THE IMPORTANCE OF SYSTEM INTEGRATION IN INTENSIVE CARE UNITS
A Review

Rui Fonseca[1,2] and Pedro Pereira Rodrigues[1,3]
[1] *Faculty of Medicine, University of Porto, Al. Prof. Hernâni Monteiro, 4200-319 Porto, Portugal*
[2] *Faculty of Sciences, University of Porto, Rua do Campo Alegre, s/n, 4169-007 Porto, Portugal*
[3] *LIAAD - INESC Porto, L.A. & CINTESIS - Center for Research in Health Technologies and Information Systems, Porto, Portugal*

Keywords: Intensive Care Units, System integration, Electronic Health Records, Patient outcome.

Abstract: Due to the severity of patients treated in the intensive care units, these units are commonly equipped with a variety of equipment that is handled by a multidisciplinary team. In order to identify problems, present and future, clinicians perform periodic assessments that produce huge amount of data, which availability is of vital importance. This study was performed in order to assess the impact of clinical data centralized in a clinical information system for inpatients in an intensive care unit, when compared with data disseminated in different systems. A literature search was conducted on PubMed in order to identify relevant articles published between 2000 and 2010. From a total of 48 articles, 7 articles were selected for assessment. 2 articles studied the impact of system integration, 4 articles studied the impact of computerized medical records and 1 article studied both the impact of computerized medical records and system integration. A centralized clinical information system was proved to have a positive impact for inpatients in an intensive care unit. These systems allow time savings on vital signs transcription, reduced medication errors, a quicker access to clinical data and a reduction in prescription errors.

1 INTRODUCTION

The Intensive Care Units (ICU) are a specialized section of an hospital containing the equipment, medical and nursing staff, monitoring and life-support devices necessary to provide continuous care to patients that are severely ill and medically unstable.

Due to the severity of the patients, these units are commonly equipped with mechanical ventilators to assist breathing, cardiac monitors including telemetry, external pacemakers and defibrillators, dialysis equipment for renal problems, equipment for the constant monitoring of bodily functions, a web of intravenous lines, feeding tubes, nasogastric tubes, suction pumps, drains and catheters, and a wide array of drugs to treat the main conditions. All of this equipment is handled by a multidisciplinary team that may be consisted, among others, by intensivists (clinicians who are specialized in critical illness care), clinical pharmacists, nutritionists, nurses, anaesthesiologists, surgeons or emergency medicine specialists.

In order to identify problems that may arise and require urgent attention or treatment, clinicians perform periodic assessments of the patient's cardiac status, breathing rate, urinary output, and blood levels. In some cases, patients may need special requirements for monitoring. That's the case for patients who are admitted to the ICU for observation after surgery. These patients may have catheters placed to detect hemodynamic changes (blood pressure changes) or require endotracheal intubation to help them breath, with the breathing tube connected to a mechanical ventilator. In order to perform a correct treatment, the availability of detailed information is of vital importance. Physicians have not only to analyze data displayed by the equipment, but also to analyze laboratory and radiology results, evaluate patient's history and current medication, analyze patient-specific information such as age, weight and height, analyze

Fonseca R. and Rodrigues P..
THE IMPORTANCE OF SYSTEM INTEGRATION IN INTENSIVE CARE UNITS - A Review.
DOI: 10.5220/0003128801420147
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2011), pages 142-147
ISBN: 978-989-8425-34-8

warnings of drug interactions and evaluate diagnoses.

All the mentioned information is extremely important to physicians in order to prevent mistakes, to decide the better treatment plan and to perform acts that allow a better patient outcome. However, in some cases, the information is distributed by various information systems, which may result in a huge time loss when looking for specific data.

The aim of this study is to provide an assessment of the impact of data centralized in one Clinical Information System (CIS) for inpatients in an ICU, when compared with data distributed in different systems. In order to do so, the following question should be answered at the end of this study:

- Is system integration important in patient outcome in the ICU, when compared with the evaluation of data from different systems?
- Can computerized medical records in ICU allow a better decision making?
- Can system integration decrease the length of stay in ICU?

In order to answer these questions, a review will be performed on the importance of integrating clinical data provided from equipments, laboratory and radiology results, administrative inputs and clinician's assessments into one centralized system. This review will be carried out in order to identify the results of length of stay, mortality rate and patient outcome and the ability of a better decision making, which should result in a better overall treatment.

2 METHODS

A literature search was conducted by one reviewer in January 2010 on PubMed in order to identify articles published between January 2000 and January 2010. The search was performed based on Medical Subject Heading (MeSH) terms, in order to identify the importance that system integration or computerized medical records have on ICU, influencing patient outcome results.

The keywords that were used included ICU in conjunction with System integration or Computerized medical records. These terms were then used in conjunction with Decision support system or Decision making or Outcome and process assessment or Hospital mortality or Length of stay as it can be seen in figure 1.

The inclusion criteria required that the studies: (1) where based on intensive care units, (2) were related to system or data integration, (3) evaluated the patient outcome, (4) were published in English or Portuguese and (5) where available in Full text.

In order to identify the articles used in the review, the following selection method was used, as identified in figure 2. After performing the search on PubMed database, the availability of full text was analyzed, resulting in the exclusion of the articles that weren't available. At this point, a screening of the title and abstract was performed, resulting in the exclusion of articles by lack of the correct content. Finally, the digital document corresponding to the article was searched and the articles that couldn't be found were excluded. After the identification of the articles included for revision, its quality was analyzed through the process of reading and selection.

Figure 1: Keywords used in the search strategy.

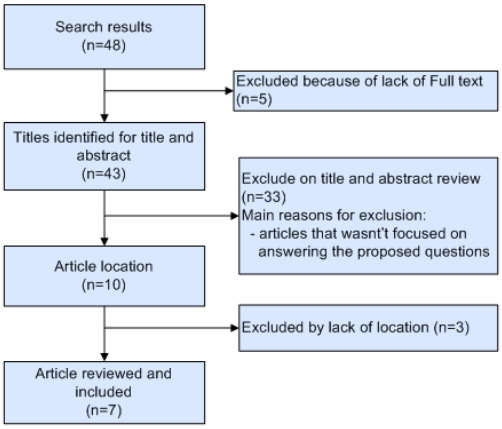

Figure 2: Data search, analysis and selection process.

3 RESULTS

As shown in figure 2, a total of 48 articles were found in scientific literature (2000-2010) that

examined the outcomes of decision making, decision support system and patient outcome with the use of system integration and clinical information systems. However, the analyses and selection process outlined in figure 2 guided to an evaluation of the availability of full text articles, which lead to an exclusion of 5 articles. The 43 remaining articles were considered for title/abstract review and a detailed screening of titles and abstracts resulted in a selection of 10 articles which were considered for full text review. After the identification of these articles, 3 of them could not be located for review, even though its title and abstract suggested that they would have been selected for inclusion. Performing this process led to an inclusion of 7 articles. One of these articles is a narrative review that focuses on the benefit of using Computerized Physician Order Entry (CPOE) in performing a better patient outcome (Rothschild, 2004).

As shown in table 1, most of the selected articles assessed the evaluation of the impact of computerized medical record systems (5 articles) while only a few number of articles assessed the impact of system integration (3 articles). All the articles that studied the impact of the system integration also evaluated the outcome of computerized decision making. In the set of articles that studied the impact of computerized medical records were found articles that analyzed the outcome on: length of stay (1 article), computerized decision making (3 articles) and outcome and process assessment (2 articles).

The studies can be classified in three groups of interest: computerized medical records with outcome and process assessment; computerized medical records with computerized decision making; system integration with computerized decision making. One of the articles (Reina-Tosina et al., 2002) evaluated simultaneously the effect of system integration and computerized medical records with computerized decision making.

3.1 Computerized Medical Records and Outcome and Process Assessment

(Ward, Snyder, Ross, Haze, Levy , 2004) conducted a randomized analysis in order to evaluate the correctness and completeness of the use of a CIS, when compared with direct and indirect methods of measuring critical care outcomes. Medication administration is used to analyze the medication that is being administered to the patients. The CIS was implemented in an ICU where medications are dispensed by automated machines. Since the CIS records information about the patient, time, and medication dosage, a review of this information can be done at any time, allowing physicians to perform a better decision making. However, within the analysis period, 411 medications were administered but only 341 were logged in the CIS.

(Donati et al., 2008) conducted a before and after study in a European Medical and Surgical ICU, in order to evaluate the impact of a CIS in an ICU. The study focused on the comparison of the time spent charting on paper and on the CIS by physicians and nurses. The activities evaluated were: transcription of vital signs, physician therapeutic orders and laboratory data and time spent for computing fluid balance and scores. The time spent on performing one of these activities was measured separately and, when using the CIS, the time spent for the same activities was measured by the difference between the login and the logout. All the measure was done by a person not involved in the study. The time spent charting on paper and on CIS was highly decreased (3 ± 2 minutes/day versus 37 ± 7 minutes/day respectively, $P < 0.001$). In some cases, such as fluid balance and exam transcription, the time was reduced to 0 minutes.

3.2 Computerized Medical Records and Computerized Decision Making

(Menke, Broner, Campbell, McKissick, Edwards-Beckett, 2001) conducted a before and after comparison study in a Paediatrics ICU in order to identify the impact of a clinical decision system on decision making and overall patient outcome. The study was performed by an independent observer that measured the time spent in direct patient care, number of medication errors, medication's delay evaluation and speed of clinical decision-making. The previous measures were done before and after the implementation of a centralized CIS, through the observation of the clinicians. After the implementation of the CIS, no significant difference devoted to direct patient care was identified. However, the number of medication errors and delay decreased substantially and there was an increase in the speed of clinical decision-making due to the availability of data provided from laboratory and vital signs. There was an improvement in data access due to the availability of data on several computers. The rapid access to previous medication, laboratory and vital signs data also allowed a better patient outcome.

Table 1: Details for studies found for the outcomes System integration and Electronic Health Records in an ICU. The numbers in brackets represent the articles, as described at the bottom of this table.

	System integration	Electronic Health Records
Number of studies	3 (43%) [2] [4] [6]	5 (71%) [1] [3] [4] [5] [7]
Year of publication		
2008		1
2004		2
2003	2	
2002	1	1
2001		1
Study outcome		
Outcome and Process Assessment		2
Length of Stay		1
Computerized decision making	3	3
Study design		
Before and after	1 [6]	2 [1] [3]
Review		1 [5]
Non Randomized control trial	2 [2] [4]	2 [4] [7]
Study population		
Not specified	2 [2] [4]	3 [1] [4] [7]
Paediatric/Neonate	1 [6]	1 [3]
Not applicable		1 [5]

[1] Donati et al., 2008; [2] Kowe and Burgess, 2003; [3] Menke et al., 2001; [4] Reina-Tosina et al., 2002; [5] Rothschild, 2004; [6] Shin, Huh, Lee and Kim, 2003; [7] Ward et al., 2004

(Rothschild, 2004) conducted a review in order to assess the effects of CPOE on patient outcome in both general and critical care settings. The performed review included only randomized controlled trials. Study design evaluated not only before and after comparisons, but also time series (off-on-off-on). The outcomes measured included clinical and surrogate outcomes. Clinical outcomes are mortality, morbidities, adverse events and length of stay. Surrogate outcomes include medical errors, costs or charges and intermediate outcomes (e.g., laboratory results) with well-established connections to the clinical outcomes of interest such as clinical guideline compliance or the use of institutional best practices (Rothschild, 2004). In this review, the author identified three areas of interest: CPOE on medication prescribing area; the effects of CPOE on diagnostic test ordering and test result management; the effects of CPOE on injury prevention. In all areas of interest, the author identified an overall increase of patient outcome when a CPOE is used in ICU.

(Reina-Tosina et al., 2002) conducted a study in Europe in order to provide methodological issues and technological solutions for an integrated system that allows the management of a hospital unit. This study presents a proposal for the development of a clinical information system that allows the integration of all the information produced within a burn ICU. According to the author, time efficiency has grown increasingly.

3.3 System Integration and Computerized Decision Making

(Kowe and Bugess, 2003) conducted a Non-Randomized Controlled Trial study on a neonatal ICU in order to demonstrate the importance of continuous monitoring by presenting a prototype. The prototype developed is a system that provides automatic and unattended monitoring of many of the electrophysiological parameters that were shown to be useful. The purpose of this prototype is to allow untrained neurophysiologists to identify abnormal trends easier. It consists in an integrated bedside monitor that continuously monitors the function of the patient's central nervous system in a predefined interval, as well as monitors cardiac and respiratory parameters (Shin, Huh, Lee and Kim, 2003)

Table 2: Relationship between Outcomes and Interventions of studies.

Author	Year	Outcome			Intervention	
		OPA	LOS	DM	SI	EHR
Donati et al.	2008	x				x
Kowe and Bugess	2003			x	x	
Menke et al.	2001			x		x
Reina-Tosina et al.	2002			x	x	x
Rothschild	2004			x		x
Shin, Huh, Lee and Kim	2003			x	x	
Ward et al.	2004	x	x			x

OPA:Outcome and Process Assessment; LOS:Length of stay; DM:Decision Making; SI:System Integration; EHR:Electronic Health Record

conducted a study in a neonatal ICU in order to help managing and monitoring conditions within incubators in the infant ICU using the hospital network. In order to accomplish this goal, a pilot system that monitors the humidity and temperature of infant incubators was developed. This system is connected to a centralized supervisory monitoring system, allowing clinicians to monitor the overall state of the inpatients of the ICU in one single system. As a result, the author identified that a centralized control centre in a neonatal ICU performs a primary supervision, allowing for an immediate response. However, the overall supervision shouldn't rely only on this system.

4 DISCUSSION

This study was designed with particular attention to evaluate the importance of centralization of data provided from equipment, such as vital signs and life-support monitoring, and from other information systems within the ICU, like radiology and laboratory results, in order to access the results of patient outcome, such as mortality rate, length of stay and overall quality of care. From a total of 7 articles identified, 4 articles studied the importance of computerized medical records, 2 articles studied the importance of system integration and 1 articled studied both the importance of system integration and computerized medical records. A few limitations can be found in this review: the search was only based on MeSH terms; only one database – PubMed – was used to perform the search.

From the analysis of the searched studies, this is the first review exclusively dedicated to evaluating such case-control study. However, one study was found mentioning the importance of such integration (Donati et al., 2008). In this study, the author was focused on comparing the importance of a CIS in order to reduce the time spent on charting, while compared to paper based records. As mentioned by the author, their system is able to "retrieve automatically data from physiologic monitoring, IV pumps, ventilators and moreover interfaces with a blood gas analyzer and utilizes web browser technology to provide users with access to chemistry and microbiology labs, radiology systems and intranet sites" (Donati et al., 2008), but the evaluation of the relevance of this integration was not part of the study. Despite of identifying the reduction of time in charting by all the clinicians inside the ICU, this study didn't evaluate if the time was correctly applied to patient's treatment, which could have been done evaluating patient outcome.

The importance of system integration was mentioned through the use of continuous monitoring systems that had the ability to display current status of the variables in analysis. Both studies were performed in a neonatal ICU. One of the systems had the ability to produce alarms when values were above or below some parameters. Both systems have the ability of reviewing previously recorded values, using a web browser with intranet access. While one of the articles conducted a non-randomized controlled trial, the other one conducted a before-after comparison. However, the information was relevant for this article (Kowe and Burgess, 2003; Shin, Huh, Lee and Kim, 2003).

The importance of computerized medical records was mentioned through the use of centralized systems that allowed a better access to data, such as vital signs and laboratory results, and an improvement in prescription. Due to the amount of data that has to be transcribed for each patient, a centralized system that registers signals automatically allows a substantial decrease in transcription time and errors (Ward et al., 2004; Donati et al., 2008).

The use of a CIS in order to prescribe medication can allow a reduction in transcription errors in the nurse team and gives physicians the ability to easily review all the prescribed and administrated prescription, leading to a better decision making.

The integration of prescription with laboratory results and vital signs can allow better decision making, prevent the prescription of drugs that could be harmful for the patient and reduce prescription errors. The centralization of this information into one single CIS allows the reduction of time on searching medical records and results, providing more time for patient care (Ward et al., 2004; Menke et al., 2001; Rothschild, 2004; Donati et al., 2008).

In order for the integration of information to produce benefits, it's necessary to take into account the availability of systems that can be affected by viruses, system incompatibilities or computer downtime (Donati et al., 2008).

The use of a CIS represents a change in the way clinician's access to data. Taking this factor into account, it is necessary to consider the problem associated to the learning curve that, in an initial implementation's phase, may not produce the expected results (Menke et al., 2001). A significant lack in the number of studies addressing the effect of the physician's time in the treatment of patients was also mentioned (Donati et al., 2008).

There was a study that mentioned limitations on demonstrating the usage of system integration for certain situations, which might not have any influence in patient outcomes (Rothschild, 2004).

In some situations, although the usage of innovating technologies could be seen as an improvement for patient, clinical staff discarded this approaches due to the long needed training on the technology and the difficulty in learning.

5 CONCLUSIONS

The clinical use of computers has been increasing substantially, especially in critical care, where they have become routinely integrated with patient monitoring, laboratory results and the overall data resulted from an ICU episode. The evaluation of such data is extremely important in order to improve decision making and a better care. However, due to the large amount of data, clinicians spend a lot of time searching and analyzing this information.

This review attempted to answer one question: Is system integration important for the treatment of inpatients in the ICU?

There are difficulties related to the learning curve with the usage of a new technology, which may require an initial higher dedication from clinical staff. These difficulties can be caused by the complexity of the systems and by the level of knowledge in using computers by the clinical staff. However, a centralized CIS allows the reduction of incidents resulting from serious medication errors, including adverse drug events and transcription errors, allows a significant reduction on time spent documenting information and vital signs improving the accessibility to patient data, the quality, the efficiency and timeliness to data important in the overall patient care.

Comparing both advantages and disadvantages, it can be stated that a centralized CIS is extremely important for inpatients in an ICU.

In future work, a systematic review should be performed in more databases in order to include a larger number of articles. In order to effectively assess a correct evaluation of the importance of a centralized system in an ICU, a CIS should be implemented and a clinical case should be evaluated.

REFERENCES

Donati, A., Gabbanelli, V., Pantanetti, S., Carletti, P., Principi, T., Marini, B., Nataloni, S., Sambo, G., Pelaia, P. (2008). The impact of a clinical information system in an intensive care unit. *Journal of Clinical Monitoring and Compuing*. (Vol.22, pp.31-36).

Kouwe, A., Burgess, J. (2003). Neurointensive care unit system for continuous electrophysiological monitoring with remote web-based review. *IEEE Transactions on Information Technology in Biomedicine*. (Vol. 7 No 2, pp.130-140).

Menke, J., Broner, C., Campbell, D., McKissick, M., Edwards-Beckett, J. (2001, September 17). Computerized clinical documentation system in the pediatric intensive care unit. *BMC Med Inform Decis Mak*. 1-3.

Reina-Tosina, J., Roa, L., Cáceres, J., Gómez-Cía, T. (2002). New approaches toward the fully digital integrated management of a burn unit. *IEEE Transactions on Biomedical Engineering*. (Vol. 49, No. 12, pp.1470-1476).

Rothschild, J. (2004). Computerized physician order entry in the critical care and general inpatient setting: a narrative review. *Journal of Critical Care (Vol*.19, No 4, pp. 271-278).

Shin, D., Huh S., Lee, T., Kim, I. (2003). Web-based remote monitoring of infant incubators in the ICU. *Inernationalt Journal of Medical Informatics*. (Vol. 71, pp.151-156).

Ward, N., Snyder, J., Ross, S., Haze, D., Levy, M. (2004). Comparison of a commercially available clinical information system with other methods of measuring critical care outcomes data. *Journal of Critical Care* (Vol. 19, No 1, pp.10-15).

Pubmed. Available at: http://www.ncbi.nlm.nih.gov/sites/entrerz [Accessed 2nd Feb, 2010]