Health Care Manage Sci (2008) 11:139–146
DOI 10.1007/s10729-008-9059-6

# Managing an emergency department by analysing HIS medical data:a focus on elderly patient clinical pathways

**Delphine Rossille · Marc Cuggia · Aude Arnault · Jacques Bouget · Pierre Le Beux**

Received: 11 February 2008 / Accepted: 12 February 2008 / Published online: 18 March 2008


**Abstract**
*Introduction* The objective of this paper is to present complementary views of the activity of the emergency department for a specific group of patients. Once validated, these views will be used as decision support tools for better managing the department and providing better care delivery for this population. The views are produced from the data stored in Healthcare Information Systems that correspond potentially to a vast source of information for supporting decisions on management or public health issues.
*Method* The study focuses on two groups of patients: the elderly population (over 75 years old) and the under 75 year old patients, at the Rennes hospital. The validation of the views is performed by comparing results for the two distinct groups. Relevant data were extracted from the Emergency Department database. Several analysis (like cusum chart) and representation tools (Graphviz) were used to study the patients' pathways, the dynamics of arrivals and the patients' characteristics.
*Results* The representations provided a synthetic, global and comprehensive view of the department activities, to the satisfaction of the clinicians. The study showed that ICD-10 coding, assigned at the patient's departure from the emergency department hence from all available known clinical data, is not appropriate for the elderly population as these patients are mainly diagnosed by "symptoms" and several solutions are proposed. Finally, it is stressed out that a proper delivery of care to elderly patients should require some level of scheduling in the emergency department that is by essence characterized by its non scheduled activity.

**Keywords** Management information systems · Emergency service · Hospital · Critical pathways · Decision making · Computer-assisted

## 1 Introduction

Traditionally, scheduled activities in a hospital differ from non scheduled activities. In the case of scheduled medical activities, the patient's caring and the required resources can be anticipated. The Emergency Department (ED) is by essence representative of non scheduled activities. A non negligible part of the incoming patients at the emergency department are elderly patients. These patients, in opposition to younger patients, are fragile due to poly-pathologies and medico-social problems. Sometimes patients are sent to the emergency department as a way to force their hospitalisation, and the emergency department has to find solutions appropriate to their illnesses, one of them being to send them afterwards to external nursing homes. However nowadays there is a lack of available beds in nursing homes and it is most important to be able to anticipate such demands by the emergency department. Therefore the

D. Rossille · M. Cuggia · P. Le Beux
Faculté de Médecine, Université de Rennes1,
Rennes EA3888, France

A. Arnault
ENSAI,
Bruz, France

J. Bouget
Service de l'accueil des Urgences, CHU Pontchaillou,
Rennes, France

M. Cuggia (✉)
Département d'information médicale, CHU Pontchaillou,
2, rue H. Le Guilloux,
35033 Rennes Cedex, France
e-mail: marc.cuggia@univ-rennes1.fr

emergency department is interested in better knowing the characteristics of this population in order to anticipate their global caring in the most appropriate manner.

The objective of this paper is to present a set of decision support tools appropriate for analysing the overall activity of an emergency department with regards to the caring of one specific group of patients. These tools must be comprehensive and pertinent to the department's managers and health professionals. In order to provide a global view of the characteristics of the patients, the group of patients will be described by different complementary representations. The descriptions are expected to be used to help better manage the department and provide more adequate caring according to the group of patients.

The population characteristics will be derived from the Hospital Information System. While the very first data to be computerized were for the financial and administrative departments, clinical data are now stored in the hospital information system. They are collected in databases in a day-to-day basis, are exhaustive, up-to-date, with a fine granularity and in a storage format easing their exploitation. These databases provide unprecedented sources of exhaustive and precise data making possible to have a complete picture of the incoming population, while in the past only retrospective studies from paper-based files or prospective studies on selected patients were to be used. The reports will exploit these data, highlighting their limits and advantages.

The present study focuses on the care delivery to the group of elderly patients (aged 75 or over) in the ED of the Rennes hospital. It is well known that the current conditions of hospital care of elderly patients are not satisfactory: waiting time at the ED is usually too long and patients are not always transferred to the hospital departments relevant to their conditions. The situation becomes worse in times of crisis, such as during the long spell of very hot weather in the summer of 2003 when the ED could not handle the patients flow and an unexpectedly high mortality rate was reached. In this context, the emergency department is in demand of better understanding its activity related to elderly patients, especially in terms of patient pathways.

## 2 Background

Data produced by hospital information systems have been exploited for decision support on medical, management or public-health issues.

Several medical decision supports systems have been implemented in order to support clinicians in their clinical practice, from simple to "expert" systems. In the emergency department settings [1], reported on how well two general decision support systems (Quick Medical Reference and Iliad) can parallel physician decision making for diagnosis, given the data collected in the emergency department.

Other decision support systems provide insights on management issues by helping coordinating, allocating resources, and documenting emergency department operations [2]. Some focus on the triage process and help prioritize incoming patients. For instance, the MET-AT system [3] provides triage plans for acute paediatric abdominal pain. Others propose methods (based on the cumulative sum chart) to manage hospital bed occupancy crisis [4].

Finally, several papers relate experiences of exploiting data for public-health purposes. In Sydney [5], Australia, during the 2003 Rugby World Cup in a context of bioterrorism threats and emergent diseases, national public health authorities tested a near real-time syndromic surveillance system. In this system, EDs in the Sydney metropolitan area automatically transmitted surveillance data from their existing information systems to a central database in near real-time. These information included patient demographic details, presenting problem and nursing assessment entered as free-text at triage time, physician-assigned provisional diagnosis codes, and status at departure from the ED. Automated processes were used to analyse both diagnosis and free text-based syndrome data and to produce web-based statistical summaries for daily review. An adjusted cumulative sum (cusum) and Bayesian methods were used to assess the statistical significance of trends. In France, at a national level, the Heat Health Watch Warning System [6] was developed in 2003 to anticipate heat waves that may result in a large excess of mortality. The system was developed on the basis of a mortality analysis, healthcare activities in EDs and meteorological data. Several meteorological indicators were tested in relation to levels of excess mortality. The system requires close cooperation between the French Weather Bureau (Météo France), the National Institute of Health Surveillance and the Ministry of Health. The system is supported by a panel of preventive actions, to prevent the health impact of heat waves.

Such systems illustrate the current interest in exploiting healthcare data for public health, management and medical purposes. They rely on information whose format and sources are heterogeneous.

## 3 Materials and methods

The choice of the emergency department was motivated by its central dispatching role in the hospital and the daily contribution of medical records in its clinical database. The two groups of patients selected for this study are the elderly patients (aged 75 and over) and the under 75 year old patients. The choice of the age of 75 was proposed by the clinicians of the emergency department who strongly feel in their practice a difference of care delivery from that age on. The elderly population was chosen as it represents an ever increasing part of the population in developed countries.

The emergency department at Rennes is divided into three services: medicine, surgery and small traumatology. A proximity unit (named Duhamel ward), attached to the emergency department, is aimed for patients needing to stay in observation or to wait for an available bed in an appropriate hospital department (theoretically for a maximum of 24 h).

### 3.1 Materials

Data were extracted from two databases: *RESURGENCE*, the ED clinical database and *DRG*, the medico-economic database produced by the HIS. The clinical medical records include general data (s.a. sex, age), data on arrival, departure and transfer (s.a. arrival mode), data on the follow-up at ED, on the diagnoses and medical status. Medico-economic data include ICD-10-coded diagnoses, medical procedures (coded with a French classification named CDAM), date of hospitalisation and the various hospitalisation departments where the patient went. The ICD-10 coding is based on all available clinical data stored in the patient's record at the patient's departure from the emergency department. Only inpatients appear in the medico-economic database. All the extracted data are limited vocabularies.

The period of study is from October 2005 to May 2006. During these 6 months, 32,883 patients came to the emergency department, 4,951 were aged 75 or over.

### 3.2 Method

The objective was to provide descriptive representations of the care delivered to a subgroup of the population admitted at the emergency department. To this end, different views or representations of the activity were applied and compared on two different groups of patients: the under 75 year old patients and the over 75 year old patients.

The relevant data were first extracted from the HIS databases and their quality controlled. Static characterization was provided by descriptive statistics, such as the percentage of the population of interest with respect to the day of the week and the diagnoses.

The dynamics of the arrival rates at the emergency department was displayed by a cusum chart. The cusum chart displays the cumulative sum of consecutive differences between an individual measurement and a selected target. In the article, we applied it to the daily arrivals compared to its mean over the studied period. The cusum chart has been widely used in the industry for Statistical Process Control since the 1950s. It aims at detecting small drifts from the process mean, hence quickly detects gradually developing outbreaks more easily than autoregressive integrated moving average (ARIMA) models. ARIMA models "adjust" to outbreaks hence will miss a slowly spreading outbreak [7]. Furthermore ARIMA models require long historical data, that we don't have as we studied the first 6 months of electronically recorded ED data. The cusum technique has been applied to monitor healthcare processes in particular for surveillance [5, 8].

Patient pathways within the emergency department characterized spatially the group of patients. After having pre processed the data according to a new arrangement of the operational structures, patterns of patient pathways were displayed using the visualization tool Graphviz (www.research.att.com/sw/tools/graphviz/). The chosen visualization tool provided a global representation of the most frequent (and typical) pathways for the population, giving insights on the use of the different ED wards as well as on the waiting times.

## 4 Results

The demographic study shows that the admitted elderly population is representative of the elderly in France and corresponds to 15.1% of the total number of patients admitted at the ED, the national percentages being between 15% and 17%.

### 4.1 Characterisation of the population

The *percentage of patients present during day time or night time versus the week day* (Fig. 1) shows that more than 80% of the elderly patients come during day time (8 A.M. to 10 P.M.) whatever the week day while the under 75 year old patients

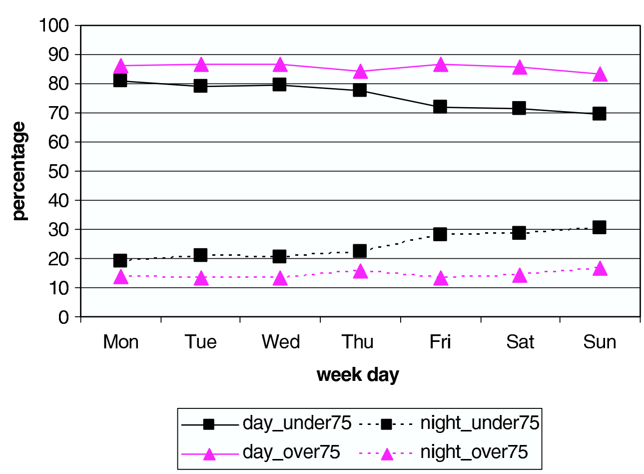


**Fig. 1** Percentage of patients present during the day time or night time versus week day

have a different behaviour according of the week day, arriving at the emergency department more frequently at night (10 P.M. to 8 A.M.) during week ends.

Analysing the distribution of the *diagnoses* (Fig. 2) as a function of the ICD-10 main chapters (www.icd10.ch/; Table 1), the three most represented principal diagnoses at the ED for elderly patients, are Chapter 18 "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified" (22.7%), Chapter 19 "Injury, poisoning and certain other consequences of external causes" (20.9%) and Chapter 9 "Diseases of the circulatory system" (13.3%). More precise diagnoses for the three principal diagnoses for the elderly patients show that 48.5% of the diagnoses related to Chapter 18 correspond to "General symptoms and signs", that is almost 11% of the elderly patients are diagnosed by non specific pathologies.

In comparison, the distribution of the diagnoses for patients under 75 (Fig. 2) shows clearly that the most frequently diagnoses coded corresponds to Chapter 19 "Injury, poisoning and certain other consequences of external causes" for 45.8%, then at around 10% are used diagnoses of Chapter 5 "Mental diseases and behavioural comportment" and Chapter 18 "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified". 21.4% of the diagnoses related to Chapter 19 correspond to "injuries to the wrist and hand", 10.3% to "injuries of scalp" and 9.3% to "injuries to the ankle and foot".

## 4.2 Dynamics of arrivals

The temporal characteristics of patients over the 6 month period can be displayed by a cusum chart. Figure 3 shows the arrivals at the emergency department per date for patients over and under 75. For the purpose of better displaying each group of patients on the same graph, arrivals were normalized and the mean of the arrivals of patients over 75 was artificially set to 3. As the curve is not

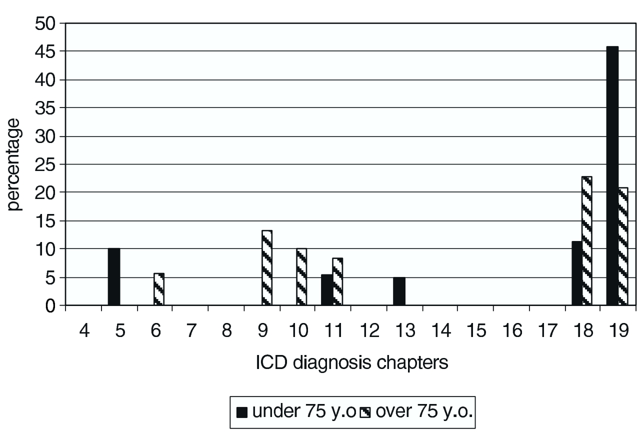


**Fig. 2** Distribution of the principal diagnoses at ED for both groups of patients (only values greater or equal to 5% shown)

**Table 1** Labels of main ICD10 chapters for ED patients (International statistical classification of diseases and other health related problems)

| Chapter | Title |
|---|---|
| Chapter 5 | Mental and behavioural disorders |
| Chapter 6 | Diseases of the nervous system |
| Chapter 9 | Diseases of the circulatory system |
| Chapter 10 | Diseases of the respiratory system |
| Chapter 11 | Diseases of the digestive system |
| Chapter 13 | Diseases of the musculoskeletal system and connective tissue |
| Chapter 18 | Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified |
| Chapter 19 | Injury, poisoning and certain other consequences of external causes |

easily interpretable (Fig. 3), a cusum chart was preferred as it provides a comprehensive and easily readable view of the variations (Fig. 4). Indeed, an increasing slope represents the cumulative deviations from the mean of the arrivals, and inversely. Hence it can detect very small shift from the mean. From Fig. 4 are highlighted three periods of increased arrivals for elderly patients (mid December/mid January and February, hence winter time, and April) while arrivals for under 75 year old patients were constant in the fall (equivalent to its mean), dropped early January then increased during the spring.

## 4.3 Patient pathways

The emergency department found it very valuable to have a (temporal and spatial) view of the use of the different medical and non medical wards by specific groups of patients. These patient pathways within the emergency department were chosen to be represented visually by oriented graphs using the GraphViz tool (www.research.att.com/sw/tools/graphviz/). A "step" consists of one of the four ED wards or an exit mode. At each step is given the median waiting time. Each branch of the graph displays the percentage of the patients following this path between the two nodes, 100% referring to the father node. The width of a

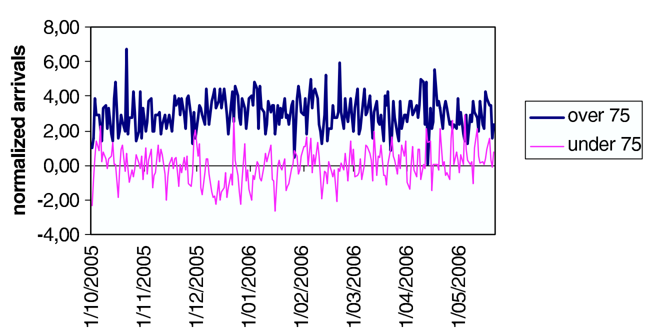


**Fig. 3** Number of normalized arrivals per date for patients over and under 75

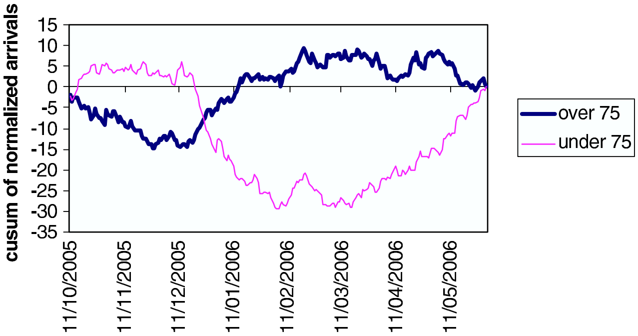


**Fig. 4** Cusum chart of normalized arrivals per date for patients over and under 75

branch is proportional to the percentage, easing the interpretation and reading.

Figure 5 provides the representation of the patient pathways for the elderly population. Only pathways of type <triage–step 1–step 2> are considered. They represent alone 82.7% of the total patient pathways. The pathways not represented correspond to complex pathways of more than three steps, or to pathways taken by very few patients. The most followed pathway corresponds to <triage–medicine service–exit> (49%, represented in red). Then come the pathway <triage–surgery service–exit> (30%, in grey), far behind <triage–traumatology service–exit> (2.42%, in yellow) and <triage–exit> (0.67%, in blue).

For the group of patients under 75 (Fig. 6), the pathway <triage–surgery service–exit> is the most frequently used (39.1% in grey), then are the pathways <triage–medicine service–exit> (26.7% in red) and <triage–traumatology service–exit> (20.8% in yellow). Comparing the two graphs shows that a significant care delivery for patients under 75 is at the traumatology service, in accordance with their most frequent diagnosis coded (Chapter 19).

## 5 Discussion

The study showed that the vast source of medical data stored for healthcare purposes in the HIS databases can provide valuable insights to the clinicians in a comprehensive and straightforward manner. Indeed, the working group in charge of the reorganisation of the emergency department at the hospital level used the results to propose new

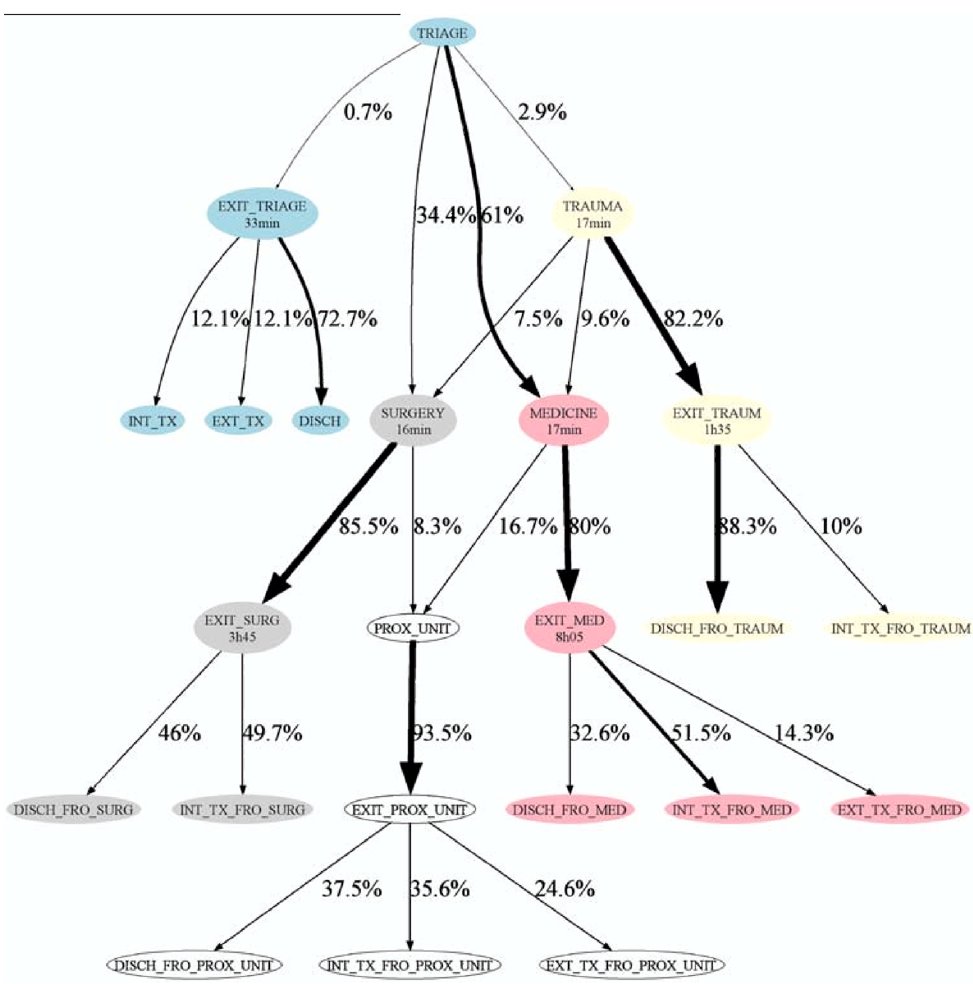


**Fig. 5** Patients' pathways at the emergency department—group of patients over 75

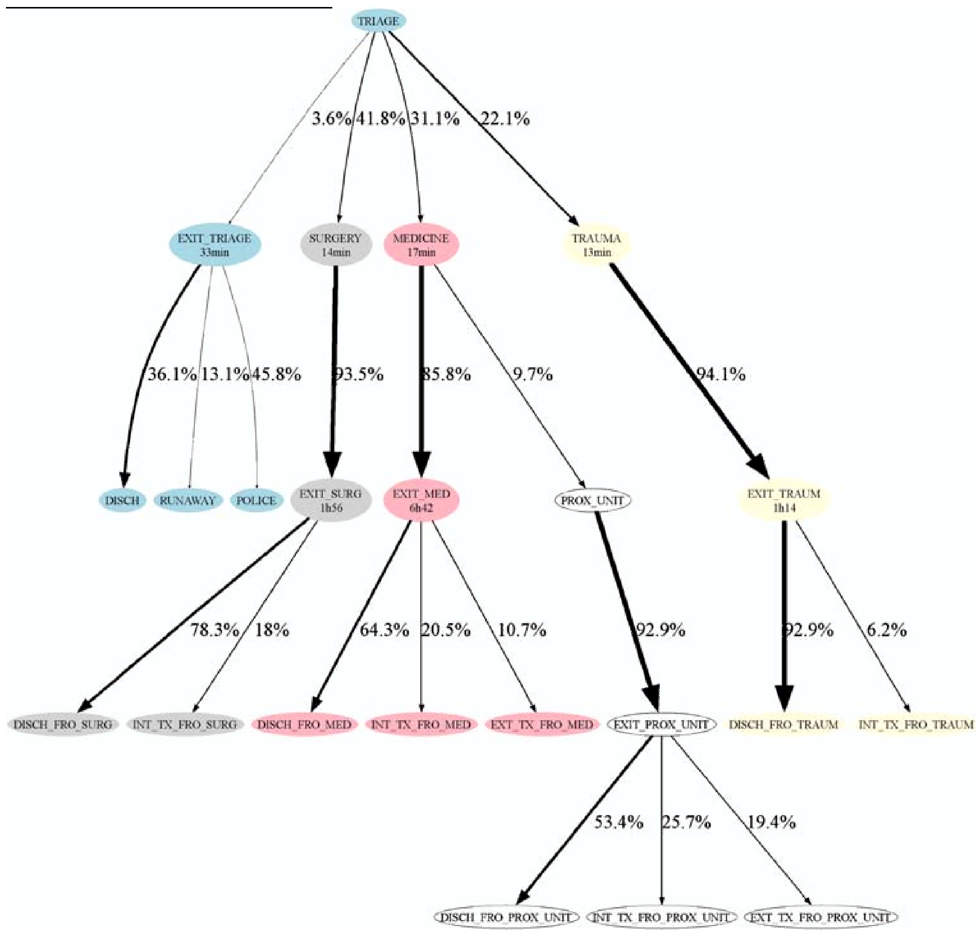


**Fig. 6** Patients' pathways at the emergency department—group of patients under 75

organisations aiming at optimizing the patients' care, especially for elderly patients. Highlighting (with statistics) the excessive waiting time of some pathways (like <triage–medicine service–exit>) led to faster transfers from the ED to hospitalization departments, as soon as the diagnosis was given without waiting for all the exam results. Hence these views can be used as decision support tools for delivering better care to specific populations, from a tuned management of the resources (health professionals and use of the medical wards) to the adequate delivery of care from before, during and after their coming to the hospital (for instance, by reducing waiting time for this population or providing appropriate social assistance to the patient and the accompanying persons).

Thanks to the representation tools used, the patients' characteristics, the dynamics of arrivals and the patients' pathways provide a multifaceted and complete view of the emergency department. The patient pathways were particularly of interest to the clinicians at the emergency department as it provided for the first time a temporal and spatial representation of the activities of the various medical wards, for a specific group of patients. However many pathways had a frequency of almost one. It was decided to represent graphically only the most important pathways in terms of percentage. Hence a subjective threshold was applied to patients' pathways. The threshold could have been calculated using the statistics of the Galois lattice [9]. A Galois lattice is a multi-faceted tool for designing hierarchies of concepts: it allows the construction of a hierarchical structure both for representing knowledge and for reasoning from data. This data mining technique has been used to automatically determine patients' pathways in healthcare networks [9]. The threshold is automatically selected to only display representative pathways. However produced graphs are much more difficult to interpret by health professionals than the proposed GraphViz representation, due to the Galois lattice's construction logic.

Limitations of the exploitation of healthcare data appear to lie on the use of ICD-10 coding for diagnoses. Indeed, for elderly patients, the most frequently-used code for diagnoses at the ED corresponds to "Symptoms and general signs" of Chapter 18 of ICD10 "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified". Determining precise diagnosis at the ED is often difficult as for instance several complementary exams may be required whose results may not be available before the diagnosis is made. Priority is first of all to deal with acute situation, to start symptomatic treatment and to transfer the patient to the more appropriate hospitalisation department when needed. It is not surprising that ED clinicians often code the symptoms (for example abdominal pain, migraines) instead of precise diagnoses. However the ICD-10 is primarily intended to classify diseases while the symptoms are described only in one chapter out of 22, therefore not being linked in any way (into the ICD-10 structure) to the underlying disease.

To solve this problem of coherency of ICD-10, a recent work suggests SNOMED CT® to be the coding reference. SNOMED CT® (www.snomed.org/) is a clinical terminology of more than 370,000 concepts, aiming to be the common computerized language in clinical practice so to ensure consistency between healthcare systems. It has the ability to create new concepts by combining its own concepts. Hence SNOMED CT® has a higher expressiveness than ICD-10 coding. A comparative study within the UMLS showed that SNOMED CT® covers better the needs for coding medical records in the emergency department [10]. Another paper [11] showed that better semantic coherency is possible with SNOMED CT® when comparing diagnoses codes at the different steps of the patient pathway in the hospital.

### 5.1 Perspective

One of the objectives of this study was to see if, by exploiting the clinical and medico-economic data, it was possible to help the emergency department detect activities that could be scheduled, by opposition to non scheduled ones. This point is of particular importance for delivering care to the elderly population. As the study showed, the diagnoses for elderly patients being most of the time coded by “Symptoms” and its variants, the current classification is not appropriate for this group of patients. Furthermore this classification does not include a medico-social dimension which is often present for these patients (related for instance to the degree of dependence). In order to better care for this population, a solution could be either to look for a more adequate coding system (SNOMED CT® for instance) or enhance the database by collecting specific items (indicators) s.a. for instance the presence of the family of the patient. The final objective would be for the emergency department to be able to anticipate the appropriate exit mode as soon as the elderly patient arrives.

## 6 Conclusion

The objective of the paper was to propose different complementary views characterizing a specific group of patients and to confirm their usefulness as a first step before using them as decision support tools for management issues and care delivery. These views had to be easily interpretable by clinicians and managers. The validation was performed on two groups of the patients: the elderly population and the under 75 year old patients. The views were produced from data collected during healthcare processes in the hospital information system.

The results point to the fact that providing a synthetic and global view of the department’s activities, thanks to appropriate representation tools comprehensive to clinicians, is particularly relevant for the department’s manager and clinicians. This was possible thanks to the daily storage of clinical data on each patient coming to the emergency department. Indeed the various views give insights into the needs of elderly people in contrast to younger ones and it validates the assumption of clinicians about differences in needs of elderly patients.

The discussion points out that the ICD-10 coding system is not appropriate for characterizing the elderly population. Furthermore it limits considerably the scaling of the application to the hospital level, as issues of syntaxic and semantic interoperabilities have to be considered. Finally, it is stressed that proper delivery of care to elderly patients should require some level of scheduling in the emergency department that is by essence characterized by its non scheduled activities. Scheduling would be required for example for placement in nursing homes, for planning on specially trained staff or organizing the department according to the patients and the time of year.

## References

1. Graber MA, VanScoy D (2003) How well does decision support software perform in the emergency department. Emerg Med J 20 (5):426–428, Sep
2. Ceglowski R, Churilov L, Wassertheil J (2005) Facilitating decision support in Hospital Emergency Departments: a process-oriented perspective, in Proceedings of the 13th European Conference on Information Systems. Regensburg, Germany
3. Farion KJ, Michalowski W, Rubin S, Wilk S, Correll R, Gaboury I (2008) Prospective evaluation of the MET-AP system providing triage plans for acute pediatric abdominal pain. Int J Med Inform 77 (3):208–218
4. Burns CM, Bennett CJ, Myers CT, Ward M (2005) The use of cusum analysis in the early detection and management of hospital bed occupancy crises. Med J Aust 183:291–294
5. Muscatello DJ, Churches T, Kaldor J, Zheng W, Chiu C, Correll P, Jorm L (2005) An automated, broad-based, near real-time public health surveillance system using presentations to hospital Emergency Departments in New South Wales, Australia. BMC Public Health 5:141
6. Pascal M, Laaidi K, Ledrans M, Baffert E, Caserio-Schonemann C, Le Tertre A, Manach J, Medina S, Rudant J, Empereur-Bissonnet P (2006) France’s heat health watch warning system. Int J Biometeorol 50:144–153

7. Shtatland E, Kleinman K, Cain E (2006) Biosurveillance and outbreak detection using the ARIMA and logistic procedures, SUGI'31 Proceeding, San Francisco, CA, USA, March 26–29
8. Sibanda T, Sibanda N (2007) The cusum chart method as a tool for continuous monitoring of clinical outcomes using routinely collected data. BMC Medical Research Methodology 7:46
9. Jay N, Napoli A, Kohler F (2006) Cancer patient flows discovery in DRG databases. Stud Health Technol Inform 124:725–730
10. McClay JC, Campbell J (2002) Improved coding of the primary reason for visit to the emergency department using SNOMED. Proc AMIA Symp pp. 499–503
11. Elkin PL, Ruggieri AP, Brown SH, Buntrock J, Bauer BA, Wahner-Roedler D, Litin SC, Beinborn J, Bailey KR, Bergstrom L (2001) A randomized controlled trial of the accuracy of clinical record retrieval using SNOMED-RT as compared with ICD9-CM. Proc AMIA Symp, pp. 159–63