ORIGINAL

Application of Medical Information Systems for the detection of high risk patients: Rapid care alerts. Pilot study of the RCA-Son Llàtzer Project

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KEYWORDS
Clinical information system;
Medical emergency team;
Rapid response system;
Hospital mortality;
Cardiac arrest;
Early warning sign

Abstract
Objective: To describe the implementation of a Medical Information System (MIS) in the Critical Care Department (CCD).
Design: A prospective observational cohort study was carried out.
Setting: Clinical and Surgical wards in Son Llàtzer Hospital.
Patients: Patients with criteria of rapid care alert (RCA) without treatment, cardiac arrest (CA), and unexpected ward deaths (UWD), during 2010.
Main variables: Age, sex, nursing shift, nursing alert, vital signs, unplanned admission to intensive care, CA, UWD and death.
Results: The MIS detected 9647 episodes with RCA signs in 4020 patients (26.4 episodes/day). A total of 8547 episodes were reviewed. Sixty-five patients required rapid response by the intensive care staff; 61.5% were detected in the afternoon shift (15:00–22:00), and 61.5% were admitted to the CCD. Diminished consciousness (DC) and respiratory failure were the most frequent problems. The sepsis rate was 23%. We reviewed 45 CA and 35 UWD. Of the total cases of CA, 33 patients died (73.3%) and 66.7% had criteria of untreated RCA. Monitoring (p < 0.05) and rhythms amenable to defibrillation (p < 0.002) were associated to survival. As regards the UWD, 75% had criteria of untreated RCA, and 40.6% presented diminished consciousness. In the last 6 months there was a significant reduction in UWD (p < 0.01).
Conclusions: The MIS could be a complimentary tool in the activity of the CCD to improve the prognosis of hospitalized patients.

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Introduction

Unexpected deaths and cardiac arrest (CA) episodes occurring in hospitals\(^1,2\) are often preceded by alarm signs.\(^3,4\) Likewise, unprogrammed admissions of hospitalized patients to the Critical Care Department (CCD) are usually preceded by alterations in vital signs that have not been detected and/or registered, and which have not received medical intervention.\(^5,6\)

It is clear that not all the technology of a CCD can be found in conventional hospital wards, but Medical Information Systems (MIS) currently allow the early detection of certain parameters that identify patients at risk of suffering serious adverse events.

The continuous work burden of Emergency Departments and the increased complexity of patients admitted to hospital are causing a rise in the proportion of admissions of patients at a high risk of developing serious disease susceptible to ulterior admission to the CCD.

Correctly understanding this problem allows us to consider possibilities for interprofessional and multidisciplinary collaboration not only with the medical specialties but also with other professional areas such as communications engineering. In fact, collaboration and coordinated clinical management constitute the basis for guaranteeing care continuity in a patient-centered structure or system. The development of computer programs offers a fast and easy way to detect variables indicative of physiological and laboratory test instability, with a view to detecting possible patients at risk.

The use of Medical Information Systems (MIS) in hospitals aims to improve the outcomes of the healthcare process, placing emphasis on safety and quality. The adoption of tools that allow us to manage the care of such patients can lead to a more efficient distribution of the existing healthcare resources, since they provide us in time with the information needed for optimizing decision making.\(^7\)

In Son Llátzer Hospital (Palma de Mallorca, Spain) we attempt to secure the integration of communication technologies for use in healthcare activities, with a view to increasing the quality of patient care and thereby improving survival and lowering the costs.

The main objective of the present study was to describe the implementation of an automatic MIS for detecting rapid care alerts (RCA) in hospitalized patients. Likewise, an analysis was made of the characteristics of the patients with CA and unexpected death.

Materials and methods

Study design

A prospective, observational cohort study was carried out covering the period between 1 January 2010 and 31 December 2010.

Study setting

Clinical and surgical hospitalization areas.

Study population

All patients admitted by the Emergency Department were evaluated. The inclusion criteria comprised individuals with...
criteria of RCA not subjected to treatment (or treated inad-
quately) and who required early intervention (within 12 h
following detection) by the Critical Care Department (CCD)
(Table 1). In-hospital cardiac arrests and unexpected deaths
were also evaluated.

 Patients admitted on a programmed basis for ambula-
tory major surgery, and patients with criteria of RCA treated
adequately by the ward physician, were excluded from the
study.

Table 1 Criteria of RCA activation – Son Llàtzer Hospital.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory frequency</td>
<td>&gt;30 rpm or &lt;8 rpm</td>
</tr>
<tr>
<td>Sudden change in heart rate</td>
<td>&lt;40 bpm or &gt;130 bpm</td>
</tr>
<tr>
<td>Sudden change in arterial pressure</td>
<td>&lt;80 mmHg or &gt;200 mmHg</td>
</tr>
<tr>
<td>Administration of VMK (Venturi mask)</td>
<td>≥ 50%</td>
</tr>
<tr>
<td>Sudden change in level of consciousness*</td>
<td></td>
</tr>
<tr>
<td>Seizures</td>
<td></td>
</tr>
<tr>
<td>Hemoglobin ≤ 7 g/dl</td>
<td></td>
</tr>
<tr>
<td>Potassium ≤ 3 mEq/l or ≥ 6 mEq/l</td>
<td></td>
</tr>
<tr>
<td>Lactate ≥ 4 mmol/l</td>
<td></td>
</tr>
<tr>
<td>pH ≤ 7.28; PaCO₂ ≥ 70 mmHg</td>
<td></td>
</tr>
</tbody>
</table>

* One-point decrease with respect to previous score on the
Canadian scale or two points on the Glasgow scale.

Principal study variables

Patients with criteria of rapid care alert not subjected
to treatment

Patient age and gender were recorded, together with the
nursing shift during which the event occurred, the nursing
alert, the cause and the criteria of RCA. The three nurs-
ing shifts comprised the following periods: a first shift from
08:00 a.m. to 15:00 p.m., a second shift from 15:00 p.m. to
22:00 p.m., and a third shift from 22:00 p.m. to 08:00 a.m.

Cardiac arrest

The demographic characteristics of the in-hospital cardiac
arrests were analyzed. Data collection was carried out fol-
lowing the Utstein guidelines.³

Unexpected deaths

Each month an analysis was made of all the deaths occurring
in the hospital center, differentiating expected or foresee-
able deaths (on the basis of disease evolution) from
unexpected ward deaths (sudden death or death occurring
as a result of an event that proved unexpected or was influ-
enced by a delay in diagnosis and/or treatment). Among the
unexpected ward deaths, avoidable death was defined as an
unforeseeable fatality with criteria of RCA not subjected to
treatment within the 12 h prior to the event, and in which
the fatal outcome might have been avoidable if treatment
had been provided. These deaths were reviewed by 5 physi-
cians unrelated to the physician in charge of the patient.
Classification as avoidable death required agreement among
all 5 physicians.

In the case of CA and in unexpected deaths we recorded
the criteria of RCA not subjected to treatment that were
not adequately detected or evaluated by the CCD or by the
ward physician.

Patient consent was not requested, since the study was
considered to comprise an emergency clinical situation. The
study was approved by the Research Ethics Committee of
both the Hospital and the Autonomous Community (Balearic
Islands, Spain).

Description of the Medical Information System

Son Llàtzer Hospital is a second level center with
450 functioning beds and a recruitment population of
250,000 inhabitants. It has been a pioneer in the
use of information systems in the hospital setting.
The system introduced in our center is the HP-HIS
(Hewlett-Packard), which allows us to manage all written
documentation, tests requests, and the reception of results
and images through an MIS. The use of this system has
resulted in digitalization of the case histories and nursing
graphic plots, with a link to the hospital laboratory.

During the year 2009 the hospital established an early
detection software network, and the medical and nursing
personnel of the center were trained in its use (Fig. 1).
Specifically, continued training was carried out in the form of
6 basic cardiopulmonary resuscitation ad defibrilliation work-
shops accredited by the Spanish National Cardiopulmonary
Resuscitation Plan. In these workshops the professionals
were made aware of the fact that the early detection of
alert criteria based on the electronic case history can pre-
vent cardiac arrest. Posters were developed and placed in
each hospital ward, explaining how to act in situations of
CA and detailing the alert criteria defining patients at risk
of suffering CA. Starting in January 2010 we introduced
the project for detection and intervention measures tar-
geted to patients presenting criteria of rapid care alert (RCA
project).

The MIS can be used by all the nurses and physicians of the
hospital (supervising physician, physician on duty, and inten-
sivist). It allows follow-up of all the hospitalized patients,
with early detection of those individuals presenting cer-
tain previously defined alterations. The nursing personnel
register the vital signs on the electronic chart. When the
entered variables fall outside the ranges defined as nor-
mal, or when the laboratory reports abnormal values, an
alarm indicator appears in the electronic case history of the
patient. The laboratory test criteria of RCA (hemoglobin,
potassium, lactate, pH, PaCO₂), respiratory frequency, heart
rate, Canadian or Glasgow score, arterial pressure, oxy-
gen concentration and pulsioxometry data are automatically
transmitted to a smartphone 24 h a day (carried by the
intensivist on duty) and to the workstation of the physi-
cian reviewing the system. When the patient presents well
defined criteria of a potentially serious clinical condition
(criteria of RCA), this information is transmitted by the
MIS to the mentioned workstation and smartphone 24 h a
day. The intensivists on duty check the case histories and
establish whether the alteration giving rise to the alert has
been detected and corrected. The responses to such mes-
ages have been protocolized, and action on the part of
the intensivist is obligate. If in the course of daily work the intensivist identifies a patient at risk, detailed clinical evaluation of the case is made with the supervising physician or the physician on duty, in order to decide the best course of action. This evaluation is carried out as soon as possible, and always within the first 12 h after detection.

Statistical analysis

The data were processed using the Statistical Package for the Social Sciences (SPSS) version 18.0. The Student's t-test was used for the comparison of means, while the chi-squared test or Fisher exact test was applied for the comparison of proportions. Multivariate analysis using stepwise variable selection logistic regression analysis was used only in the CA population, with introduction of the significant variables in the univariate analysis. Statistical significance was accepted for \( p < 0.05 \).

Results

A total of 17,991 patients were admitted by the Emergency Department during the period between 1 January 2010 and 31 December 2010. A total of 507 patients died in hospital (2.8%).

An analysis was made of the alerts transmitted online. During the study period, the MIS registered 9647 rapid care alerts (RCA) in a total of 4020 patients--this being equivalent to 26.4 alerts a day. Of these alert episodes, 1100 (11.4%) proved to be false (e.g., wrong automated arterial pressure recordings, or wrong respiratory frequency or oxygen saturation measurements). A final total of 8547 alerts were thus reviewed. Sixty-five patients (8 patients/1000 interventions) presented episodes with criteria of RCA requiring early intervention by the CCD either because adequate treatment had not been provided or because detection by the intensivist preceded action on the part of the ward physician (Table 2).

During the study period we registered 45 cardiac arrests (2.5 CA/1000 admissions); of these cases, 29 (64%) presented prior criteria of RCA that were either not treated or were not evaluated adequately by the CCD or ward physician. Of the patients who survived CA (12 cases), 58.3% (7 patients) had not received prior care referred to the observed RCA. Table 3 describes the demographic characteristics, establishing comparisons according to survival. In the multivariate analysis of the predictors of survival at hospital discharge among the patients who had suffered CA, including in the analysis those factors of statistical significance and of clinical relevance, we identified monitorization (odds ratio [OR]: 0.226; 95% confidence interval [95%CI]: 0.050–0.903; \( p = 0.045 \)) and cardiac rhythm amenable to defibrillation (OR: 0.5; 95%CI 0.009–0.134; \( p < 0.002 \)) as independent predictors of a good prognosis.

A total of 507 deaths were evaluated. We registered 35 unexpected deaths (6.9% of the total mortality), of which 32 occurred in the ward (UWD) and three in the CCD. Of the UWD, 24 (75%) were preceded by criteria of RCA not subjected to treatment or evaluated by either the CCD or the ward physician; two were preceded by criteria of RCA subjected to treatment; and 6 presented no criteria of RCA.

A total of 34.4% of the deaths (11 patients) were evaluated as avoidable deaths. In 9 patients with criteria of RCA not subjected to treatment (13.8%) and in 10 unexpected deaths (31.3%), the nurse had expressed concern to the ward physician regarding the evolution of the patient.

On comparing the two semesters of the year regarding the incidence of mortality and CA since the start of the project, a significant reduction in unexpected deaths was noted (OR: 0.404; 95%CI 0.194–0.842; \( p = 0.012 \)) in the second semester (Table 4).

Discussion

In the present study, a large percentage of cardiac arrests and unexpected deaths were preceded by criteria of RCA not
Table 2  Characteristics of the patients with RCA detected by the Critical Care Department, and of the unexpected ward deaths during the year 2010.

<table>
<thead>
<tr>
<th></th>
<th>Patients with RCA (CCD)(^a)</th>
<th>UWD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>65</td>
<td>32</td>
</tr>
<tr>
<td>Age (SD)</td>
<td>66.17 (16.33)</td>
<td>74.34 (9.61)</td>
</tr>
<tr>
<td>Gender; male, n (%)</td>
<td>36 (55.4)</td>
<td>29 (90.6)</td>
</tr>
<tr>
<td>Shifts, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:00–15:00</td>
<td>21 (32.3)</td>
<td>14 (43.8)</td>
</tr>
<tr>
<td>15:00–22:00</td>
<td>40 (61.5)</td>
<td>13 (40.6)</td>
</tr>
<tr>
<td>22:00–08:00</td>
<td>4 (6.2)</td>
<td>5 (15.6)</td>
</tr>
<tr>
<td>Reason for admission, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>9 (13.8)</td>
<td>2 (6.3)</td>
</tr>
<tr>
<td>Non-surgical sepsis</td>
<td>15 (23.1)</td>
<td>11 (34.4)</td>
</tr>
<tr>
<td>Post-surgery</td>
<td>9 (13.8)</td>
<td>9 (28.1)</td>
</tr>
<tr>
<td>COPD</td>
<td>3 (4.6)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>RCA, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treated</td>
<td>65 (100)</td>
<td>2 (6.3)(^b)</td>
</tr>
<tr>
<td>Not treated</td>
<td>0</td>
<td>24 (75)(^c)</td>
</tr>
<tr>
<td>Absence</td>
<td>0</td>
<td>6 (18.7)</td>
</tr>
<tr>
<td>Respiratory failure, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diminished consciousness, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursing alert, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypotension, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admission ICU, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28 (43.1)</td>
<td>16 (50)</td>
</tr>
<tr>
<td></td>
<td>11 (16.9)</td>
<td>13 (40.6)</td>
</tr>
<tr>
<td></td>
<td>9 (13.8)</td>
<td>10 (31.3)</td>
</tr>
<tr>
<td></td>
<td>4 (13.8)</td>
<td>6 (18.8)</td>
</tr>
<tr>
<td></td>
<td>40 (61.5)</td>
<td>11 (34.4)</td>
</tr>
</tbody>
</table>

SD, standard deviation; COPD, chronic obstructive pulmonary disease; UWD, unexpected ward deaths; CCD, Critical Care Department; ICU, Intensive Care Unit.

\(^a\) Patients requiring early intervention by the CCD.

\(^b\) Patients treated by the supervising ward physician.

\(^c\) Patients with criteria of RCA not adequately evaluated.

subjected to treatment. These results coincide with those obtained by other authors.\(^9\)-\(^12\)\(^a\) Prior, it is logical to assume that an intervention during this period of time can improve the patient prognosis. However, different studies evaluating rapid response systems have yielded contradictory results that may be a consequence of the application of different methodological designs.\(^13\)-\(^15\)

There are not data supporting the idea that teams led by physicians are more effective than those supervised by nurses. Such systems make use of apparently very costly resources.\(^14\),\(^15\) In a special article published in 2010 in this journal, Murias et al.\(^16\) conducted an exhaustive review of the advantages of Telemedicine, regarding it as a complementing tool capable of improving the medical care offered by intensivists. Recently, Gómez-Tello et al.\(^7\) underscored the importance of the introduction of Medical Information Systems in the CCD. Our study is new in that it involves utilization of the MIS for rapidly responding to alarm situations. In Son Llàtzer Hospital, implementation of the MIS for the detection of RCA in hospitalized patients has given rise to a considerable cultural change as regards patient safety, thanks to the training program for hospital nurses and physicians (including intensivists). Launching of the project did not imply increased resource utilization for the hospital, and made it possible to increase the activity of the CCD, due to the large number of patients detected by the system on a daily basis, which otherwise would not have been systematically reviewed. This increase in intensive care activity (with the assessment of 25 alert activations a day) has not required the assignment of added material or human resources giving rise to associated cost increments.

There is scientific evidence that early identification and intervention in clinical situations characterized by physiological instability can prevent cardiac arrest, deaths and readmissions to the SM.\(^17\),\(^18\) During the year of our study we recorded no decrease in the incidence of cardiac arrest. Monitorization and rhythms amenable to defibrillation were associated to an improved prognosis. These results are similar to those obtained by other investigators.\(^19\) A large percentage of patients with criteria of RCA not subjected to treatment or who were not adequately evaluated, and a large proportion of unexpected deaths, occurred during the first and second nursing shifts. These data suggest that we must intensify and improve our efforts to secure early care for such patients, offering monitorization and admission to the CCD where necessary, and must improve nursing and medical personnel training in the detection of high-risk patients in the ward.

In the present study, the intensivists considered it appropriate to decide admission for treatment or monitorization in the case of those patients with criteria of RCA requiring early intervention on the part of the CCD. This observation points to the importance of the adoption of new strategies by the Extended Intensive Care Services (EICS),\(^10\),\(^21\) with the purpose of improving morbidity–mortality through the early detection of high risk patients outside the ICU. In our
In conclusion, the studies in nurses, that consciousness, all of the study, to diminished fit to patients with criteria of RCA not subjected to treatment and unexpected deaths. Recently, the studies of Mitchel et al. and of the investigators of the MERIT and ANZICS studies concluded that it is of benefit to establish regular training programs for physicians and nurses, with a view to detecting these patients at risk and to secure early action. In our hospital, and in reference to all patients without life support limitations who require high oxygen concentrations (FiO2 > 50%) or suffer diminished consciousness, we have advised the physicians to examine each case jointly with the supervising physician, and to evaluate the advisability of early admission to the ICU. Future investigations in our field should attempt to unify the alert criteria and response times of the intensivists in an adequate cost-effectiveness scenario.

There is sufficient evidence that early intervention in patients with sepsis avoids progression to severe sepsis and septic shock. The clinical data suggest that those patients who develop sepsis in hospital wards may suffer a delay in treatment (fluid therapy, vasoactive drugs, antibiotic treatment, delayed admission to the CCD). In our study, sepsis was the etiology most commonly detected by the MIS. Although not the objective of our study, early transmission of the criteria of RCA through the MIS, and rapid action on the part of the CCD, could contribute to the early

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Demographic characteristics of the patient population with cardiac arrest during 2010.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Survivors 12</td>
</tr>
<tr>
<td>Age (SD)</td>
<td>68.25 (16.01)</td>
</tr>
<tr>
<td>Gender; male, n (%)</td>
<td>9 (75)</td>
</tr>
<tr>
<td>Location, n (%)</td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>Out-ICU</td>
<td>10 (83.3)</td>
</tr>
<tr>
<td>Work shift, n (%)</td>
<td></td>
</tr>
<tr>
<td>1st shift (08:00-15:00)</td>
<td>6 (50)</td>
</tr>
<tr>
<td>2nd shift (15:00-22:00)</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>3rd shift (22:00-08:00)</td>
<td>4 (33.3)</td>
</tr>
<tr>
<td>Monitored, n (%)</td>
<td>9 (75%)</td>
</tr>
<tr>
<td>Cardiac origin, n (%)</td>
<td>7 (58.3)</td>
</tr>
<tr>
<td>Cause of arrest, n (%)</td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>5 (41.6)</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>3 (25)</td>
</tr>
<tr>
<td>Others</td>
<td>4 (33.3)</td>
</tr>
<tr>
<td>Criteria of RCA not subjected to treatment, n (%)</td>
<td>7 (41.7)</td>
</tr>
<tr>
<td>Rhythm amenable to defibrillation, n (%)</td>
<td>9 (75)</td>
</tr>
<tr>
<td>Duration CPR (min) (SD)</td>
<td>4 (3.29)</td>
</tr>
<tr>
<td>Maneuvers, n (%)</td>
<td></td>
</tr>
<tr>
<td>Only massage</td>
<td>9 (75)</td>
</tr>
<tr>
<td>Only defibrillation</td>
<td>2 (16.7)</td>
</tr>
<tr>
<td>Both</td>
<td>1 (8.3)</td>
</tr>
</tbody>
</table>

SD, standard deviation; ICU, Intensive Care Unit.
* Criteria of RCA not adequately evaluated.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Incidence of mortality and cardiac arrest in the two semesters of the year 2010.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions Emergency Department</td>
<td>January–June 9051</td>
</tr>
<tr>
<td>Total deaths</td>
<td>264</td>
</tr>
<tr>
<td>Incidence/1000 admissions</td>
<td>29.17</td>
</tr>
<tr>
<td>Unexpected ward deaths</td>
<td>25</td>
</tr>
<tr>
<td>Incidence/1000 admissions</td>
<td>2.76</td>
</tr>
<tr>
<td>Avoidable deaths</td>
<td>10</td>
</tr>
<tr>
<td>Incidence/1000 admissions</td>
<td>1.10</td>
</tr>
<tr>
<td>Cardiac arrests</td>
<td>26</td>
</tr>
<tr>
<td>Incidence/1000 admissions</td>
<td>2.87</td>
</tr>
</tbody>
</table>
diagnosis and treatment of these patients, as evidenced by other authors.²⁹

Among the main limitations of our study, mention must be made of the lack of data referred to the period prior to introduction of the MIS. The availability of such information, and evaluation of the patients treated by the ward physicians, would have allowed us to assess the impact of the intervention. Mention also must be made of the lack of measurement of the response times on the part of the intensivists. Other limitations in turn may be related to divagation of the project among all the hospital nursing and medical personnel members, which in some cases undergo constant renewal. A study involving a larger number of patients is needed, with prolongation of the study period, in order to corroborate and consolidate our conclusions.

Conclusions

The present study shows that the MIS can be a promising complementary tool in the daily work of the CCD that may contribute to improve the prognosis of patients admitted to hospital wards.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Acknowledgements

The authors thank the interest, effort and dedication of the nursing team supervised by María Cano and Ana Pérez, the ward supervisors implicated in the project, the team of intensivists, medical personnel of the hospitalization wards, the medical personnel on duty, Medical Management and Informatics Department (supervised by María Ponseti). The RCA project would not have been possible without their collaboration. Our most sincere gratitude to all of them.

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