the comparison with published instruments during the course of this study. This framework was refined selecting representative clinical workflows that serve as concrete instances for the measurements. The four processes are sample processes, i.e. taken from the large "population" of processes. They were selected deliberately based on the criteria mentioned. Studying four core processes seems to be a good balance between depth-of-analysis and feasibility. There may be some variations in the clinical processes across hospitals and across countries. We therefore tried to reduce the complexity and differences of each of the four workflows to a similar pattern of requirements based on the descriptors data and information, function, integration and distribution that characterises each type of workflow.

The final framework was thus constituted by a 16-cell matrix. The primary assumptions of all descriptors and workflows contributing equally to the WCS were confirmed by the expert discussions. The incremental phases for constructing the WCS then lead to an accepted and usable inventory and its application in a sufficiently large sample.

The WCS is a measure that was symmetrically distributed in the sample with an average in the middle of its codomain. The WCS could discriminate between hospitals of different size, ownership and teaching status in a way that was congruent with what was expected from previous studies. Fonkych and Taylor [26] could show that the number and type of health IT systems available in the hospital increased with the size of the organisation. The same effect could be observed with teaching status in the sense that teaching hospitals had adopted more applications and functions [25]. It is also consistent with the literature that private hospitals had a lower WCS than public hospitals, which mirrors studies that showed lower adoption rates of clinical IT in private hospitals [27]. We can thus conclude that the WCS behaved in a well-predicted manner. The correlations of the workflow scores with the subjective ratings for the quality of IT support for these workflows lied in a medium range (between 0.4 and 0.5). Only one workflow, i.e. discharge, deviated from this result with a correlation of 0.2. A possible reason for the discrepancy between the discharge score and the rating is the different focus on what is important for discharge. Hospital CIOs might have been satisfied with IT discharge support even if their system did not provide a function to send clinical summaries outside the hospital. However, the missing communication with external health care providers contributed to low values in the score. Correlations between the global WCS and external criteria, i.e. the two EHR models, yielded moderate values of about 0.4. This shows that the WCS and the EHR models measure concepts that overlap but are not identical. We did not expect the correlations to be much

### Table 5  Split-Half Reliability – Spearman-Brown coefficients for WCS and workflow scores

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>number of features</th>
<th>number of features half A</th>
<th>number of features half B</th>
<th>Spearman-Brown coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCS</td>
<td>113</td>
<td>92</td>
<td>46</td>
<td>46</td>
<td>0.886</td>
</tr>
<tr>
<td>Ward round score</td>
<td>117</td>
<td>76</td>
<td>38</td>
<td>38</td>
<td>0.885</td>
</tr>
<tr>
<td>Pre-surgery score</td>
<td>144</td>
<td>53</td>
<td>27</td>
<td>26</td>
<td>0.885</td>
</tr>
<tr>
<td>Post-surgery score</td>
<td>145</td>
<td>60</td>
<td>30</td>
<td>30</td>
<td>0.722</td>
</tr>
<tr>
<td>Discharge score</td>
<td>143</td>
<td>59</td>
<td>30</td>
<td>29</td>
<td>0.886</td>
</tr>
<tr>
<td>Data and information score</td>
<td>146</td>
<td>41</td>
<td>21</td>
<td>21</td>
<td>0.977</td>
</tr>
<tr>
<td>Function score</td>
<td>144</td>
<td>37</td>
<td>19</td>
<td>18</td>
<td>0.885</td>
</tr>
<tr>
<td>Integration score</td>
<td>167</td>
<td>9</td>
<td>5</td>
<td>4</td>
<td>0.359</td>
</tr>
<tr>
<td>Distribution score</td>
<td>183</td>
<td>13</td>
<td>7</td>
<td>6</td>
<td>0.127</td>
</tr>
</tbody>
</table>

### Table 6  Testing internal and external validity (workflow rating were measured on a scale from 1 (very bad) to 5 (very good))

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>r</th>
<th>p</th>
<th>workflow score $\bar{x} \pm SD$</th>
<th>workflow rating Median (Q1–Q3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ward rounds: subjective rating and workflow score</td>
<td>180</td>
<td>0.489</td>
<td>&lt;0.01</td>
<td>$6.1 \pm 1.5$</td>
<td>3 (2.25–4)</td>
</tr>
<tr>
<td>Pre-surgery: subjective rating and workflow score</td>
<td>180</td>
<td>0.442</td>
<td>&lt;0.01</td>
<td>$5.9 \pm 1.4$</td>
<td>2 (2–3)</td>
</tr>
<tr>
<td>Post-surgery: subjective rating and workflow score</td>
<td>180</td>
<td>0.457</td>
<td>&lt;0.01</td>
<td>$5.9 \pm 1.5$</td>
<td>2 (2–3)</td>
</tr>
<tr>
<td>Discharge: subjective rating and workflow score</td>
<td>180</td>
<td>0.179</td>
<td>&lt;0.05</td>
<td>$5.3 \pm 1.5$</td>
<td>2 (2–2)</td>
</tr>
<tr>
<td>WCS – EHR model 1</td>
<td>183</td>
<td>0.419</td>
<td>&lt;0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCS – EHR model 2</td>
<td>183</td>
<td>0.364</td>
<td>&lt;0.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
higher because both EHR models primarily address IT functions. EHRs are meant to support clinical workflows but it is not their singular purpose. The evaluation results of the practical use of the WCS in the context of IT benchmarking give hint at the acceptance of the score in terms of comprehensibility, usefulness and expectation in the CIO community. Altogether, these different measures of validity act as pieces in a puzzle and contribute to the overall interpretation of the WCS to measure what it intended to measure. However, caution is still advisable because the WCS could not be correlated against a gold standard. This is because no such gold standard exists and the questions or subscales in other instruments that cover workflow issues could not be used in our validation because we did not include them 1:1 in our survey. Another point is the expertise required to give account of the quality of IT support of clinical workflow. Do CIOs have enough insight into the clinical world or is the clinicians’ judgment needed? We therefore believe it necessary to carry on the validation work.

Reliability measures of the WCS yielded highly satisfying results for the most, i.e. for the WCS as such, all workflow scores, and the scores for the workflow descriptors data and information and function. The split-half correlations for the workflow descriptors integration and distribution in contrast were rather low. This was probably due to the fact that not as many features covered these descriptors as compared to the other two descriptors. With a few features at hand splitting these subscale into two halves could have resulted in the two halves measuring different aspects of integration and distribution. More redundancy in the features in these descriptors seems desirable.

We chose a top-down approach in this study for decomposing clinical information logistics into its descriptors. This procedure provided valid results. A top-down approach, however, does not preclude a bottom-up attempt. Our next step therefore is to calculate confirmatory factor analyses and based on these results to consider additional exploratory statistical approaches when appropriate.

The procedural model proposed by MacKenzie and colleagues [18] provided a very useful framework for conducting this study and we did not exploit all possibilities by far. The purification and the refinement of the inventory and its questions is described in great detail and gives a reason to perform more in-depth analyses. Furthermore the model specification definitely needs additional studies. In our work, we specified an internal model, however, MacKenzie and colleagues [18] also have construct models on mind, i.e. models that reflect the complex network of antecedents and consequences of the construct measured. One of the crucial questions therefore is: What are factors influencing clinical information logistics and to which extent do they influence it? This question is closely connected with the adoption and usage rates of certain applications and functions and the respective promoters and inhibitors. This type of work has gained much ground in the wake of the Meaningful Use Program [e.g. 30, 31, 32]. A relevant question is also: What impact does clinical information logistics exert on health out-

Figure 4 Evaluation results
comes and on health care outcomes? This affects efficacy and quality of care, patient safety and patient-centred care in as much as cost effectiveness, efficiency and staff satisfaction – just to name a few endpoints. For both types of questions the WCS can serve as an important measure, in terms of an independent variable (predictor) as well as the dependent variable (criterion).

5. Conclusions

This study resulted in the proposition of a workflow composite score to measure the construct clinical information logistics. The score was tested for reliability and validity and encouraging results could be obtained that suggest the further utilisation of the WCS. This study presents the first but the most significant steps towards a WCS. As the construction followed a top-down approach the next step will be to validate the score in a bottom-up approach (e.g. with factor analyses). On top of that, the inventory might need to be refined in a limited way as described. The goal is to establish the WCS as a constant indicator for the IT support of clinical processes in German hospitals and beyond. As the WCS does not assume ideal workflows as a gold standard but measures IT support of clinical workflows according to descriptors validated by the international literature, a high portability of the WCS to other hospitals in other countries is very likely. One limitation and likewise a challenge might be the trade off between a most detailed and likewise a challenge might be other countries is very likely. One limited by the international literature, a high workflow validation study among Canadian hospitals, Int J Med Inform 2001; 63: 205–223.


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