Chapter 14

Intelligent Decision Support in Intensive Care Units - Nursing Information Modelling

M.F. Santos,[1] F. Portela,[1] M. Vilas-Boas,[1] J. Machado,[2] A. Abelha,[2] J. Neves,[2] A. Silva,[3] F. Rua,[3] M. Salazar,[4] C. Quintas,[4] A.F. Cabral [4]

[1]Departamento de Sistemas de Informação, Universidade do Minho, Guimarães, Portugal, {mfs,cfp,mvb}@dsi.uminho.pt
[2]Departamento de Informática, Universidade do Minho, Braga, Portugal, {jmac,abelha,jneves}@di.uminho.pt
[3]Serviço de Cuidados Intensivos, Hospital Geral de Santo António, Porto, Portugal, moreirasilva@clix.pt, fernandorua.sci@hgsa.min-saude.pt
[4]Serviço de Sistemas de Informação, Hospital Geral de Santo António, Porto, Portugal, {msalazar,César.quintas,alexandra}@hgsa.min-saude.pt

Abstract. The amount of clinical data that is produced everyday in an intensive care environment makes it difficult and time-consuming for health care professionals to find and analyze the information related to the patients' clinical condition. Moreover, some of that data is in paper-based nursing records, which aggravates this scenario. Increasing the health care provided to the patients is a concern, hence the initiative to develop an electronic nursing record. As a major goal, it will also integrate the decision support system INTCare, providing the means for a rapid access to the patient's clinical information. This paper presents a specification of the electronic nursing record in development in Hospital Geral de Santo António, Oporto, Portugal. It is fed by three types of information sources and their integration is possible thanks to AIDA, an Agency for Integration, Diffusion and Archiving of Medical Information, implemented at the hospital.

Keywords. Nursing Record, Electronic Nursing Record, Information System, Intensive Care, INTCare

14.1 Introduction

Daily, in an intensive care unit (ICU), a great amount of data related to the patients' condition is produced, collected, retrieved and analyzed. Valuable information may be hidden in the data but it can be excessively time-consuming for physicians to analyze all the data available [1].
It is also possible to use that information to generate predictive models about the patients' condition, mainly about organ failure.
Having this challenge in mind, we are developing a real-time and situated intelligent decision support system, called INTCare[1], whose main goal is to improve the health care, allowing the physicians to take a pro-active attitude in the patients' best interest [2-7].
For a decision support system in real-time, we must guarantee that it will be fed with online and real-time data, hence the need for the dematerialization of processes, particularly the paper-base Nursing Record [8].
Physiological variables such as heart rate, blood pressure, temperature, ventilation and brain activity are constantly monitored on-line [9], one of the objectives is memorize all the data available [1], allowing rapid interpretation of physiological time-series data and accurate assessment of patient state are crucial tasks for patient monitoring in critical care. Algorithms that use artificial intelligence techniques have the potential to help achieve these tasks, but their development requires well-annotated patient data [10, 11].
The development of an electronic nursing record (ENR) is a crucial task. By replacing the paper-based nursing record (PBNR), we will have the conditions to create a solid knowledge base for the data mining models.
This paper relates to the development of an ENR to support the information architecture underlying the real-time and online requirements of the INTCare system. It is organized as follows. In section 2 we present some background concepts and related work and describe the INTCare system and how its requirements are related to the necessity of an ENR. In section 3 we present our proposal for the development of the ENR. In section 4 we describe the information sources that will support our application. In section 5 we discuss some aspects related to technology acceptance and in section 6 we explain the deployment phase of the ENR. In section 7 and 8 we conclude this paper with some discussions and guidelines for future work.

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14.2 Background and related work

14.2.1 INTCare

INTCare is an intelligent decision support system for intensive medicine that is being developed in the ICU of the Hospital Santo António in Porto, Portugal. It makes use of intelligent agents [2] that are capable of autonomous actions in order to meet its goals [3], [12].
The development of an automated information system for ICU has to be in harmony with the whole information system and activities within the unit and the hospital [13], [14].
Patient management is supported by complex information systems, which brings the need for integration of the various types and sources of data.
In figure 1.1 it is presented the conceptual design of the INTCare data acquisition sub-system, which is responsible for the data gathering that will feed the data entry sub-system. This sub-system includes three types of information sources: Bedside monitors, Clinical analysis and Nursing records. All sources produce and feed information to the INTCare system. The data will be used to develop and update predicting models in Intensive Care, producing knowledge in real-time to support the medical decision. The development of an automated information system for ICU has to be in harmony with the whole information system and activities within the unit and the hospital [13].

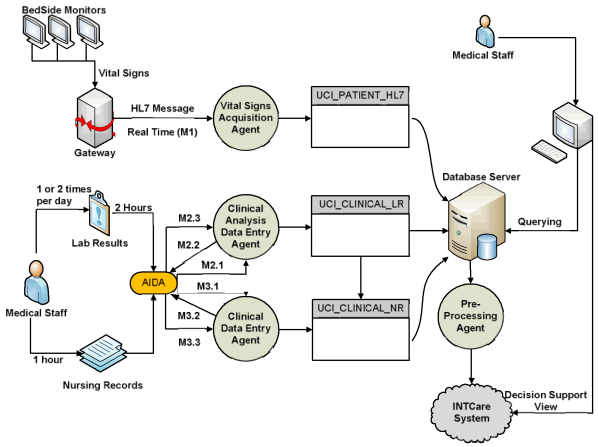


Fig. 1.1. INTCare Data Acquisition System

The sub-system present in figure 1.1 represents an important part of all INTCare System because it is responsible for acquiring data that will feed

data mining models, which will predict, in real-time, organ failure and mortality assessment and, according to these predictions, suggest therapeutic treatment. In critical situations, such quick access to knowledge saves lives [14].
Due to the new requirement of real-time decision, some changes need to be made, particularly the end of paper-based electronic records. By analyzing the requirements presented in the previous article about the INTCare system [15], we can summarize them into 3 main goals:

- Online Learning - The models should be induced using online data in opposition to an offline approach, where the data is gathered and processed later;
- Real-Time - Data acquisition and storing must be made immediately after the events, because the decisions must be made when an event occurs;
- Adaptability - The system must have the capacity to automatically optimize the prediction models with the new data.

In order to meet the most important requirements presented, there can't be paper-based data sources, hence the need of an ENR.

14.2.2 Nursing Records

There are three types of electronic health records [16]. Traditionally, the medical records [19] have been a paper-based solution. However, the paper-based files have become a sub-optimal solution [8]. The nursing records are one type of medical record and, in the ICU environment, they typically contain demographic and historical data. The later includes the current nursing diagnosis and observations, drugs administered, monitoring data such as heart rate, dieresis and Glasgow coma score.
This way of working is very time-consuming because it implies the access and analysis of the patient information throughout the days, as well as the integration with the data from other applications. Also, critical information may not be available when needed and there can be issues of legibility of handwritten data.

14.3 Electronic Nursing Record

The Electronic Nursing Record (ENR) concept derives from the paper-based version. It is a mechanism for integrating and subsequently access patient data. The digital nature of an ENR allows data contained within it to be searched and retrieved.
Due to the medical information sources being distributed, heterogeneous and complex, the ENR takes advantage of the Agency for Integration, Diffusion and Archive of Medical Information (AIDA) implemented at the hospital [17, 18].
The ENR simplifies the work of the nursing staff, reduces number of paper-based records and minimizes the access time to information [19].

ENR is defined as a tuple $E \equiv <_{pid,\ feb,\ vsm,\ ss,\ ti,\ av,\ sv,\ mca,\ hmd\ hmf\ nl,\ plc,\ alt,\ pd,\ sez,\ pp,\ sop,\ np,\ sop,\ pc,\ oth}>$ where

pid=Patient Identification; *feb*=Fluid and Electrolyte; *vsm*=Vital Signs Monitoring; *ss*=Suction Secretions; *ti*=Tracheal Intubation; *av*=Artificial Ventilation; sv=Spontaneous Ventilation; *mca*=Metabolic Control Analysis; *hmd*=Hemodynamic; *hmf*=Hemofiltration; *npl*=Neuropsychic Levels; *pos*=Positionings; *alt*=Alerts; *pd*=Pupillary Diameter; *seiz*=Seizures; *pp*=Peripheral Pulses; *sop*=Scale Of Pain; *np*=Nursing Plan; *pcd*=Procedures; *oth*=Others [20].

14.4 Information Sources

For the development of the ENR, it is necessary to integrate four different types of electronic information sources, as shown in fugure 1.2: Gateway, Electronic Clinical Process, Nursing Plan and Medication System. These will feed the ENR, which will be automatically filled.
The gateway is responsible for capturing the vital signal data from bedside monitors. This data is packed into HL7 messages, sent to the Vital Signs Acquisition Agent [15] and sent to the ENR.
The Electronic Health Record receives and stores the patient demographic and historical information and sends it to the ENR. The Nursing Plan contains the working and treatment plan, which will be available in the ENR.
The medication system is responsible for sending a plan with the medication prescribed to the patient. In this case the system sends the drug names and dosages to the ENR. Some variables like feces, drainage,

diereses, cannot be filled automatically, so the nurses must fill them in. After all the values are confirmed by the nursing staff, the information is stored.

AIDA (Agency for Integration, Diffusion and Archiving of Medical Information) [17, 18, 21] is the underlying system that supports the ENR.

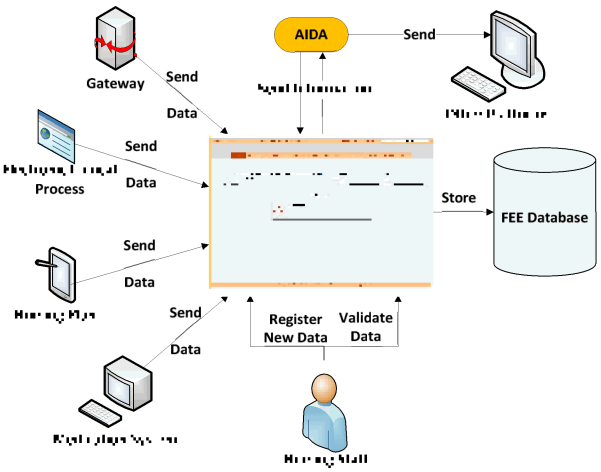


Fig. 1.2. ENR: Information Sources

14.5 Technology acceptance of the ENR

In a wider view, there are other considerations that must be taken into account related to the human resources. Particularly, resistance to change by the end users of the ENR. The nursing staff is accustomed with the paper-based data records, so the changes must occur with some precautions.

Despite the advantages of using the ENR as part of a decision making process being recognized, medical professionals might subtly differ in their acceptance of technology when compared with individuals in an ordinary business setting [21].

However, we became aware of the acceptance tone in the service by the nursing staff. They are sympathetic with this new approach to the nursing record.

This shift can be an agent for change and improvement by eliminating confusing or illegible hand-written documentation, minimizing transcription errors and fundamentally reducing clinical mistakes [22]. Easier data storage and information availability makes nurses'

administrative tasks less time-consuming, therefore, they may commit more to the patients' care.
Final considerations about the acceptance of the ENR will be made as the next phase – deployment – occurs.

14.6 Deployment

We presented a prototype of the ENR and collected the first impressions for validation. The first version was well accepted, however some adjustments and new requirements arose.
Figure 1.3 presents the development, approval and deployment cycle of the ENR.

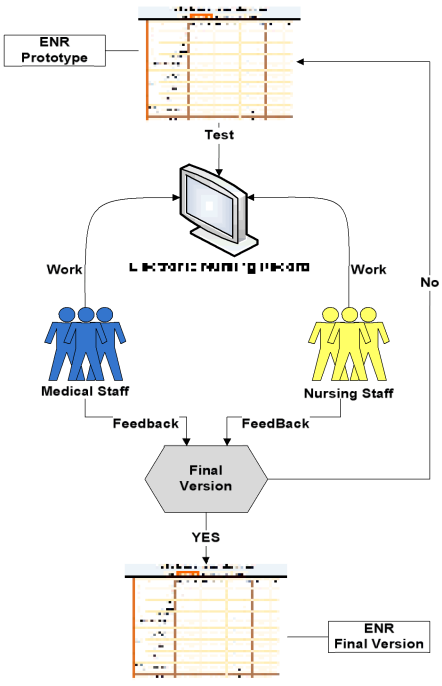


Fig. 1.1. ENR deployment cycle

We are developing the second version ENR and next it will be deployed in the real environment for the medical and nursing staff to test and approve it. It will be installed in one computer of the service and limited to a reduced group of users. With this approach we expect them to experiment

and report issues that might occur, as well as new requirements and improvements. Their feedback is of maximum importance because of issues of acceptance discussed earlier and to guarantee that the ENR does exactly and correctly what is expected to.

14.7 Discussion

The INTCare system has evolved to real-time and online requirements in order to assist physicians with a decision support system in real-time. As a result, some redesign is taking place. In particular, the paper-based nursing record must be replaced with an electronic version, so that it can store and retrieve online and real-time data. We intend to make the ENR as much automatically filled as possible, avoiding human intervention.
Data integration is a crucial task because the ENR will be fed with various data sources. The dematerialization of processes requires great care in the design of suitable interfaces for consulting, registering and analyzing data. Physicians must have readily accessible data in formats that conform to their visualization paradigms [24].
With the aim of making the transition from paper to electronic version of the nursing record as smooth as possible, we first designed a prototype for validation by the medical and nursing staff. Having it approved, we are adjusting it accordingly and soon it will be deployed it for a testing phase in the service. The nursing staff is aware of the advantages of the ENR and, at the time, we haven't encountered resistance to change. Physicians and nurses are looking forward to have this new tool in the service.

14.8 Conclusions and further work

The approach to the electronic nursing record enables electronic data registry on real-time and implements online data acquisition and processing. It also represents an improvement in the daily work of nurses in the ICU because the ENR is filled as much automatically as possible, and will integrate all the relevant information about the patients' in the context of an ICU.
Having studying this approach, we can affirm that the ENR is the future of ICU's and the dematerialization of processes has been welcomed by the heath care professionals involved. Both medical and nursing staff are

aware of the benefits of the ENR. Patients' information will be rapidly available and, in the cases where automatic filling isn't possible, the input of data will be quicker than it is at the moment. This represents more time available to take care of the patients, so we can say that the ENR will contribute for the quality of the service. Our future work includes finishing the development of the ENR and adding some important items, like nursing record plan, procedures and data querying about the patients' past clinical information.

For INTCare, it is an important step because it serves the on-line and real-time data acquisition requirements.

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