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Intensive care information system reduces documentation time of the nurses after cardiothoracic surgery

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Abstract *Objective:* Nowadays, registration of patient data on paper is gradually being replaced by registration using an intensive care information system (ICIS). The aim of this study was to evaluate the effect of the use of an ICIS on nursing activity. *Design:* Randomized controlled trial with a crossover design. *Setting:* An 18-bed medical-surgical ICU in a teaching hospital. *Patients, nurses and interventions:* During a 6week period 145 consecutive adult patients admitted to the ICU after uncomplicated cardiothoracic surgery were randomized into two groups: for one group the documentation was carried out using a paper-based registration (Paper), in the second group an ICIS was used for documentation. *Measurements and results:* The nursing activities for these patients were studied during two separate periods: the admission period and the registration phase (the period directly following the admission procedure). The duration of the admission procedure was measured by time-motion analysis and the nursing activities in the registration phase were studied by work sampling methodology. All nursing activities during the registration phase were grouped in four main categories: patient care, documentation, unit-related and personal time. The duration of the admission procedure was longer in the ICIS group (18.1±4.1 versus 16.8±3.1 min, $p<0.05$). In the registration phase, a 30% reduction in documentation time (Paper 20.5% of total nursing time versus ICIS 14.4%, $p<0.001$), corresponding to 29 min (per 8h nursing shift) was achieved. This time was completely re-allocated to patient care. *Conclusions:* The use of the present ICIS in patients after cardiothoracic surgery alters nursing activity; it reduces the time for documentation and increases the time devoted to patient care. *Electronic Supplementary Material:* is available if you access this article at http://dx.org/10.1007/s00134-002-1542-9. On that page (frame on the left side), a link takes you directly to the supplementary material.

Keywords Intensive care unit · Intensive care information systems · Clinical information systems · Patient data management systems · Nursing activity · Work sampling methodology

Introduction

Intensive care information systems (ICISs, also known as patient data management systems or clinical information systems) have been available for several years. The vendors often promoted their systems by promising (among others) a reduction in charting time for the nurses and improved data quality. Some proof of the latter can be found in the literature [1, 2]. Reviewing recent literature on commercially available ICISs, a reduction in

documentation time has not been verified [3, 4], while some studies even suggest a reduction in patient care time [5, 6].

Our intensive care unit (ICU) implemented an ICIS on all beds in April 2001. By using an ICIS we hoped to improve the quality and quantity of the documented data without an increase in the amount of nurses' time spent on documentation. The present study evaluates one of these aspects, namely, documentation time of the nurses.

Patients and methods

Intensive care unit characteristics

The study unit is an 18-bed closed format medical-surgical ICU in a teaching hospital. Approximately 1850 patients are admitted to the ICU annually, about 1100 of these after cardiothoracic surgery. As the study did not interfere with the treatment of the patient, the institutional review board waived the need for informed consent.

Intensive care information systems

Full implementation of an intensive care information system (ICIS, MetaVision, iMDsoft, Tel Aviv, Israel) was achieved on April 1st, 2001. Since then documentation on every patient admitted to our ICU (except the Paper group in the study) has been carried out using the ICIS. All charting and documentation regarding the patient (by nurses, intensivists, consultants, physiotherapists, secretaries, medical students and so on) is done using ICIS. No information is primarily stored on paper. All nursing and physician staff use the system, even temporary employees from the employment agency. The system is fully integrated in our unit from automated medical notes and discharge letters to pre-filled laboratory and microbiology requests. The ICIS is connected to the bedside monitor (Siemens SC8000, Siemens-Elema, Solna, Sweden), the ventilator (Siemens Servo 300, Dräger Evita II, Dräger Evita IV, Dräger Lübeck Germany), the medication pumps (P1000, Alaris Medical, San Diego, USA) and to the hospital information system (HIS). Each bed is equipped with an ICIS workstation and in every patient room (two ICU beds) an additional ICIS workstation is present. During the study the system was operating under Windows NT with Pentium III 550 MHz workstations with client server architecture.

Patients, nurses and intervention

Prior to ICU admission, consecutive patients after uncomplicated cardiothoracic surgery (coronary artery bypass grafting and/or heart valve replacement) were randomized into two groups, either to paper registration (Paper) or to ICIS registration. Patients admitted during the night or during weekends, supported by an intra-aortic balloon pump (IABP) or noradrenaline infusion exceeding 0.1 μg/kg per min, or requiring resuscitation and/or re-operation within the first few hours after ICU admission were excluded from the study. The nurses whose activities were studied were assigned to the patient in a blinded manner by the head-nurse, who was unaware of the randomization results. These nurses were experienced intensive care nurses, working in the unit for a longer period of time (>1 year) and familiar with both systems of charting. Both methods of documentation were used simultaneously during the study period and the subjects (the ICU nurses) were alternately exposed to both methods (crossover design).

Study design

Two periods were studied: the admission procedure and the hours directly following the admission (registration phase). For the admission procedure the time-motion analysis (continuous observation and direct measurement of elapsed time) method was used, while for the registration phase work sampling methodology (see data collection procedure) was used. The admission procedure was initiated as the patient was brought into the ICU room. Two ICU nurses were assigned to the patient during the admission procedure. The procedure ended when they had completed a pre-set list of tasks (Table 1). The registration phase started immediately after the admission procedure ended. During the registration phase one nurse was responsible for the two ICU patients in that particular ICU room.

Documentation

Paper charting was performed by using the same flowcharts and other forms (e.g. medical and nursing notes, laboratory results) as

Table 1 List of tasks to be performed during the admission procedure

Paper	ICIS
Direct patient care	
Connect patient to monitor and ventilator	Connect patient to monitor and ventilator
Install chest drainage system	Install chest drainage system
Connect medication pumps to mount	Connect medication pumps to mount
Check nasogastric tube	Check nasogastric tube
Take first blood samples	Take first blood samples
Empty urine collector	Empty urine collector
Documentation	
Enter patient name, weight, height in monitor	Enter patient name, weight, height in monitor
Enter patient demographic data on ICU flowchart	Admit patient in ICIS (get demographic data from HIS)
Zero pressures, set alarms on monitor and ventilator	Zero pressures, set alarms on monitor and ventilator
Enter cardiac rhythm, running fluids, blood loss, diuresis	Enter cardiac rhythm, running fluids, blood loss, diuresis
Enter vital signs (monitor, ventilator)	Validate vital signs (monitor, ventilator)
Enter medication pumps: medication and rate	Connect medication pumps, assign correct drug
Measure and enter cardiac output and pulmonary capillary wedge pressure	Measure and validate cardiac output and pulmonary capillary wedge pressure

Table 2 Four main categories of nursing activity

Patient care	All nursing care activities directed at the patient (either the "study" patient or the other patient assigned to the nurse) and in the vicinity of the patient, such as administration of drugs, endotracheal suctioning, sampling for biochemistry, stripping of blood drainage tubes, observation of patient, cleaning sheets, changing ventilator setting
Documentation	All activities associated with documenting or reviewing patient condition and care. Includes registration of fluids, blood loss, diuresis, calculation of the fluid balance, laboratory results, writing shift change notes
Unit-related	Activities related to general maintenance of the unit. Includes duties such as cleaning the room, ordering supplies, checking defibrillators or other equipment and running errands
Personal	Personal activities not related to patient care or unit activities. Includes activities related to meals, breaks, personal phone calls, personal use of the internet and liaising with colleagues

had been used before the implementation of the ICIS. The nursing staff recorded at least one value on the flowchart for each parameter per hour, plus deviant values in instable patients. Laboratory results were extracted from printed result forms and manually recorded on dedicated forms. Nurses or physicians abstained from using the ICIS.

If the patient was randomized to the ICIS group, all patient documentation (nursing, medical, physiotherapist) and order management was carried out via the ICIS. The ICIS captures data coming from the monitor, ventilator and medication pumps each minute. At least once an hour the nurses validated the data coming from monitor, ventilator and HIS in the ICIS, plus deviant values in instable patients. Several other items (e.g. diuresis, blood loss) were entered manually every hour.

Data collection procedure

The study was performed over a period of 6 weeks. In order to limit the inter-observer variability, only two observers were used. The observers are experienced ICU nurses, employed in our ICU for 9 and 11 years, respectively. A dedicated database running on a laptop was created for the study, in which the observations were entered directly. During the admission procedure, the subjects (ICU nurses) were continuously observed (time-motion analysis). After completing the pre-set list of tasks, the duration of the procedure was recorded. For the registration phase all possible nursing activities were categorized into 148 items. These 148 items were grouped into four categories: patient care, documentation, unit-related activities and personal activities (adapted from Urden and Roode [7] Table 2). Work sampling methodology was applied during the registration phase: observations on the nurses were made every 5 min. During every separate observation the current activity of the nurse was assigned to one of the 148 items. The quality of the work sampling data was checked using control charts [8].

The amount of data generated by a postoperative patient after cardiothoracic surgery initially induces a high workload, but the latter shows a sharp decline during the first 24 h of ICU treatment [9]. As an indicator of the amount of data collected, the number of annotations on vital signs (hemodynamic and respiratory parameters, urine output and drain production, laboratory results) was measured for both groups during the first 24 h after ICU admission. As the ICIS collects data from monitor and ventilator each minute, only validated and manually entered values from the ICIS were counted for comparison reasons. To provide the reader with an impression of whether the results, obtained from the population of uncomplicated cardiothoracic surgery patients studied, could possibly be extrapolated to a general population of ICU patients, the number of validated and manually entered annotations on vital signs in the first 24 h of ICU admission was extracted from the ICIS database for all non-cardiothoracic patients admitted in November and December 2001.

Analysis

No attempt was made to produce an interim analysis. The duration of the admission procedure was analyzed by using the Student *t*-test for independent samples. Differences between the groups are given with the 95% confidence interval (CI) of the difference. Nursing activity in the registration phase is presented as the percentage of the observations spent in one of the four activity groups. To convert these results of the work sampling analysis to effective nursing time, the percentage of observations spent in one of the nursing categories was extrapolated to a theoretical 8h (480 min) nursing shift and expressed in minutes.

Results

In the study period (6 consecutive weeks in November–December 2001) 174 patients were admitted to the ICU after cardiothoracic surgery. Twenty-nine patients met the exclusion criteria. Demographics of the remaining 145 patients (ICIS n=71, Paper n=74) are provided in Table 3. The APACHE II [10], APACHE III [11] scores and two risk stratification models specific for cardiothoracic patients [12, 13] are given as indicators of severity of illness and physiologic derangement. Besides slightly higher APACHE II and III scores in the ICIS group, no significant differences in demographics were found between the ICIS and Paper groups.

As some of the 145 eligible admissions occurred simultaneously or before the observer arrived, 31 admissions were not measured. A total of 114 admission procedures were analyzed: 55 in the ICIS group, 59 in the Paper group. The duration of the admission procedure was slightly longer in the ICIS group: 18.1±4.1 versus 16.8±3.1 min (difference 1.3 min, 95% CI for the difference 0.04–2.72).

Table 3 Description of study population (*ICIS* intensive care information system, *ns* not significant, *CABG* coronary artery bypass grafting, *APACHE* Acute Physiology And Chronic Health Evaluation, *CSSS* Cleveland Clinical Severity Score: preoperative risk assessment tool for cardiothoracic patients [12], *ICURSS* ICU Risk Stratification Score: risk assessment tool for cardiothoracic patients incorporating pre-, peri- and direct postoperative factors [13], *LOS* length of stay in ICU in hours)

	ICIS	Paper	Significance
No. of patients	71	74	ns
Age (years)	67.8 (11.6)	64.7 (11.7)	ns
Gender male (%)	50 (70.4)	48 (64.9)	ns
Operation (%)			
Heart valve surgery (± CABG)	24 (33.8)	18 (24.3)	ns
Only CABG	47 (66.2)	56 (75.7)	
APACHE II score	14.6 (4.3)	12.9 (3.8)	p=0.012
APACHE III score	58.0 (15.0)	51.6 (15.4)	p=0.013
CSSS	2.6 (2.3)	1.9 (2.1)	ns
ICURSS	5.8 (4.3)	5.7 (3.5)	ns
Median LOS	22	22	ns

Unless indicated in first column, all figures in brackets depict standard deviation

Table 4 Observations during the registration phase for both intensive care information system (*ICIS*) and Paper group

	No. (%) of observations			Nursing activity (min)		
	ICIS (%)	Paper (%)	Difference of proportion (95% CI)	ICIS	Paper	Difference in time
Patient care	1633 (61.0)	1442 (54.9)	+6.1 (+3.5 to +8.8)	293	264	+29
Documentation	385 (14.4)	537 (20.5)	–6.1 (–8.1 to –4.0)	69	98	–29
Unit-related	89 (3.3)	114 (4.3)	–1.0 (–2.1 to +0.0)	16	21	–5
Personal	568 (21.2)	532 (20.3)	+1.0 (–1.2 to +3.2)	102	97	+5
	2675 (100)	2625 (100)		480	480	

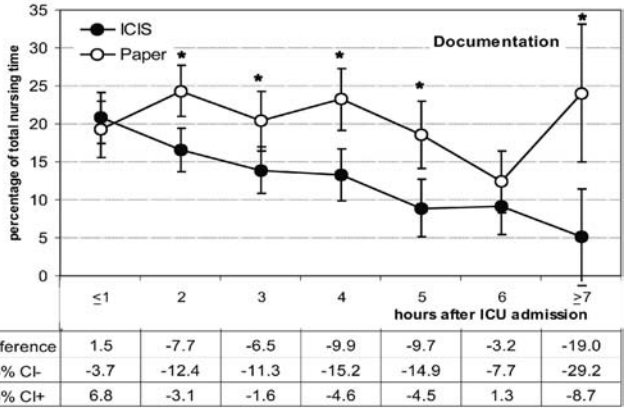
Observations expressed as proportion of total number of observations in each group. Difference is displayed as ICIS(%)–Paper (%). For the difference between proportions, the 95% confidence interval (CI) is given. To provide an impression of the nursing activity during a shift, the proportions are recalculated to minutes, based on an 8h (480 min) shift

Table 5 The five most frequently observed documentation activities in both ICIS and Paper groups (*Time spent* recalculated approximation of time dedicated by the nurse to specified task, based on an 8h nursing shift, *n.a.* not applicable in the ICIS group)

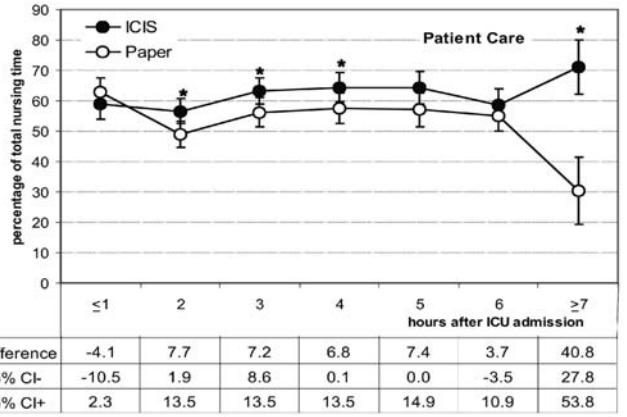
	No. of observations in documentation category		Time spent (min)	
	ICIS (%)[a]	Paper (%)[a]	ICIS	Paper
Total	385	537	69	98
Logging/validation of hourly checks	113 (29.4)	158 (29.4)	20.3	28.8
Collecting/entering lab results	n.a.	75 (14.0)		13.7
Registration of i.v. fluids	41 (10.6)	b	7.4	
Calculating fluid balance	n.a.	45 (8.4)		8.2
Shift change	39 (10.1)	36 (6.7)	7.0	6.6
Reviewing/writing medical/nurses' notes	36 (9.4)	27 (5.0)	6.5	5.0
Validating given medication	23 (6.0)	b	4.1	
Total of “top 5”	252 (65.5)	341 (63.5)	45.2	62.3

[a] Percentage of total number of observations in documentation category
[b] Not among five most frequently registered observations in the documentation category

During the registration phase, a total of 5300 observations (corresponding to 441 h of observation) were made: 2675 in the ICIS group and 2625 in the Paper group. The observations spanned the time from the end of the admission procedure to up to 11 h after admission (mean 182±122 min after admission, median 160 min, IQR 181 after admission, no differences between groups). In the ICIS group, the time spent on documentation was significantly shorter whereas time dedicated to patient care was significantly longer. No differences between the groups were found in the nursing activity categories “unit-related” and “personal” (Table 4). Table 5 shows the five most frequently observed documentation activities and an approximation of the time spent by the



	≤1	2	3	4	5	6	≥7
difference	1.5	-7.7	-6.5	-9.9	-9.7	-3.2	-19.0
95% CI-	-3.7	-12.4	-11.3	-15.2	-14.9	-7.7	-29.2
95% CI+	6.8	-3.1	-1.6	-4.6	-4.5	1.3	-8.7



	≤1	2	3	4	5	6	≥7
difference	-4.1	7.7	7.2	6.8	7.4	3.7	40.8
95% CI-	-10.5	1.9	8.6	0.1	0.0	-3.5	27.8
95% CI+	2.3	13.5	13.5	13.5	14.9	10.9	53.8

Fig. 1 Time spent on documentation (*top graph*) and patient care (*bottom graph*) displayed versus hours after ICU admission (±95% confidence interval). Time displayed as percentage of total nursing time, *bars* displaying 95% confidence interval. The lower tabular part of each graph displays the difference between the two groups (ICIS – Paper) with lower and upper boundary of 95% confidence interval for the difference (respectively, 95% CI– and 95% CI+). The category "≥7h" groups together all observations between 7 and 11 h after ICU admission. *indicates where 95% CI of difference does not include zero

nurses for these tasks. In the Paper group, more time was spent on logging hourly checks, collecting and entering the laboratory results and calculating the fluid balance. The pattern of activities in the "patient care" category did not differ between the groups. The changes in time during the registration phase for the categories "documentation" and "patient care" are shown in Fig. 1. During the first 24 h of ICU treatment an average of 1134 (range 510–1567) measurements of vital signs were recorded per hour in the ICIS group, of which, on average, 30 (range 12–67) were validated or manually entered. The number of hourly annotations on vital signs during the first 24 h of ICU admission was higher in the ICIS group (significantly in 17 of the 24 h, Fig. 2). Figure 3 shows the number of validated vital signs for the ICIS group and for all non-cardiothoracic patients admitted in the same period (contemporary non-cardio-surgical group).

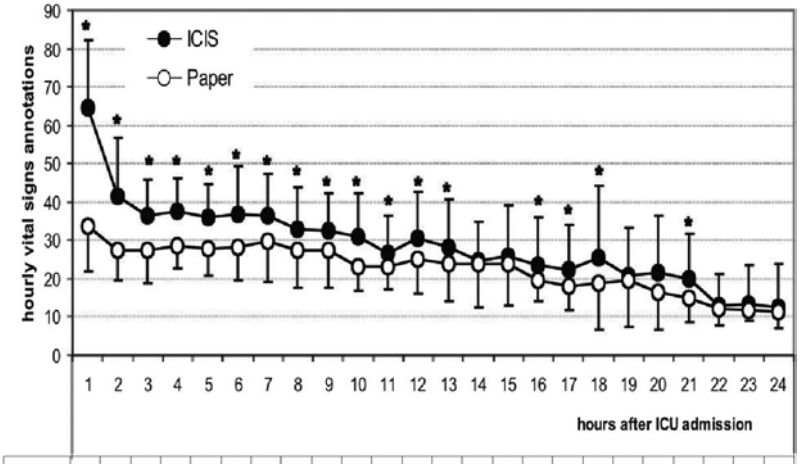
Discussion

The hypothesis tested in the presented study states that documentation using an ICIS would not consume more nursing time than the traditional paper-based alternative. The results show that a substantial reduction in documentation time can be achieved with the present ICIS in patients after uncomplicated cardiothoracic surgery. This reduction in registration time of nearly half an hour per 8h shift, largely compensates for the slightly longer admission period of 1.3 min.

A "classic" admission procedure using paper flowcharts requires registration of free-text items. Performing an admission procedure in the ICIS group involves the entry of many items in a structured way and additional tasks, e.g. making the link between the medication pumps and the corresponding drug order in the ICIS. The expectation was that these new tasks would extend the duration of the admission procedure. It appeared, however, that the difference in the duration of the admission procedure between Paper and ICIS was statistically significant, but a difference of 1.3 min, on average, is clinically irrelevant.

Compared to the Paper group, the ICIS group showed a significant reduction in documentation time of 29.8%: 14.4 versus 20.5% of total nursing time. This clinically relevant difference corresponds to a reduction in documentation time of approximately 29 min of each 8h nurse shift. In the Paper group the nurses spent 20.5% of their time on documentation in the registration phase. This figure is comparable to other studies [3, 6]. In a recent study the nurses devoted approximately 30% of their time to charting, the specific setting of this study (a pediatric intensive care) may account for the difference [4]. The reduction in documentation time in the ICIS group was largely attributable to a reduction in time needed for hourly checks, entering laboratory results and calculation of fluid balance. Time spent on patient care significantly increased from 54.9% in the Paper group to 60.0% in the ICIS group, corresponding to 264 and 293 min of an 8h shift. As the other two nursing activity categories (unit-related and personal time) are comparable between the groups, the time gained by the reduction in documentation time through the ICIS is completely re-allocated to patient care.

As previously reported, the average number of annotations on vital signs decreased steadily in time during the first 24 h of ICU admission (Fig. 3) in both study groups [9]. This is the reflection of the natural course of a postoperative cardiothoracic patient: e.g. cessation of respiratory support, removal of pulmonary artery catheter.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
difference	31.1	13.8	8.9	8.9	8.1	8.8	6.6	5.5	5.2	7.9	3.5	5.5	4	0.7	2.2	3.9	4.1	6.5	1.4	5.2	5.1	1.0	1.8	1.3
95% CI-	25.9	9.2	5.6	6.4	5.2	5.0	3.1	1.8	1.8	4.8	0.5	1.4	0.1	-3.3	-2.4	0.4	0.5	0.1	-3.3	-0.4	0.5	-2.5	-2.7	-5.1
95% CI+	36.3	18.4	12.2	11.4	11.0	12.6	10.1	9.3	8.6	11.0	6.5	9.6	7.9	4.7	6.8	7.4	7.9	13.0	6.1	10.8	9.8	4.5	6.3	7.7

Fig. 2 Average number (± SD) of vital sign annotations (hemodynamic and respiratory values, drain output, urine production, laboratory results) validated (ICIS) or written down on the flowchart (Paper) in the first 24 h after ICU admission per hour. The lower tabular part displays the difference between two groups (ICIS – Paper) with lower and upper boundary of 95% confidence interval for the difference (respectively, 95% CI– and 95% CI+). *indicates where 95% CI of difference does not include zero

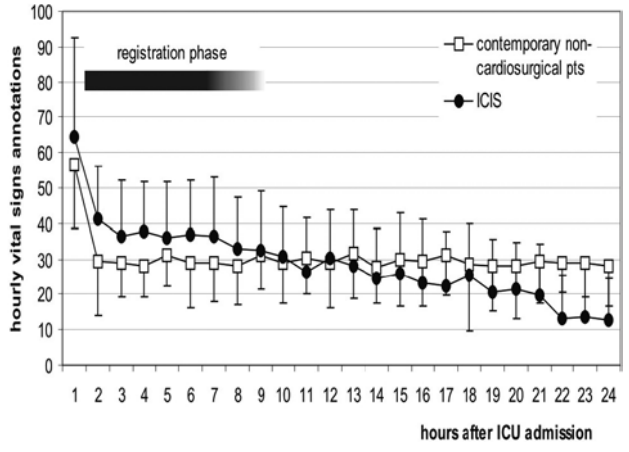


Fig. 3 Average number (± SD) of validated vital sign annotations in the first 24 h after ICU admission per hour for a contemporary non-cardio-surgical group. Data from ICIS group is displayed for reference. *Horizontal bar* indicates duration of the registration phase

The present study only evaluated the effect of different methods of documentation in patients after uncomplicated cardiothoracic surgery. To evaluate whether these results could possibly be extrapolated to a general ICU population, we extracted the number of validated vital signs during the first 24 h of ICU treatment of all non-cardio-surgical patients admitted to the ICU in the study period and compared them to the study group. In the ICIS group the decline in the documentation time in the post-admission hours (Fig. 1) is closely mimicked by the pattern of validated vital signs in the same period, signifying their logical relation. The number of vital sign annotations per hour in the contemporary non-cardio-surgical group is very stable. The number of vital sign annotations during the registration phase of this study (from immediately after the admission procedure up to approximately 7–8 h after ICU admission) is very similar to that of the contemporary non-cardio-surgical group (Fig. 3). This might imply that our results could be extrapolated to all our ICU patients. This suggestion has to be studied prospectively.

Since both methods of documentation were used simultaneous during the study period and the subjects (the ICU nurses) were alternately exposed to both methods (crossover), effects other than the use of either of the systems, such as different level of experience or other ways of working, can be excluded. The case-mix of patients and severity of illness are similar in the two groups; the only differences are the higher APACHE II and APACHE III scores found in the ICIS group. This difference can be explained by the effect of ICIS charting on severity of illness scores; using an ICIS will result in a rise of approximately 10% of the severity of illness score [14, 15].

The admission procedure was measured using "time-motion analysis", which is especially appropriate when comparing two different work patterns that produce the same result and additionally provides a direct measurement of the amount of time spent on the task [8]. Work sampling methodology was used to record nursing activity in the registration phase. Since the nursing activities being observed with the work sampling methodology are random in nature, a fixed interval for the observations had been selected, which is preferable to random observations [16]. The actual observations can be converted into percentage of time spent on the actual nursing activities [8].

We chose to exclude those patients in whom the observations could possibly be clouded by the presence of more than one nurse, i.e. the instable patients. With instable patients (the ones with IABP, resuscitation, need

for re-operation) there is often more than one nurse active around the bed of the patient. In such cases it is not evident for the observers which activity to record. We therefore separated the admission phase (two nurses assigned to the patient) from the registration phase (nursing activities from a single nurse per patient). This way we could be more confident that our recordings represented the actual activity around the patient bedside.

To our knowledge, this is the first paper to report a statistically significant reduction in documentation time using a commercial "off-the-shelf" software package covering all aspects of nursing documentation. A time reduction has been reported in the past only for specific nursing tasks (e.g. shift-change reports) using dedicated or "home-made" software. One other paper mentions a reduction in charting time using a commercial system [17]. However, the authors of this paper only mention the method (activity analysis during three 24h periods) and the results (4% reduction in charting time). No data or statistical analysis are presented, the short observation period makes it unlikely the 4% reduction in charting time reached statistical significance. Other recent studies using different commercial software were not able to demonstrate a reduction in nursing time for charting or an increase in patient care time [2, 3, 4, 6].

Possible explanations why this study was able to demonstrate a reduction in documentation time seem to be twofold. Firstly, in contrast to some previous reports [4, 6], the present ICIS uses a high level of interfacing to bedside devices (monitor, ventilator, medication pumps) and to the hospital information system, while previous studies reported on systems with partial interfacing. Validating a column of data is faster than entering the data manually. The second part of the explanation can be found in the user-interface of the ICIS software used: the "spreadsheet" look-and-feel of the software allows direct entry into the cell, no (sub-)menus have to be opened. Almost all data are just "one click away".

The present study shows that, by using an ICIS, more data can be collected without an increase in documentation time. New disciplines such as Health Informatics rely heavily on the collection of huge amounts of data. The European Society of Intensive Care Medicine recently stated their view on Health Informatics as "the development and assessment of methods and systems for the acquisition, processing and interpretation of patient data with the help of knowledge from scientific research" [18]. Health Informatics should lead to better and more cost-effective care. Looking at the amount of data to be collected, the ICIS plays a pivotal role in the broader implementation of Health Informatics in the ICU [18].

The aim of the present study was to demonstrate that the use of ICIS would not result in an increase of documentation time for the nurses. Despite a marginal increase in the duration of the admission procedure, a clinically relevant decrease of documentation time in the registration phase was found. What the ICIS vendors have been promising for years seems finally to have been realized: increased data quantity, improved data quality and reduction of documentation time. This leads us to the question of when the next step will be taken: a randomized controlled trial proving that ICIS can contribute to improved patient outcome.

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