Can We Trust Open Source Software in Intensive Care

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Electronic Health Record: advantages

- precision,
- coherence,
- readability,
- presentation of data (simple)

Information technology must allow

- To enhance the quality of information
- The accurate and fast transmission of information
- To encounter specific needs
- To access patient's data where and when it is needed.
- To better treat the patient.


System powered by a database

- The data can be stored efficiently
- Past data can be retrieved by queries
- And the results combined to be analysed
- That can facilitate audit and retrospective (and prospective) studies.
These advantages are also expected in Intensive Care where we find

- High quantity of data
- High Turnover
- Need for safety
- Necessity of analysis and audit processes
Choice of the information system

- Commercial PDMS for Intensive Care with locking in proprietary software

- Use of Open Source Components and Software (OSS)


The aim of our realization

- Was initially to respond to the needs of our surgical Intensive Care Unit (12 beds)
- Actually, is to enhance the reliability of the system and allow the utilisation by several units in our CHU (30 beds)

The constrains: a limited budget (Scientific foundation not able to support costly licences)

The retained solution: use of Open Source Resources
The requirements were to realize a medical electronic record system with:

- The patient history
- Daily notes
- Medical prescriptions and orders
- Flow charts of bedside data
- Medical activity recordings
- Query for statistics, clinical audit and scientific studies.
Methodology used for the design and development

- Some modelling was performed based on
  > the environment study,
  > data flow and existing procedures analysis
- Powered by the open source PostgreSQL database
- The development follows a client server architecture with the client interface coded in C
- The actual upgrade uses Ada and SparkAda languages
The Intensive Care Environment includes
• A high number of workers

* High numbers of interventions for every worker

* Complexity due to simultaneous accesses

* Necessity for a daily and continuous processing.
The system is powered by

Relational database.

The database structure reflects the structure of the electronic health record.
The database structure
The system is based on a client-server architecture, the interface first developed in C is now upgraded in Ada.
The graphical interface uses the GTK library,

an object oriented library, developed in c,
open source,

available on several platforms and accessible from several programming languages (python, ada...)
The problem of C

- Debugging is difficult because
  - Of the language used
  - Of the clinical environment (« Critical »)
- Portability of C is limited

- The Upgrade of the system is based on
  the Ada et Spark ada
  heavy types languages
  allowing static analysis before compilation
  good portability of code sources.
SparkAda
Application functionalities

- Notes containing patient's history, observation and treatments
- (Flow charts for vital signs, in-out balances, ventilation parameters and settings)
- Prescription and medication administration
- Scoring possibilities for patient's classification
- Summary of Intensive Care hospitalisation
- Encoding of medical activities.
Application functionalities
Data analysis and retrospective study
Example of retrospective study: Review of factors affecting dialysis requirements

Potentially nephrotoxic antibiotic like Vancomycin have been incriminated as causes of increased need of hemodialysis in intensive care patients *

We wanted to evaluate the incidence of Vancomycin administered as continuous intravenous infusions on hemodialysis needs in our patients compared to others antibiotic agents.

For that purpose we reviewed the evolution of 1263 consecutive patients and analysed the effect of all antibiotics treatments on hemodialysis-hemofiltration (HH) requirements, using univariate and multivariate logistic regression. Data for these patients were extracted by queries on the database of the system.
Example of retrospective study:
Review of factors affecting dialysis requirements

37 patients of 1263 (2.9%) received HH. 549 (19.71%) patients received antibiotics.

At the univariate analysis, Vancomycin, Meropenem, Piperacilin-Tazobactam and Fluconasol treatments were significantly associated with the necessity of HH.
Example of retrospective study: Review of factors affecting dialysis requirements

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds Ratio</th>
<th>P value</th>
<th>95% CI (low)</th>
<th>95% CI (high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancomycin</td>
<td>4.75</td>
<td>0.002</td>
<td>1.78</td>
<td>12.70</td>
</tr>
<tr>
<td>Meropenem</td>
<td>5.67</td>
<td>0.006</td>
<td>1.65</td>
<td>19.48</td>
</tr>
<tr>
<td>Pip-Tazo</td>
<td>4.14</td>
<td>0.001</td>
<td>1.82</td>
<td>9.42</td>
</tr>
<tr>
<td>Diflucan</td>
<td>5.68</td>
<td>0.005</td>
<td>1.69</td>
<td>19.08</td>
</tr>
</tbody>
</table>

Vancomycin, Meropenem, Piperacilin-Tazobactam and Fluconasol treatments were also significantly associated with the necessity of HH at the multivariate logistic regression.
Example of retrospective study: Review of factors affecting dialysis requirements

The incidence of HH requirements following the use of Vancomycin was not significantly different (Pearson Chi-square, $p = 0.106$) from the incidence following the use of Meropenem, Piperacilin-Tazobactam and Diflucan also used in severe sepsis.

These results did not confirmed that our use of Vancomycin increases HH requirements more than other antibiotics used in severe sepsis.
Practical use of the application

- First use in February 2004
- Treatment of more than 4000 patients
- Integrity of data preserved
- Less than 5 hours interruption over one year
- Every day use
- Retrospectives studies
The application
Médical notes

Motif d'admission:
Hémotéorax après défibrillation

 Médecin traitant:

 Médecin référent:

Antécédents:

Allergies:

Adresse pour C2H5OH et passage à travers une vitre avec des plaques dans l'hyphothèque Dte et une hémotéorax

Adresse pour C2H5OH et passage à travers une vitre avec des plaques dans l'hyphothèque Dte et une hémotéorax

Adresse pour C2H5OH et passage à travers une vitre avec des plaques dans l'hyphothèque Dte et une hémotéorax

Adresse pour C2H5OH et passage à travers une vitre avec des plaques dans l'hyphothèque Dte et une hémotéorax
Notes edition

![Image of a computer interface for creating notes and medical records.](image)

- **Mots d'admission**
  - Médecin traitant
  - Renseignement personnel
- **Affection actuelle**
  - Scores
    - Glasgow Coma
    - Apache II
    - SOFA
  - Lung Injury Severity
- **État physique**
  - Évolution
  - Nouveau diagnostic
  - Bactérie

**Motif d'admission**

**Affection actuelle**

Admision aux urgences le 21/06/07 à 20h30 pour infarctus du myocarde (envoi par MT)

STEMI subaigu, malaise il y a 4 jours avec lipolymphe mail à l'hôpital d'Ostende.

Envoi aux urgences par le MT sur base de Trois Aigues.

Diagnostique d'une CIV sur récessive aiguë récente - Hypotension artérielle et surcharge pulmonaire.

**Note et examen**

Signature : [Signature]
### Scales and Scoring

#### Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E (Ouverture des yeux)</strong></td>
<td></td>
</tr>
<tr>
<td>Spontaneous</td>
<td></td>
</tr>
<tr>
<td>Open to voice</td>
<td></td>
</tr>
<tr>
<td>Open to painful stimuli</td>
<td></td>
</tr>
<tr>
<td>No response</td>
<td></td>
</tr>
<tr>
<td>Score: E = d</td>
<td></td>
</tr>
<tr>
<td><strong>V (Réponse verbale)</strong></td>
<td></td>
</tr>
<tr>
<td>Oriented to environment</td>
<td></td>
</tr>
<tr>
<td>Reactive to voice</td>
<td></td>
</tr>
<tr>
<td>Reacts to painful stimuli</td>
<td></td>
</tr>
<tr>
<td>Inappropriate responses</td>
<td></td>
</tr>
<tr>
<td>Don’t understand/Comprehension</td>
<td></td>
</tr>
<tr>
<td>Score: V = 5</td>
<td></td>
</tr>
<tr>
<td><strong>M (Réponse motrice)</strong></td>
<td></td>
</tr>
<tr>
<td>Ach to command</td>
<td></td>
</tr>
<tr>
<td>Eyes move to command</td>
<td></td>
</tr>
<tr>
<td>Face exhibits movement in pain</td>
<td></td>
</tr>
<tr>
<td>Limp or abnormal movements in flexion</td>
<td></td>
</tr>
<tr>
<td>Non-opera or intervention urgent</td>
<td></td>
</tr>
<tr>
<td>Score: M = 6</td>
<td></td>
</tr>
</tbody>
</table>

#### Other Scales

**Apache II Score**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value Min</th>
<th>Value Max</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature rectal (°C)</td>
<td>37.0</td>
<td>37.0</td>
<td>0</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>RR (bpm)</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>SpO2</td>
<td>95</td>
<td>95</td>
<td>0</td>
</tr>
<tr>
<td>pH arterial</td>
<td>7.40</td>
<td>7.40</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>40</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>45</td>
<td>45</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>55</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>60</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
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<td>65</td>
<td>0</td>
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<tr>
<td>PCO2 (mm Hg)</td>
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<td>70</td>
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<tr>
<td>PCO2 (mm Hg)</td>
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<td>75</td>
<td>0</td>
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<tr>
<td>PCO2 (mm Hg)</td>
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<td>0</td>
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<tr>
<td>PCO2 (mm Hg)</td>
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<td>85</td>
<td>0</td>
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<tr>
<td>PCO2 (mm Hg)</td>
<td>90</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>95</td>
<td>95</td>
<td>0</td>
</tr>
<tr>
<td>PCO2 (mm Hg)</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**Score Apache**

- Score: 0
Prescription
Medication administration
## Vital signs

<table>
<thead>
<tr>
<th>Time</th>
<th>TA syst</th>
<th>TA diast</th>
<th>TA moy</th>
<th>RC</th>
<th>PVC</th>
<th>SNaO2</th>
<th>FAP syst</th>
<th>FAP diast</th>
<th>FAP moy</th>
<th>PAO</th>
<th>SvO2</th>
<th>Débit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120</td>
<td>95</td>
<td>115</td>
<td>101</td>
<td>104</td>
<td>108</td>
<td>125</td>
<td>158</td>
<td>100</td>
<td>121</td>
<td>109</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>79</td>
<td>71</td>
<td>77</td>
<td>70</td>
<td>71</td>
<td>73</td>
<td>77</td>
<td>64</td>
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<tr>
<td></td>
<td>91</td>
<td>76</td>
<td>86</td>
<td>77</td>
<td>77</td>
<td>86</td>
<td>97</td>
<td>73</td>
<td>66</td>
<td>66</td>
<td>66</td>
<td>66</td>
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<td>2</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>56</td>
<td>58</td>
<td>100</td>
<td>100</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Note:** The table above displays vital signs such as blood pressure (TA syst, TA diast, TA moy), respiratory rate (RC), heart rate (P), and other related physiological parameters measured at various time intervals.
Centre Hospitalier universitaire Brugmann
Soins Intensifs Chirurgicaux

Soins Intensifs Chirurgicaux,
CHU Brugmann,
4 Place Van Gehuchten,
H921 Brussels.
Tel. 02/4772335

Professeur Jacques Mues, Chef de Clinique.
Docteur Pascal Regier, Chef de Clinique Arrêté.

Bruxelles le

Résultat de l’observation de Mme ******* ******* née le 1929-12-26,
admissée à l’USI chirurgicale le 2007-08-04 12h18.
Billet de lit : *******.

MOTIF D’ADMISSION :
débatte respiratoire

LISTE DES DIAGNOSTICS :
- traitement respiratoire éOPA.
- Embolie pulmonaire sur TVP.

TRAITÉ ACTUEL :
Prescription 0819 08 08
Accessibility

At desks and at the bedside
The actual upgrade must allows

- A better integration with others medical applications
- Multi-platform capabilities
- Enhancement of stability and Security and Identification
- Conviviality of the client interface
- To deserve several units
- or departments
Multi platform upgrade
More convivial
And better integrated
Conclusions:

- The system developed from open source components is effective and able to respond to requirements of intensive care environments.
- By the use of open source components we were able to adapt the software to the pre-existing organisation at low cost, facilitating the acceptability by the staff.
Conclusions:

- The knowledge of the database structure allowed us to conduct retrospective clinical studies based on data queries and analysis.
- Of course the system is far from perfect and does not cover all the domains of intensive care, but is robust and effective.