**Nursing Information Architecture for Situated Decision Support in Intensive Care Units**

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**Abstract:**

*Paper-based nursing records are yet a reality in intensive care units. Due to the amount of data that is daily produced, it can be difficult and time-consuming to find the clinical information related to the patient. Therefore, an electronic nursing record is a means to increase the health care. Moreover, it will also embed the decision support system INTCare by guaranteeing that the necessary patient’s clinical information is rapidly available. In this paper we present a specification for the electronic nursing record to be developed in Hospital Geral de Santo António, Oporto, Portugal. The electronic nursing record will have various sources of information and its integration will be possible thanks to AIDA, an Agency for Integration, Diffusion and Archiving of Medical Information, implemented at the hospital.*

**Key-Words:** Nursing Record, Electronic Nursing Record, Information System, Intensive Care, INTCare

1. **Introduction**

Intensive care units (ICU’s) are a particular environment where a great amount of data related to the patients’ condition is daily produced, collected, retrieved and analyzed. Due to the complex condition of critical patients and the huge amount of data, it can be difficult for physicians to decide about the best procedure to provide them the best health care possible. The human factor can lead to errors in the decision making process, while not all the knowable parameters are always taken into account. Frequently, there is not enough time to analyze the situation because of stressful circumstances. Furthermore, it is not possible to continuously analyze and memorize all the data available [1].

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, 3].

INTCare is capable of predicting organ failure probability, outcome of the patient for the next-day, as well as the best suited treatment to apply.

To achieve this, it includes models induced by means of data mining techniques [2], [4-7]. Over time, the historic data contain sequential events that chronicle the development of various diseases and the investigations, complications and treatment of these disease states [8]. 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.

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].

Data related to the patients’ vital signs is already being collected in real time. However, there is still a great amount of paper-based clinical information. The latest work had pointed to the need of a digital data archive in order to promote the dematerialization of paper based processes (e.g., nursing records). Therefore, the development of an electronic nursing record (ENR) is a crucial task and, at the moment, that’s where our efforts are concentrated. By replacing the paper-based nursing record (PBNR), we will have the conditions to create a solid knowledge base for the data mining models. Taking advantage of the maturity level of the hospital information system, we have an opportunity of contributing to the dematerialization process on the whole hospital.

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. We discuss why a PBNR doesn’t fit the goals of our system and in section 3 we present our proposal for the development of the ENR, describing its specifications. In section 4 we describe the information sources that will support our application. In section 5 and 6 we conclude this paper with some discussions and guidelines for future work.

2 Background and related work

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]. This system includes three types of information sources: Bedside monitors; Clinical analysis; and Nursing records.

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.

2.2 Nursing Records

There are three types of electronic health records [15]. Traditionally, the medical records [18] have been a paper-based solution. The data about the patients was kept in handwritten files. Nowadays, the medical environment has evolved to a stage where it relies upon electronic media to access patients’ information. Therefore, 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. Critical information may not be available when needed and there can be issues of legibility of handwritten data. Moreover, with the

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amount of data that is daily produced, it would be a waste not to use it for supporting the decision making process and that can only be possible with digital data.

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. While improving health care practices and patient care, it also provides easily and rapidly available data for a decision support system in real time. There are usually common attributes of an ENR. The digital nature of an ENR allows data contained within it to be searched and retrieved. Other attributes include system accessibility and usability, information readability and accuracy and decision support by data analysis [8]. Human-computer interaction (HCI) is an import subject to regard. The consequences of design-induced errors can be catastrophic in a medical environment. Furthermore, HCI principles, such as usability should also be considered to increase acceptability among its future users [8]. The dematerialization of processes requires great care in the design of suitable interfaces for consulting and analyzing data. Physicians must have readily accessible data in formats that conform to their visualization paradigms [14].

We have studied the paper-based nursing record (PBNR) in the ICU of the hospital and, by workflow analysis, we have identified the medical information required in the ENR, as well as the best approach to present it. To achieve this, HCI principles were also considered. We focused on understanding which of the existing items are necessary for the ENR as well as others that would be desirable to be included. We expect to, not only have a correct and robust, effective and user-friendly representation of the current PBNR, but also to improve its benefits. Our concerns are about the system quality, information quality and user satisfaction. In our approach, the development of the ENR has a committed medical and nursing staff involvement to guarantee user satisfaction with the end result. Also by interacting with them, we have found new and interesting requirements that will improve the information flow and availability. While with the PBNR, the information required by the nursing staff to accomplish their work is distributed by some applications, the ENR will integrate all the information into just one and in the best convenient way. We expect to have a positive impact of the system on its users (typically nurses) and the general clinical workflow, mostly by having lower response times and providing legible, correct and accessible information.

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 [16, 17].

Nurses have a particular position that could allow them to contribute to the decision-making because of the daily care of patients and the direct contact with their families. Despite this position, nurses are not always invited to participate in decision-making process [18]. Their involvement is limited and usually they are only responsible for completing the nursing sheet that later helps the medical staff in decision-making.

One of the problems in decision making that has been described is the time delay of decision. According to the nurses, time is a very important factor in the decision of whether withholding or withdrawing treatment.

The ENR simplifies the work of the nursing staff, reduces number of paper-based records and minimizes the access time to information. Furthermore, it suggests the opportunity for nurses to have more time to take care of the patients. Therefore, the implementation of this solution will engender a positive impact for both nurses and patients.

Currently, the information related to the nursing records is available on paper format and everyday it is used a new nursing sheet. The previous records are archived in the patient’s paper-based clinical process, which makes it difficult and time-consuming to find data of previous days. With the ENR, all the information will be in digital format, updated and available, which will simplify the process of storing and retrieving information. With the dematerialization of processes, some relevant alterations related to the organization and visualization of information will occur. Instead of having a stack of paper-based nursing sheets, there will be a unique electronic application with the entire patient’s clinical information relevant to the context of the ICU. Moreover, the nursing record will be automatically filled with data that comes from other applications, such as the therapeutic plan
specified by the doctors, with the hours and doses to be applied to the patient.

ENR was defined as a tuple:

\[
E = < \text{pid}, \text{feb}, \text{vsm}, \text{ss}, \text{ti}, \text{av}, \text{sv}, \text{mca}, \text{hmd}, \text{hmf}, \text{npl}, \text{alt}, \text{pd}, \text{sez}, \text{pp}, \text{sop}, \text{np}, \text{sop}, \text{pc}, \text{oth} >
\]

where

**Patient Identification** (pid): Contains demographic and historical information about the patient, which is in its clinical record.

\[\text{PID} \subseteq \{\text{name}, \text{id}, \text{episode number}, \text{birthday date}, \text{age}, \text{sex}, \text{weight}, \text{height}, \text{body mass index}, \text{bed}\}\]

**Fluid and Electrolyte Balance** (feb): represents the volume of fluids entering and exiting the patient’s body. Input fluids are diets, perfusion and therapeutics and, for each, there is a set of possible values that can be administrated to patient. Excretion is the process of eliminating waste fluids of the metabolism through feces, vomiting and diuresis.

\[\text{FEB} \subseteq \{\text{diets}, \text{perfusion}, \text{therapeutics}, \text{feces}, \text{vomiting}, \text{gastric aspirate}, \text{drainage}, \text{diuresis}, \text{time for spontaneous respiration (TSR)}, \text{others}\}\]

**Vital Signs Monitoring** (vsm): Includes the most important information about the patient’s vital signs acquired by the bedside monitors. The nurses watch the values on the vital signs monitors, and confirm, in the ENR registries, if they match.

\[\text{VSM} \subseteq \{\text{systolic bp}, \text{diastolic bp}, \text{ICP}, \text{CVP}, \text{SPO2}, \text{temperature}, \text{heart rate}, \text{respiratory rate}\}\]

**Suction Secretions** (ss): Contains the results of secretions for each hour.

**Tracheal Intubation** (ti): Tracheal intubation is the placement of a flexible plastic tube into the trachea to protect the patient’s airway and provide a means of mechanical ventilation [19]. That intubation has 3 types and different levels of tube.

\[\text{TI} \subseteq \{\text{Type}, \text{Tube Level}\}\]

**Artificial Ventilation** (av): the process of supporting respiration by manual or mechanical means when normal breathing is inefficient or has stopped. If artificial ventilation is unsuccessful, the patient is repositioned and the airway is tested for the presence of an obstruction [19]. This process contains a set of configurations / results for the patient.

\[\text{AI} \subseteq \{\text{ventilator mode}, \text{frequency}, \text{minute volume}, \text{tidal volume}, \text{PEEP}, \text{plateau pressure}, \text{pressure peak}\}\]

**Spontaneous Ventilation** (sv): normal, unassisted breathing in which the patient creates the pressure gradient through muscular movements that move air into and out of the lungs. This is another type of ventilation with different conditions [19].

\[\text{SV} \subseteq \{\text{FiO2}, \text{nasal catheter}\}\]

**Metabolic Control Analysis** (mca): Henomenological quantitative sensitivity analysis of fluxes and metabolite concentrations [19].

\[\text{MCA} \subseteq \{\text{Glucose}, \text{urinary density}, \text{other}\}\]

**Hemodynamic** (hmd): meaning literally "blood movement", is the study of blood flow or the circulation [19].

\[\text{HMD} \subseteq \{\text{D.C.}, \text{I.C.}, \text{S.V.}, \text{LVSWI}, \text{RVSWI}, \text{SVRI}, \text{PVRI}\}\]

**Hemofiltration** (hmf): During hemofiltration, a patient’s blood is passed through a set of tubing (a filtration circuit) via a machine to a semipermeable membrane (the filter), where waste products and water are removed. Replacement fluid is added and the blood is returned to the patient [19].

\[\text{HMF} \subseteq \{\text{period of history}, \text{actual time of treatment}, \text{entry of respiratory solution}, \text{dialyser}, \text{effluent}, \text{actual liquid volume removed}\}\]

**Neuropsychic Levels** (npl): Set of scales that evaluate the patient’s neuropsychic condition.

\[\text{NPL} \subseteq \{\text{ramsay}, \text{interactive behavior}, \text{Glasgow}\}\]

**Positionings** (pos): specifies the patient’s body positioning in bed.

**Alerts** (alt): It is a counting variable that sums the number of alerts for each hour for a patient.

**Pupillary Diameter** (pd): Scale that indicates the extent of the pupillary diameter.

**Seizures** (sez): Temporary abnormal electrophysiologic phenomenon of the brain, resulting in
abnormal synchronization of electrical neuronal activity.

**Peripheral Pulses** *(pp)*: The series of waves of arterial pressure caused by left ventricular systoles as measured in the limbs.

**Scale Of Pain** *(sop)*: Scale that assesses the level of pain.

\[ \text{SOP} \subseteq \{\text{scale 1, scale2}\} \]

**Nursing Plan** *(np)*: A descriptive plan that contains all the tasks to be executed for the patients’ care.

**Procedures** *(pcd)*: Procedures that are executed in patient body, like catheters and infused solutions.

**Others** *(oth)*: Non-clinical data that is daily or occasionally registered, like date and hour, nurse staff identification.

### 4 Information sources

For the development of the ENR, it is necessary to integrate four different types of electronic information sources: Gateway, Electronic Clinical Process, Nursing Plan and Medication System. These will feed the ENR, which will be automatically filled.

Fig. 1 presents the information sources of the electronic nursing records. 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 [14] 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. It is required that the nursing staff validates the values and results on the electronic sheet. Whenever a drug is applied, the nurse must validate it in 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 in the database.

**AIDA** *(Agency for Integration, Diffusion and Archiving of Medical Information)* [16, 17, 20] is the underlying system that supports the ENR.

### 5 Discussion

In order to meet the new challenges of the INTCare system, we are currently undergoing on some redesigning. In particular, the development of an ENR is a crucial part of it because it will provide online data and in real-time. With the ENR, our concern is to make its filling as much automatic as possible. Some parameters that are written in the paper-based version are already being stored digitally elsewhere, so we are studying the best approach to include them in the ENR, avoiding unnecessary replication of data. At this point we must have a close interaction with the medical and nursing staff. 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. Moreover, health care professionals have to trust the systems that support the clinical data records [21].

### 6 Conclusions and further work

This paper presented an approach to the nursing records in order to enable electronic data registry on real-time and implement online data acquisition and processing. This approach represents a collapse with the pass, and a need of change in the acting and thinking mode, but after studying the case we can affirm that ENR is the future of ICU’s, because the medical and nursing staff will have the possibility of having the necessary patients clinical information rapidly available. For INTCare, it is an important step for the development of the decision support system to intensive care in real time.
References:


