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HIS-Monitor: An approach to assess the quality of information processing in hospitals

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ABSTRACT

Objectives: Hospital information systems (HIS) are a substantial quality and cost factor for hospitals. Systematic monitoring of HIS quality is an important task; however, this task is often seen to be insufficiently supported. To support systematic HIS monitoring, we developed HIS-Monitor, comprising about 107 questions, focusing on how a hospital information system does efficiently support clinical and administrative tasks.
Methods: The structure of HIS-Monitor consists of a matrix, crossing HIS quality criteria on one axis with a list of process steps within patient care on the other axis. HIS-Monitor was developed based on several pretests and was now tested in a larger feasibility study with 102 participants.
Results: HIS-Monitor intends to describe strengths and weaknesses of information processing in a hospital. Results of the feasibility study show that HIS-Monitor was able to highlight certain HIS problems such as insufficiently supported cross-departmental communication, legibility of drug orders and other paper-based documents, and overall time needed for documentation. We discuss feasibility of HIS-Monitor and the reliability and validity of the results.
Conclusions: Further refinement and more formal validation of HIS-Monitor are planned.

1. Introduction

Nowadays, it is hard to imagine health care without information technology (IT). The quality of information processing is an important factor for the success of health care institutions [1]. Good information systems can support clinical workflow in various ways and thus, contribute to a better patient care [2]. On the other side, insufficiently designed information systems can have negative effects on efficiency and quality of patient care [3]. Information processing in health care not only depends on computer-based tools, but also still relies to a large part on paper-based tools such as the paper-based patient record. Therefore, we understand hospital information systems (HIS) as the complete information processing and information storing subsystem of a hospital, including both computer-based and paper-based information processing tools [4].

Systematic management of information systems is essential, and the major tasks of information management comprise planning, directing and monitoring the hospital information system [4]. While planning and directing of information systems are well understood and supported (see, e.g. guidelines in [4] or [5]), monitoring of information systems is often seen as insufficient. Monitoring means to regularly analyse and supervise the quality of the HIS in order to promptly recognize weaknesses (such as technical problems, problems

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with data quality, information losses, low user acceptance, etc.).

In most hospitals, regular HIS monitoring activities using a quantified assessment of HIS quality are missing. One reason could be that standardized methods and tools for monitoring are missing. For example, hospital quality programmes such as JCAHO [6] or KTQ [7] only comprise few aspects of HIS quality. Other approaches such as software ergonomic standards (e.g. ISO 9241 [8]) focus only on computer-based tools and ignore the significance of paper-based tools. Projects developing requirement indexes such as Ref. [9] describe HIS functionality in a rather comprehensive form, but do not support the evaluation of quality, and also do not consider the effects of HIS on working processes.

Consequently, the objective of this research project was to develop and validate a comprehensive monitoring system to assess the quality of a hospital information system. This HIS monitoring system should support systematic, quantitative monitoring of HIS quality and the comparison of HIS quality between departments and institutions.

2. Development of HIS-Monitor

2.1. *Basic assumptions*

Based on a review of the available literature on HIS quality from, e.g. health informatics e.g. [10–12], business informatics (e.g. COBIT, [13]), information management theory [14,15], quality management and organisational science e.g. [16,17], accreditation programmes e.g. [6,7] and supported by informal interviews with representatives of IT departments and by our own experiences in the area of HIS assessment (see, e.g. Refs. [18,19]), the following basic assumptions guided the development of HIS-Monitor:

- HIS-Monitor should be a screening instrument of HIS quality. It should not show in detail HIS quality in a given well-defined situation, but rather describe HIS quality from a global point of view, i.e. comprising various areas, workflows and professional groups. It should allow comparison of HIS quality between areas, groups and points in time. This means that it must offer a quantitative score (consisting of sub-scores) of HIS quality.
- Quality can typically be split into quality of structure, quality of processes and outcome quality (according to Donabedian, [20]). We decided to focus on outcome-oriented quality criteria: how well do information processing tools support the clinical and administrative workflows. For example, aspects of structural quality of HIS (e.g. how many computers are used, what is the bandwidth of the network) seem insufficient to describe HIS quality—plenty of computer technology does not guarantee good information processing.
- The outcome of information processing, i.e. the quality of support of patient care, is well reflected by the definition of "information logistics" [21]: to make available the right information and knowledge at the right time and place in the right form to the right people, so that these people can make the right decisions. This definition contains the most important criteria for outcome quality for hospital information systems and should thus be reflected in the monitoring system.
- Clinical working processes are best supported when all information processing tools collaborate in an optimal way. From the point of view of the user, there is no difference *how* he gets, e.g. lab data—on paper or by the computer. The only importance is that this lab data is available when he needs it. This means the monitoring system must address both computer-based and paper-based information processing tools.
- HIS quality should be assessed with regard to the typical clinical and administrative workflows. Thus, the main process steps of patient care should be part of the monitoring system, to allow a context-dependent assessment (e.g. "how is the availability of lab data *during a ward round*"). For the first version of HIS-Monitor, we decided to focus on direct patient care, excluding, e.g. research and education as well as all supporting processes such as facility management, financial accounting, etc.
- HIS quality, defined as the fulfilment of certain criteria in a given clinical or administrative workflow, can best be assessed by asking those people involved in this workflow. Whether an HIS is seen as "good" or "bad" can only be answered from the point of view of the stakeholder groups directly involved. These involved staff members are the real experts of HIS quality because they alone can tell how well they are supported by the various information processing tools in their daily working activities. (We will discuss this critical decision in Section 5 in more detail).
- Based on the previous assumption, a survey approach using a questionnaire seems to be best suited to assess HIS quality. A questionnaire allows the involvement of a large number of participants and a quantitative presentation of results to support screening of HIS quality.

2.2. *Structure of the HIS-Monitor questionnaire*

Defining HIS quality as answer to the question how good patient care activities are being supported by the information processing tools we developed the monitoring system by using two axes: axis 1 defines the most important patient care activities and axis 2 refers to most relevant criteria to assess HIS quality.

We defined the following major *process steps of patient care* as first axis:

- P1 Patient admission (e.g. administrative and clinical admission)
  - P1.1 Appointment scheduling.
  - P1.2 Administrative admission.
  - P1.3 Clinical admission.
- P2 Decision-making, planning and organisation of treatment (e.g. care planning)
  - P2.1 Presentation of patient-related information.
  - P2.2 Care plan management.
  - P2.3 Resource management.
- P3 Order entry and communication of findings

- P4 Execution and documentation of diagnostic and therapeutic tasks
  - P4.1 Execution of diagnostic and therapeutic tasks.
  - P4.2 Documentation of diagnostic and therapeutic tasks.
- P5 Patient discharge and transfer to other institutions
  - P5.1 Clinical discharge.
  - P5.2 Administrative discharge.

The quality of process support can be investigated with regard to the following major outcome-oriented *quality criteria*:

- Q1 Availability of information.
- Q2 Correctness and completeness of information.
- Q3 Readability and clarity of information.
- Q4 Usability of information (e.g. performance of statistical analysis of patient data).
- Q5 Fulfilment of legal regulations (e.g. data security).
- Q6 Time needed for information processing.

We then developed concrete questions for HIS quality by crossing the process steps with the general quality criteria. For example, the "availability of information" (Q1) during the process step "order entry and communication of findings" (P3) (Q1 × P3) can be assessed by questions such as "How easily can an overview on new lab findings be obtained during a ward round?". From the large number of potential questions, we selected the most significant ones in a step-wise development and evaluation process (see below). Fig. 1 summarizes the main structure of HIS-Monitor.

2.3. *First pretests of HIS-Monitor*

The resulting 165 questions were refined step by step and optimized based on several pretests.

2.3.1. *Pretest to check relevance, completeness and comprehensibility of the questions*

First, we checked relevance, completeness and comprehensibility of the questions by conducting informal interviews with representatives from information management (e.g. CIOs) and from various clinical user groups. Twelve interviews, each lasting for 1 h were conducted in summer 2004. Four nurses, two physicians, one co-therapist and five IT staff members from two hospitals in Germany and Austria were interviewed.

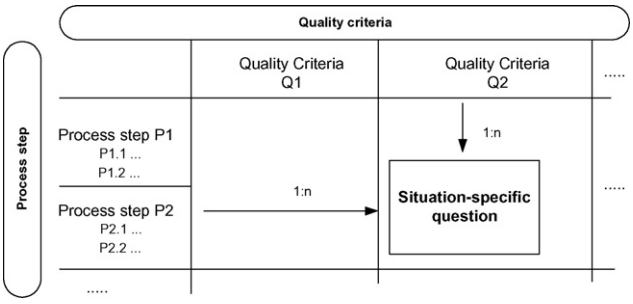

Fig. 1 – General structure of HIS-Monitor. Questions to assess HIS quality were developed for each process step by choosing relevant quality criteria and defining one or more situation-specific questions.

They were asked about the relevance, completeness and comprehensibility of the HIS-Monitor questionnaire. Comments and suggestions were used to refine the questionnaire, e.g. to reword some questions and situations in a more concrete way. The interviews showed that it would be helpful to know whether the staff members use a computer-based or paper-based tool for a given task, in order to assess validity of responses. This aspect was supplemented by adding the "type of tool used" in the questionnaire (see Fig. 2).

Altogether the feedback was positive both from the clinical staff and the IT-experts. In particular the chosen way of asking questions on HIS quality of various user groups was supported—it seemed very plausible for the asked staff members that their 'subjective' view is used to measure the quality of HIS.

The results also lead to the decision to use a written questionnaire as basis for HIS-Monitor. The interview partners confirmed that a written survey (instead of interviews) is possible as the questions are sufficiently clear. A written survey also has the advantage that a larger number of people can be asked, supporting the idea of a screening instrument. To support this, a one-page instruction was added to the questionnaire.

2.3.2. *Pretest to check feasibility of the written questionnaire and its instruction*

We then applied the monitoring system as anonymous questionnaire on six units of two hospitals (two surgical wards, one internal ward, one psychiatric ward, one inpatient and

P4.2 Documentation of diagnostic and therapeutic tasks

Imagine: You have already carried out diagnostic or therapeutic tasks for one of your patients and now want to document them. Please think especially about the information processing tools that you use for the documentation and also consider efforts for finding/accessing the tool (e.g. patient record, computer).

			tools that are predominantly used	bad seldom not adequate			good frequently adequate
1.	How easy is it for you to get an overview which tasks already have been carried out?	O this question does not apply to me	O paper-based O IT	- -	-	+	+ +
2.	How often does it happen to you that tasks are not completely documented?	O this question does not apply to me	O paper-based O IT	I	II	III	IIII
3.	How adequate do you consider the time needed to complete the necessary documentation?	O this question does not apply to me	O paper-based O IT	- -	-	+	+ +

Fig. 2 – Extract from the HIS-Monitor questionnaire.

one outpatient unit of a dermatology clinic), to check the feasibility of the survey approach, the time needed to fill in the questionnaire and to check comprehensibility of the instruction.

The respondents were informed on the fact that this pretest had as main objective the further optimization of the questionnaire. Respondents were asked to mark those questions they found unclear or too complicated. Altogether, 39 questionnaires filled in by nurses and physicians could be recollected and analysed. Time needed to complete was around 30–40 min for one questionnaire. Feedback was used to reformulate certain questions, to shorten the overall questionnaire and to optimize the instructions. In addition, several general questions on demographic data and overall satisfaction with the tools used were added.

A feedback was that some questions were formulated in a rather general form, not directly reflecting the personal experience of the respondent. Here, we have to balance the need for rather general questions (that should be applicable in various clinical settings) and the need for appropriately concrete questions. We tried to support this by outlining very clearly at the beginning of each section a clinical situation (e.g. order entry) that the respondent should imagine before answering a question (cp. Fig. 2). We discussed the possibility to shorten the questionnaire by reducing those steps that were not relevant in a certain department (e.g. administrative patient discharge in an outpatient unit). However, this would mean that the relevant questions must be selected individually at the beginning of a survey, increasing preparation time and also reducing comparability of results. Instead we offered a field "This question does not apply to me", allowing the respondent to omit certain questions.

2.3.3. *Pretest to check homogeneity of the questions*

The number of respondents in the first pretest was too low to calculate reliability (e.g. Cronbach-alpha (Cronbach-α)). However, as a first indication on homogeneity of responses, we calculated the variances of the answers in different departments. Here we assumed that the answers of respondents will be homogeneous if the setting they are working in is also homogeneous. Analysis showed that, e.g. the mean deviation from the mean value for process step "order entry" in a dermatologic outpatient unit was 0.62 ($n = 8$) and in a psychiatric ward 0.67 ($n = 9$), while the overall deviation from the mean for all respondents was higher with 0.78 ($n = 39$).

As overall result of those pretests, a first version of the HIS-Monitor questionnaire and the corresponding HIS-Monitor toolbox were completed.

3. HIS-Monitor—a questionnaire and toolbox to assess HIS quality

3.1. *HIS-Monitor questionnaire*

The questions of the HIS-Monitor questionnaire are to be answered by those staff members who are involved in a given process step. The questionnaire is, therefore, to be applied on a representative sample of various stakeholder groups such as physicians, nurses and administrative staff. As not all questions are of relevance for all professional groups, various subversions of the instrument are available, e.g. for nurses, physicians and administrative staff. Each question can be answered on a standardized 4-point Likert scale (see Fig. 2).

We defined four different types of questions with specific answering categories, namely:

1. "How easy it is for you to …", "How well do you feel supported …"—answer categories from "bad" to "good".
2. "How adequate is …"—answer categories from "not adequate" to "adequate".
3. "How often does it happen…"—answer categories from "seldom" to "frequently".

HIS-Monitor comprises 107 questions. Of these 107 questions, 77 are to be answered by nurses, 81 by physicians and 20 by administrative staff. The questionnaire is organized according to the process steps, starting with questions on patient admission, followed by questions on patient treatment, etc. until patient discharge. Each process step is first introduced with a situation description (cp. Fig. 2), helping the questioned person to imagine the quality of information processing in a given clinical situation. We added general questions on demographic data, overall motivation for documentation, IT skills, overall satisfaction with the information processing tools used as well as a detailed instruction. A special emphasis in the instruction and in the situation descriptions is put on the fact that the questionnaire does not address IT aspects only, but all information processing tools used in the various situations.

3.2. *HIS-Monitor toolbox*

To support the use of the questionnaire, an HIS-Monitor toolbox was developed to generate the questionnaires for the different professional groups and to support the following functions of data entry and data analysis:

(a) Administration of questionnaires
  (a1) Definition and management of questions.
  (a2) Building and management of group-specific questionnaires.
  (a3) Management of various versions of a questionnaire.
(b) Data entry: Entering of the results of a questionnaire study.
(c) Data Analysis
  (c1) Presentation of study results, i.e. descriptive values and histogram for each question.
  (c2) Aggregation of HIS quality results, e.g. by each process step, by each professional group, by each department.
  (c3) Data export to support further statistical analysis

Fig. 3 presents an example of the descriptive data analysis offered by the HIS-Monitor toolbox. Results are presented in histograms whereby answers indicating a "good" HIS are coloured in green (light or dark green) and answers for a "bad" HIS in red (light or dark red). Mean values are calculated using the coding "1" and "2" for a "bad" HIS, and "3" and "4" for a "good" HIS.

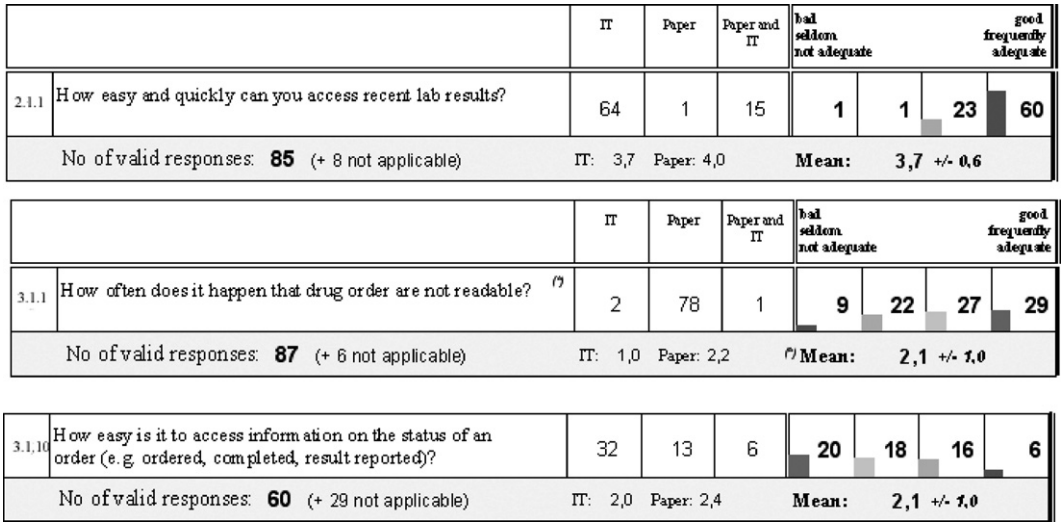

Fig. 3 – Example from the descriptive data analysis of the HIS-Monitor tool (three questions from different parts of the questionnaires are presented). For each question the mean value is indicated as well as the number of respondents using computer-based tools ("IT"), paper-based tools ("Paper") or both.

4. Feasibility study of HIS-Monitor

4.1. *Study design*

To check feasibility, validity and usefulness of the HIS-Monitor questionnaire in a larger real-life context, a feasibility study was conducted in the Department of Internal Medicine and the Department of Surgery of a university hospital in Austria. We decided to start by evaluating the nursing subset of HIS-Monitor, as nurses are the largest professional group in a hospital. The questionnaires were distributed by nursing managers in their specific wards and re-collected in anonymous collection boxes. Altogether, 150 questionnaires were distributed among the 400 nurses of the Department of Surgery, and 100 questionnaires were distributed among the 300 nurses of the Department of Internal Medicine.

Feasibility was checked by analysis of the return rate as well as looking for questions with high non-replies, as this may indicate unclear wording or a too long questionnaire.

Reliability means how reliable HIS-Monitor measures HIS quality, that is how reliable it measures the quality of support of clinical process by information processing tools. Reliability of HIS-Monitor was checked by the standard calculation of Cronbach-α for each process step. For calculating Cronbach-α, we removed those items where more than 40% of respondents answered "does not apply to me". As both departments differ in clinical processes as well partly in the used information processing tools, Cronbach-α was calculated independently for both departments. However, even the tools used within *one* process step in *one* department may vary depending on the respondents (e.g. a nurse in one unit may use other tools for patient scheduling than a nurse in another unit), and this may be reflected in heterogeneous responses.

Validity can generally be checked by comparing the results with an external value (criterion-related validity). In our case as there is no external value for the overall HIS quality; therefore, we took the subjective impression of nursing management as basis. We first asked nursing management on the expected results (e.g. which process steps are well supported, which not?). From this we condensed some results we would expect:

1. We expect HIS quality in the Department of Internal Medicine and in the Department of Surgery to be comparable, as the tools used and the workflow are mostly comparable (with two exceptions, see below).
2. We expect that HIS quality in sub-units may show differences, as the individual workflow and staffing and that the use of tools may be different.
3. We expect that HIS quality within the process step of nursing documentation will be higher in the Department of Internal Medicine than in the Department of Surgery, as in this field, the Department of Internal Medicine is advanced (even when using mostly the same paper-based tools).
4. In the Department of Surgery, three major computer-based tools are used for patient administration, workflow management and documentation. Those tools are not well integrated, leading to double documentation and unnecessary efforts; this should be reflected in the HIS-Monitor results.

Those expectations were then compared to the real results.

Usefulness was checked by analysing the results of HIS-Monitor in detail, by summarizing major results on strengths and weaknesses of information processing and by discussing those results in informal interviews with nursing management.

4.2. *Study results*

For each item of the questionnaire, the distribution and the mean were calculated for both departments. The detailed result report (in German) is available from the authors. There are no results presented for the process step P1.1 (schedul-

Table 1 – Calculations of Cronbach-α for the Department of Surgery ($n = 56$ respondents) and the Department of Internal Medicine ($n = 41$ respondents) with regard to process steps P1.2–P5.1

	Department of Surgery		Department of Internal Medicine	
	Cronbach-α	Number of items	Cronbach-α	Number of items
P1.2	0.50	5	0.53	5
P1.3	0.82	11	0.61	7
P2.1	0.55	17	0.57	17
P2.2	0.47	9	0.59	9
P3	0.62	8	0.69	10
P4.1	0.88	2	0.85	2
P4.2	0.33	6	0.35	6
P5.1	0.49	2	0.40	2

ing) and for the process step P5.2 (administrative discharge) as both are mostly not conducted by nurses in the respective departments.

4.2.1. *Feasibility of HIS-Monitor*

After 4 weeks, 102 questionnaires were returned, 93 of them being sufficiently complete for analysis, giving a return rate of around 37% with regard to the distributed 250 questionnaires. This return rate indicates a general feasibility of the chosen approach of a written survey. There was no question with unexpected high non-replies. Some questions were only answered by a lower number of respondents, partly being explained by the fact that the corresponding process steps did not apply to many nurses (e.g. scheduling of inpatient visits is only relevant for less than half of the nurses). However, this partly pointed to some questions that were not clear enough; those questions were reformulated or dropped. Eleven questionnaires were returned incompletely filled in, and there was some feedback on the length of the questionnaire and that some questions are not relevant for most nurses (e.g. questions on administrative discharge). This feedback will be used to further remove or combine certain questions and to re-check the distribution of questions to different user groups.

The selected 4-point-scale seems to allow a differentiated answering of the questions: the histograms show distributions over the complete scale and also show clear tendencies of the staff members assessing either "good" or "bad" HIS quality in the specific item (cp. Fig. 3).

4.2.2. *Reliability of HIS-Monitor*

As planned, reliability was calculated based on those items which have been answered by at least 60% of the respondents. Altogether, the analysis included 60 items in the Department of Surgery and 58 items in the Department of Internal Medicine. Results are presented in Table 1. Reliability of most scales is medium, without much difference between both departments. An analysis of inter-item correlations did not point to items that should be removed.

When interpreting reliability, we have to take into account that in each department, both the clinical processes as well as the used information processing tools can differ between several units, and therefore the answers may be rather heterogeneous. For more detailed analysis in future pilot tests, we need a detailed documentation of the tools used within each process steps, as that was not done in this first feasibility study. The low reliability of P4.2 cannot be explained based on the available data and needs further investigation.

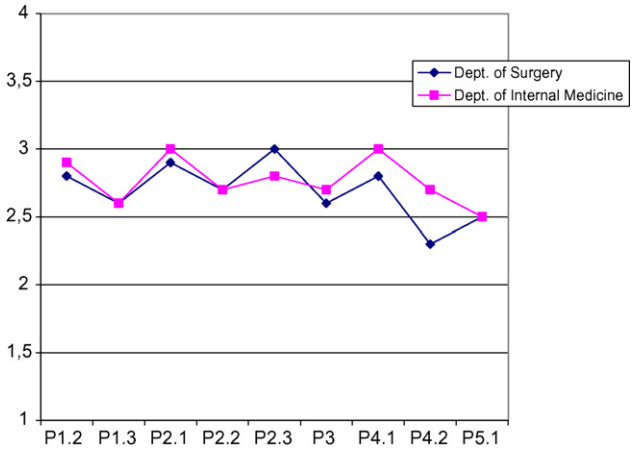

Fig. 4 – Analysis of mean score for the Department of Surgery ($n = 56$) and the Department of Internal Medicine ($n = 41$) with regard to process steps P1.2–P5.1 (for content of process steps, see Section 2.2). Higher values indicate "better" information processing. Range of standard deviations: Department of Surgery 0.33–0.94, Department of Internal Medicine 0.37–0.9.

4.2.3. *Validity of HIS-Monitor*

As expected, HIS quality in the Department of Internal Medicine and in the Department of Surgery were rather comparable. Fig. 4 shows the aggregated analysis of mean scores for each process step for the two departments. The mean values were calculated using the code "1" for the most negative answer (e.g. inappropriate, frequently) and "4" for the most positive answer, thus higher values indicate a "better" quality of information processing.

As expected, HIS quality scores between sub-units showed some differences, however, not as big as expected. Fig. 5 shows the results of a larger inpatient unit and a larger outpatient unit of the Department of Surgery.

As expected, HIS quality in the context of nursing documentation was higher in the Department of Internal Medicine than in the Department of Surgery (Fig. 6).

Finally, the insufficient integration of the computer-based tools within the Department of Surgery was reflected in the results, as expected. For example, the question "P1.2.6: How often do you have to document patient data multiple times during patient admission?" showed a mean of 2.4 in the Department of Surgery (and 3.0 in the Department of Internal Medicine).

4.2.4. *Usefulness of HIS-Monitor*

HIS-Monitor should give an overview of major strengths and weaknesses of information processing in the sense of a

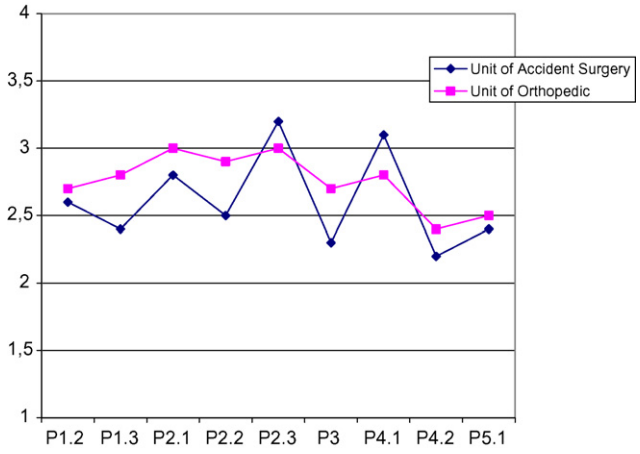

Fig. 5 – Analysis of mean score for the outpatient Unit for Accident Surgery ($n = 8$) and the inpatient Unit for Orthopedic ($n = 8$). Range of standard deviations: unit for accident surgery 0.35–0.69, unit for orthopedic 0.32–1.07.

screening. A detailed analysis of the results showed that in the majority of questions, the quality of HIS was judged as positive (indicated by larger green bars in the histograms, see Fig. 3). However, for the following questions, there were more "negative" than "positive" estimations. For this analysis, both the two negative answers and the two positive answers were combined. Mean values are calculated using the coding "1" and "2" for a "bad" HIS, and "3" and "4" for a good HIS.

- The answers highlighted some problems with regard to the availability of information from other organisational units, e.g. during clinical admission. Up to 55% (36 of 66 valid answers) of respondents indicated to have problems when they want to access information especially from other departments (to assess earlier information from his or her own department was not seen to be as problematic). Those who indicated mostly using computer-based tools answered slightly more positive (mean = 2.5, $n = 32$) compared to those who used paper-based tools (mean = 2.2, $n = 10$) (the others did not indicate the tool used).
- The readability of paper-based examination results was judged by 63% (54 of 85) as insufficient or very insufficient. The readability of paper-based drug orders was judged as problematic by 53% (45 of 85), and 66% (54 from 82) indicated that changes of drug orders were often unclear documented.
- 69% (50 of 72) indicated not to be well supported in the early detection of medication errors during order entry, and 58% (38 of 66) indicated not to be well supported in the prevention of unnecessary double examinations, comparable both for paper-based and computer-based support.
- Finding and booking free time slots for diagnostic or therapeutic examinations (e.g. X-ray, physiotherapy) that have to be ordered in other departments was seen as cumbersome by 56% (32 of 57) of respondents, also comparable both for paper-based and computer-based support.
- 63% (38 of 60) indicated to have problems to get quick information on the status of a recent examination order (e.g. X-ray-order is given, examination has begun, examination is completed, results have been transmitted). Here the judgement of those users supported by computer-based tools was better (mean = 2.0, $n = 32$) than those mostly supported by paper-based tools (mean = 2.4, $n = 13$). The others either did not give the type of tools used or said to use both.
- 71% (60 of 85) found the time needed for nursing documentation (mostly supported by paper-based tools) as partly inadequate or very inadequate, and 65% (54 of 83) complained about the frequent need to transcribe information (e.g. from one nursing plan to another).

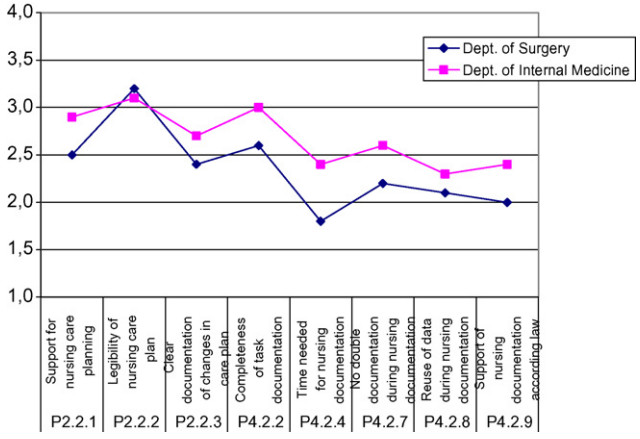

Fig. 6 – Analysis of mean score for the Department of Surgery ($n = 56$) and the Department of Internal Medicine ($n = 41$) with regard to questions on nursing care planning and nursing documentation. Higher values indicate "better" information processing range of standard deviations: Department of Surgery 0.77–0.89, Department of Internal Medicine 0.79–1.04.

The detailed results were discussed with representatives from nursing management. Besides the confirmation of most of the pre-defined expectation, and with information on the individual context of the departments, most results could be supported.

However, the results also revealed some potential sub-optimal wording of the questions. For example: 17 of 84 respondents indicated that lab results are often not readable. As lab results are only transmitted in electronic form and then printed out, this result was first difficult to interpret. Further analysis indicated that some respondents seem to have judged legibility also including the structure and design of the lab report that is in fact sub-optimal. Here we will adapt the question accordingly to include both legibility *and* structure of screen or print design.

The layout of the presentation of results (see Fig. 2) by the HIS-Monitor toolbox was supported and found helpful by nursing management. Usefulness was also supported as nursing management now plans to conduct a time-series analysis of information processing in nursing in 15 wards based on HIS-Monitor, to measure changes after the implementation of a computer-based nursing documentation system.

5. Discussion of the HIS-Monitor approach

Overall, the pretests and the feasibility study supported that HIS-Monitor results are valid and useful. Some questions will now have to be optimized and re-structured.

5.1. *Subjective versus objective assessment of HIS quality?*

The results of HIS-Monitor shall help to screen HIS quality. It will not show in detail the reasons for good or bad information processing, but rather indicate where the HIS is seen as "good" or "bad" from the point of view of the directly involved stakeholder groups. We based the assessment of HIS quality on a standardized questioning of various user groups involved ("customer voices", [22]). The staff members evaluate the quality of the information system in everyday use. If they do not feel well supported by the information processing tools and the information delivered, they will not use it efficiently or do not use it at all. There are several examples where hospital staff rejected new tools e.g. [23–25], stressing the importance of the point of view of the staff.

It is sometimes argued that only "objective" HIS evaluation brings forward new knowledge, and not "subjective" questionnaires; however, there are various arguments against this. First, to measure quantitative indicators is not always helpful to assess a situation, as indicators in themselves are just descriptions of a situation, not assessments. For example, the information that lab data needs 2 h to be transmitted from the laboratory to the ward can be judged as absolutely sufficient (e.g. in a psychiatric department) or as absolutely insufficient (e.g. in an emergency unit). Thus, the assessment of quantitative indicators always needs a target value which itself depends on the context and can only be found by asking involved people. It seems efficient to start with a screening instrument such as HIS-Monitor and then only conduct more detailed systems analysis in case of problems found. Second, indicators based on measurements are often difficult to be compared, as a lot of context information is necessary for this. Third, from a more constructivist point of view, there may not be something as an "objective reality". The "truth" is constructed by people and does not exist in itself, and facts and values cannot be separated [26]. As Ribière et al. [22] puts it "A 'good' information system, perceived by its users as a 'poor' system, is a poor system" (underlining by us, indicating that reality depends on subjective constructions).

5.2. *Possible confounders*

HIS-Monitor assesses strengths and weaknesses of information processing by asking the involved stakeholders. This may, however, introduce certain confounders in the results. For example, in case there are frequent problems with a computer-based tool, users may tend to judge more negatively on all questions where they use computers—even when the problems have only an influence on one specific situation or process step. Or, recent organisational problems (e.g. high workload, team problems) may bring the users to answer more negatively to the questions on those situations affected by the organisational problems. For example, recent problems with discharge summaries written too late due to work overload may lead to negative judgements of the information processing in this situation—even when the reasons come from organisational problems and not from the information processing tools used. On the other side, a good organisational climate or an overall high user satisfaction with computer-based tools may positively influence all answers.

We tried to minimize these confounders by asking the respondents to consider all tools used (not just the computer-based tools), and by giving guidelines on which situations he should think of when answering certain questions. In addition, we decided to concentrate on those parts of patient care where information processing and the corresponding tools play a major part—being fully aware of the fact that patient care also always depend on organistional factors, motivation of staff, etc. In the present studies, possible confounders were not systematically assessed and analysed—this should be done in subsequent studies.

5.3. *Differences to other approaches*

Our list of quality criteria on the *x*-axis was based on an extensive literature review. Therefore, compared to hospital accreditation programmes such as KTQ and JCAHO, several overlappings can be seen, but also many differences. The main difference between our approach and major accreditation programmes lies in the fact that our monitoring system takes an outcome-oriented view with regard to information processing, while accreditation programmes use a mix of structural-, process- and outcome-oriented aspects. JCAHO [5] focuses partly on process-oriented criteria. For example, JCAHO checks whether the hospital defines and evaluates criteria for confidentiality and security of data (JACHO IM.2)—it does not check primarily whether data security *is maintained*, but whether it *is controlled*. The same is true, e.g. for JCAHO IM.3 ("quality control systems ... should monitor data collection and ensure that data collection is timely and efficient"). Some parts of JCAHO focus more on outcome criteria and are, therefore, reflected in our HIS monitoring system. For example, the IM.10 ("performance data are defined ... consistently with national guidelines") matches our Q5 ("fulfilment of legal regulations"). JCAHO IM.5 ("timely and accurate transmission of data") matches Q1 ("availability of data") and Q2 ("correctness of data"). The aspect Q6 ("time needed for information processing") and Q3 ("readability") presented in our monitoring system seem not to be covered by JCAHO, although these aspects typically present major challenges to information management.

Compared to KTQ [6], a German accreditation initiative, there are also some overlapping criteria. For example, in its information management section, KTQ among others defines the following criteria: "documentation is complete and correct" (comparable to our Q2); "regulations guarantee that data are available whenever needed" (comparable to Q1), and "data protection is guaranteed" (comparable to Q5). Other aspects of KTQ focus stronger on structural aspects such as "sufficient IT is available", or "regulations for archiving of data exist".

There are other authors who tried to provide methodologies to assess HIS quality. For example, Ribière et al. [22]

presents questions which are comparable to our monitoring system. However, they only address computer-based tools (e.g. screen design, response time) and are mostly rather general (e.g. "The data and information of HIS is available every time/is unavailable."). What is missing here is the clinical context, i.e. the description of a specific process step, as the availability of information will depend on the situation where it is used. That is why we added the process steps to the monitoring system and clarified the clinical situation by extensive introductory examples.

5.4. *Precision of results*

The mean values for all questions were between 2.0 and 3.7, thus reflecting the possible range of 1–4 and pointing clearly to strength and weaknesses. The mean values for the individual process steps were between 2.5 and 3.0, reflecting the aggregation of various questions and indicating that no process step was judged very high or very low. We found that differences in judgments (e.g. between two departments) of 0.5 or more already indicate large differences in HIS quality (compare, e.g. Figs. 5 and 6).

Our results show that the individual responses can differ, even when the respondents come from the same organisational unit. This is reflected in the standard deviations. This is not surprising, as the questions often combine several aspects. For example, when asking of "availability of images such as X-rays or sonograms", one nurse may have thought of the possibility to access X-rays within the electronic patient record which is quite easy—the other may have thought about the difficulty to get sonograms as they are usually still only available in paper-based form. A third nurse may have thought of both situations. This does not reduce the validity of results, but points to the importance of having a representative sample of users to get a balanced result on the quality of information processing. The higher the diversity of working experiences, personal background, IT knowledge and overall job satisfaction is, the more informative are the results. This also means that HIS-Monitor is in fact a screening instrument where an overall assessment is represented, consisting of a lot of intra- and interpersonal viewpoints.

5.5. *Application scenarios for HIS-Monitor*

The following application and analysis scenarios can be imaged:

- HIS-Monitor can be used to get information about the quality of HIS to a given point of time: HIS quality in a given area can be screened to get an impression on strengths and weaknesses of information processing.
- HIS-Monitor can be used to support a continuous monitoring of HIS quality, e.g. by carrying out measurements at different points of time to assess changes or to evaluate effects of information processing tools recently implemented. We plan to do this in the near future, as we want to monitor changes over time during the introduction of a nursing documentation system.
- HIS-Monitor can be used to compare HIS quality in different organisational units, e.g. wards or even hospitals.

Independently of the kind of application scenario it is to be noted that the monitoring system just describes quality of HIS and does not give *explanations* for higher or lower quality scores. The reasons could be of diverse nature and could also lie in organisational problems (e.g. insufficient staffing). Therefore, the interpretation of the quality scores should be carried out carefully, considering the specific background of the concrete hospital scenario. To facilitate the interpretation, specific background information on the hospital as, e.g. number of beds, its IT equipment and its staffing, as well as some basic data on computer knowledge and computer satisfaction of the staff members should be raised parallel to the application of HIS-Monitor.

6. Conclusion

A first version of HIS-Monitor to assess the quality of a hospital information system was developed and tested in a feasibility study. The results of a pilot test showed that it seems feasible to assess strengths and weaknesses of a HIS by HIS-Monitor, but also point to some weaknesses in the current version of HIS-Monitor. Based on the results of the evaluation, we will now further refine and optimize HIS-Monitor, before evaluating it in other settings (e.g. physicians, administrative staff). It is planned to develop a web page where hospitals can compare their HIS quality profiles in anonymous form with the quality profiles of other hospitals. In addition, time-series analysis to describe changes in HIS quality after introduction of computer-based tools is just being prepared and will further help to assess the validity of HIS-Monitor.

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