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Keywords: Emergency department, Workflow, key performance indicators, overcrowding situation, Patient pathway

Abstract: The overcrowding situation in emergency department is serious problem worldwide. In fact, the majority of developing countries are interested in developing their hospital system in order to anticipate the overcrowding situations and ameliorate the quality of patient care. In this paper, we focus on patient pathway in an Adult Emergency Departments (AED). This process presents the main burden for overall system operation due to its growing dynamics and the distributed organizational structure of hospitals. In order to determine the key performance indicators for the internal functioning of AED, we are building a workflow model based on the real patient pathway to direct the patients into the dedicated service while respecting the quality of care according to the expectations and requirements of the patient. Our approach is tested on a set of real database from AED of CHRU in Lille (France). Simulation results show that the proposed model can determine 3 keys performances indicators to optimize in order to improve the patient pathway in the AED.

1 INTRODUCTION

The ultimate goal of health care systems is to provide accurate, effective and rapid treatment of patients (Kırış et al. 2010), particularly in emergency departments (ED). ED was first recognized in the 20th century (MD et al. 2005). In France, and in the world, ED provides primary health care to patients whose diseases or symptoms require immediate attention and in some cases can put the patient life in danger.

In this paper we will focus only on the Adult Emergency Department (AED) of CHRU of Lille (city of north of France). From an outside view, an emergency service should be organized as an anthill. That is, the reception and treatment of emergencies are thought and coordinated. Consequently, the functioning in the emergency services must be perfectly organized and the team spirit particularly present. However, from a closer view the internal functioning of healthcare establishments in general and of ED in particular is much more complicated to master. Among the major problems of this system we can find, on the one hand, the lack of coordination between the various services or even in the same department and on the other hand the problem of the complexity of the patient pathway management, since an ineffective patient treatment procedure can unfortunately lead to pernicious results.

Part of the complexity of this care system is that the arrival time of the patients and their pathologies are impossible to predict. In addition, we have an incoming flow that is totally random. So in order to improve the efficiency of the service by identifying several performance indicators, we have to develop a reliable model of patient pathway in order to identify the key factors of dysfunction of the AED. The fig 1 summarizes the patient pathway from the moment of his arrival in AED until his first medical consultation "taken care by doctor". So after a significant waiting period depending on the crowding status of the AED and the urgency of the patient case, the patient is finally taken in charge by a doctor.

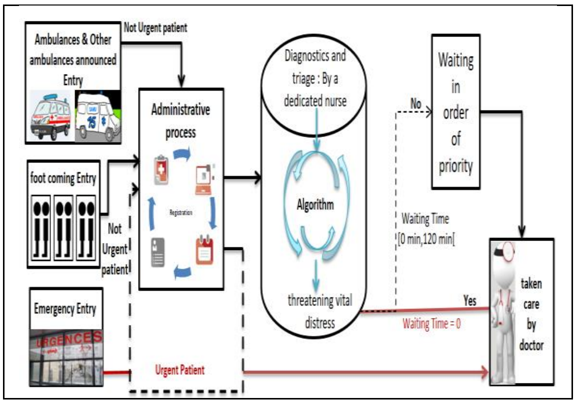


Fig 1. Patient care pathway

2 STATE OF THE ART

In order to improve the process of patient care in AED, as well as to optimize medical staff care activities, it’s necessary to model the real patient pathway within the department studied. The idea is to orient patients to the dedicated service, allowing us to trace the flow of information and to kwon the material occupied in the service. Obviously maintaining a regular flow of information is the key to take a good decision for system evolution, hence the interest of setting up a connected Workflow system.

In the literature, the most adequate definition of Workflow for our work is given by (Thomas, n.d. 1995):“Workflow management is done by a proactive system for the management of a series of tasks which are transmitted to the appropriate participants in the right order and which are completed under allocated time”. The application of this definition in the hospital system has been successful, which rendered the health system a very active area of research (RJ Salway et al. 2017), (Andrew S et al. 2018). The majority of this research has addressed about the subject of providing an efficient health care system for the patient and ensuring its continuity for the next generation (Chen et al. 2014) (Wan et al. 2013) (Hossain. 2017). Thus, this system has undergone several changes over time, due to the advancement of technology up to the application of the smart home (Chen et al., 2014) (Deen, 2015) (Saleem. 2015). (Bricon-Souf et al. 1999) used the Workflow system to model productive work in the intensive care unit, explaining that the flexibility of this system is crucial. (van der Aalst et al., 2003) proposed a Workflow mining, in order to facilitate the conception of the Workflows. (Esdar et al. 2017) used the workflow to model the logistics of clinical information by aiming to describe and explain various phenomena of information provision in order to conduct clinical processes. (Lee et al. 2011) Examined how Artificial Intelligence technologies and RFID technology can improve workflow in logistics supply chains. (Narock et al. 2015) used the multi agent system with multiple agents to identify an efficient and evolutionary system in the provenance field. Besides, new approaches try to model and optimize simultaneously these patient care pathways using scheduling and workflow techniques joined into the same system (C. L. Meli 2014).

Major problems in the management of health care production systems concentrate primarily up to: the control of hospital flows, anticipations of overcrowding and the control of process flows (Physical, information, equipment, financial...) (Schwarz et al. 2016). Including restructuring which consists of the pooling of resources and the creation of a technical platform. However health professionals do not have adequate training to solve such problems, given their lack of methodologies and tools for decision-making and management adapted to the requirements implied by their external environment (Ozkaynak et al., 2015).

Thanks to the collaboration between clinicians, healthcare, academic and industrial researchers, it is possible to model the current situation in AED in order to improve the quality patient care. Indeed, the model created will help us to identify situations of overcrowding in the service (thanks to the identification of corresponding indicators of overcrowding). Then, according to this modelling, we can establish a decision support system to provide strategies for avoiding overcrowding situations. Hence, it is essential to evaluate the relevance of the predictive models proposed below, then to develop recommendations for strategies for avoiding overcrowding situations. In this article, we focused on research based on the use of Workflow as a suitable model to represent the patient pathway and identify the key factors from the overcrowding situations.

3 METHODES

The implementation of a structured research model is made thanks to the following points:

- Several visits were realized in the AED of CHRU of Lille with researchers and physicians allowing us to build a workflow model of the patient pathway and AED treatment processes as the support for a patient mapping form to collect database.
- Each research assistant spent a continuous 15 days mapping exercise during which they independently observed and manually recorded patient pathway at the AED for a sample of presentations.
- In order to validate an all-day observation, an AED staff meets the research assistant for controlling their observations of patient flow.
- The analysis done by the researchers and AED staff medical conducted us to construct a process models. This model will be constructed with the BPMN graphical language which is an international standard.
- The last point deal with the validation and simulation of the model. A comparison with real patient pathway scenarios is necessary to identify the overcrowding indicators.

3.1 The Methodologies Included

The use of the Workflow approach and in particular the BPMN "Business Process Model and Notation" graphic tool, allows to represent the specificity of the business processes and to verify and validate this process directed by the staff medical.

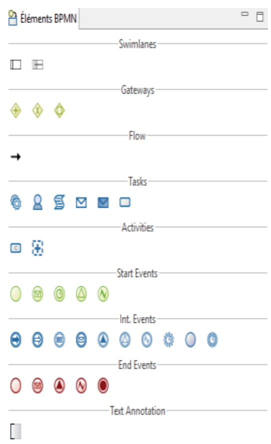
The workflow presents a graphical model that translates the flow of the patient into the service. In addition, the use of the internationally standardized language (BPMN) guarantees common understanding by different users. There are 4 categories of BPMN elements, which represent the basic elements of graphical modelling, see table 1.

We have already compared the workflow model with the UML and Petri net model. We note that the wokflow model with the “Bonita Soft” tool is better thanks to an integrated engine, the automatic generation of the interfaces, the simulation of the modeling put in place and the possibility of connecting thanks to the connectors the Workflow system to other external systems.

The idea of modelling the patient pathway by using a computerized system "Bonita Soft" tool aimed as a first step to determine the bottleneck that presents the cause of global dysfunction in the service, as a second steps to:

- Ensure the control of all transactions planned at the moment, thanks to the insertion form and the possibility of interaction between the medical staff regardless of their location.
- Ensure a fast registration of patients and their data in the system.
- Quickly identify the availability of medical staff wanted as needed.
- Trace his pathway, therefore possibility to calculate the time planned for the remaining of his treatment.

Table 1. The BPMN graphical language

Workflow	Activities Events, starts events, end events Flows Gateways	
Organisation	Swim lanes or lanes	
Readability	Text Annotation	
Specifics Behaviours	Int. Events Timers Mistakes loops	

3.2 Description of CHRU of Lille

The CHRU of Lille is the third biggest hospital in France It includes a pediatric and adult emergency department. Hence, the complexity of control its management in different sectors, the most studied are the financial sector and the sector of the take care of patients. As we mentioned at the beginning, in this paper we study the modelling of the patient pathway in this huge hospital, especially in the AED. AED dispose materiel radiology, MRI and ultrasound providing the patient with maximum in situ care, there are 5 operating rooms, one recovery room and one surgical resuscitation room.

3.3 Patient care process in the AED

From the patient arrival in the AED he must undergo this process:

1- The patient has registered in the services electronic database.

2- Half an hour later, the nurse after sorting the different patients in order of gravity, orients each of them to the most appropriate circuit. (Short Circuit or Long Circuit).
3- The patient is waiting to be treated.

There are different patients care processes depending on the severity of patient pathology.

Thanks to the visits of AED of CHRU Jeanne of Flanders at Lille. We can present the modelling of patient pathway in the AED as faithfully as possible in order to identify the various dysfunctions in this process. Especially to better encompass the problems previously faced by the service.

4 WORKFLOW MODELS

The model presented in this paper is generic to represent any patient pathway at the AED. Each healthcare unit is independent, in other words visiting one unit does not influence the patient visiting another unit. However, each instance of the model represents a full part of pathway care for each treatment. Thus, the same patient passes from one stage to another in the care process.

Although creating a Workflow process is a complex step and takes a lot of time it is obvious to find gaps between the real workflow processes and the scientific Workflow process performed. In this paper, we present the process of patient care in AED most accurately as possible.

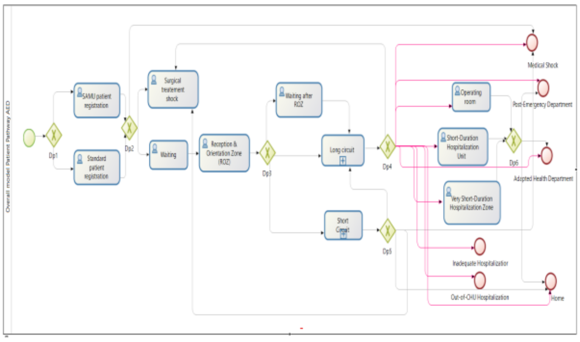


Fig 2. Global workflow for patient pathway model in the AED

Fig.2 presents the simplest overall process of the patient pathway with 2 large sub-processes characterizing two famous circuits: Long Circuit see Fig.4 and Short Circuit see Fig.3. Our workflow is composed of several BPMN components including start and end events, several kinds of tasks and indeterminism aspect presented by Several Decision Points (DP).

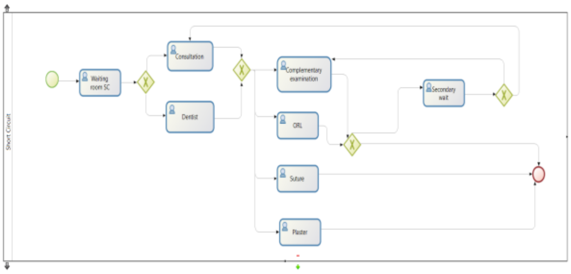


Fig 3. Short Circuit Workflow for patient pathway in the AED

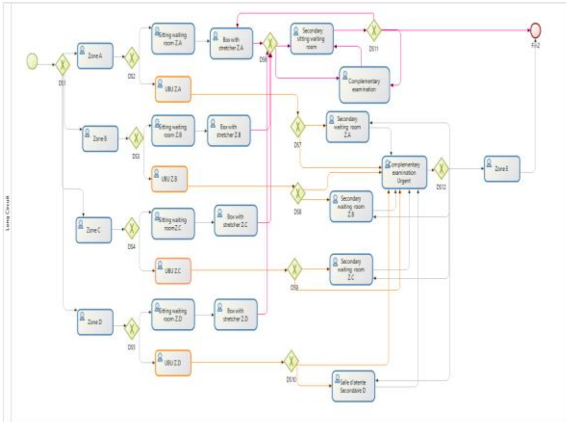


Fig 4. Long Circuit workflow for patient pathway in the AED

4.1 Overal Model

1- A single start event representing the patient arrival
2- Six end events:
   a- The patient is transferred to the Post-Emergency Department: it is a service that engages only with emergency patients; it is managed by the interns
   b- The patient is transferred to adapted health department/ specialized service: use his patients are treated out of emergency. he will continue his treatments in the adapted health department dedicated to his needs according to his pathology
   c- The medical shock: is represented by an end event because his patients are treated out of emergency. The aim is to treat very serious patient who cannot wait.

d- Out-of-CHU hospitalization: send patients to another hospital or clinic due to lack of places.
e- Inadequate hospitalization: in the case of total bottleneck and for reasons of complexity of patient assignment in a service the patient can be sent to an inadequate service.
f- The patient returns home: directly after a full consultation or after a hospital stays lasting less than 24 hours

3- Two tasks for patient reception: one dedicated for the entry of SAMU the other for the standard reception (for valid patient : who no need stretcher)
4- The surgical treatment shock task is to treat patients who have a very serious health condition that should not wait.

If the patient is treated less severely he will go through the waiting task (x minutes) and then to the reception and orientation zone (ROZ) task to give him a ground of appeal.

Depending on the severity of his state of health, he will be sent either in Short Circuit SC or Long Circuit LC. The same step for valid patients or patients on a stretcher (SAMU patient).

At this stage we have two different types of pathway depending if the patient is on a stretcher or he is valid. However, it all depends on the state of the service at that moment, the patient can wait or not wait before being taken care. Then the patient will be oriented or reoriented to one of these units where some of them are represented by a sub-process in our model:

5- Long Circuit (LC) task; Sub-process.
6- Short Circuit (SC)task; Sub-process.
7- The Waiting task after the "ROZ": for only the patient who is placed on a stretcher, they wait that there is available box to call them in the LC.
8- Operating room task.
9- Very short-duration hospitalization zone VSHZ task.
10- Short-duration hospitalization unit SDHU task.

We worked in an environment of uncertain care that increases the risks during a patient pathway. This uncertainty confirms the complexity of the emergency care system. These decisions are expressed in the model by six synchronization decision points Dpi (1< i <6) (see Fig.2) these graphical connections are used to control the behavior of sequence flows in a process. Decision points Dpi (1 < i <6) of our global model are detailed as follows:

Dp1: represent the type of patient arrival. Valid patient or patient coming by SAMU "urgent" if the patient is urgent it goes directly to the SAMU reception where he is going to be directed either towards the medical shock or the surgical shock. If he is valid he goes directly to the standard reception.

Dp2: control the orientation of the patient according to his / her state of health either towards medical shock or the surgical shock or the waiting depending of its health state.

Dp3: This point is important because it determines the number of patients in the service who will subsequently oriented in the LC or in the SC. It is essential because it represents the input bottleneck point of the global model.

Dp5, Dp4: These points are central because they represent the second input bottleneck point of the global model. They guide patients in appropriate care according to their pathologies. In case of blocking of these points we will have "a zone E, LC and SC" complete / overpopulated and we cannot accept new entries in the LC/SC.

Dp6: this point is essential because it represents the output bottleneck point of the global model. It redirects the patients to one of these points:

- Post-emergency service: it is managing by interns ‘physicians. It only takes emergency patients, includes 20 beds for a total of 50 patients in the AED per day.
- Adapted service: concerned patients who are hospitalized in the VSHZ or SDHU and then sent in order to continue their treatment in a service adapted according to their pathologies
- Home: the patient returns home with good quality of care. Also allows the exit of a patient and the recovery of another patient.

4.2 Sub-process SC

If the patient has a small medical problem, he is oriented to the SC which supports valid patients under the age of 65 who do not need for stretchers or extensive biological analysis. This is represented by a BPMN sub-process (call task).

4.3 Sub-process LC

If the patient is oriented to the LC, his is then oriented to a special care zone $X \in \{A,B,C,D\}$

From the special care zone X∈{A,B,C,D}, the patient is oriented to the Urgent Box Unit (UBU) for urgent cases and to other box units, otherwise.

A set of decision points DSi (1≤i≤12):

- DS1: Allows to orient the patient to the zone where it was sent from the global model
- {DS2, DS3, DS4, DS5}: Separating the pathway of valid patients from the patient pathway most urgent one.

These DSi {DS1, DS2, DS3, DS4, DS5} allow to control the common process of the patient pathway in the LC from this each patient will follow its own pathway.

- {DS6, DS11}: allows the control and the differentiation of the paths of the patients for the remaining of the valid patient treatments
- {DS7, DS8, DS9, DS10, DS12}: allows the control and the differentiation of the paths of the patients for the remaining of the urgent patient treatment.

The BPMN has some limitations to model a complex processes, especially the ability to represent queues and data-driven decision points. A tow interesting work in the literature has been developed to address these limitations:

- a conceptual design for an extension to BPMN (BPMN4SIM) using model-driven architecture. (B. S. S. Onggo et al. 2017)
- a conceptual design for a multi-agent system architecture in which each agent has a real time information about the patient such as the evolution of patient care state in order to orchestrate the workflow (S. Ben Othman et al. 2016)

5 SIMULATION & RESUTS

Based on the real data in the AED at CHRU of Lille, We note that it is rather difficult to collect exact and precise data notably because there are a many data censored. However, we selected two types of situations: Normal and Overcrowding Situations (NS, OS). In order to model the patient pathway in the AED, we choose firstly the workflow as an adequate model to represent these patient care activities in order to better understand and identify the dysfunction zones in the AED. Secondly, thanks to this model we use real data for analyse and identify several key performances indicators (KPIs) such us: Length of Stay indicator (LOS), Care Load Rate (CLR), and Left without Seen Rate (LSR). These KPIs are needed to indicate any possible issue with the current system. The evaluation of these indicators is crucial to determine in the AED the overcrowding situation. In addition, the analysis of the database and the modelling of the patient pathway presented in this paper are complementary to ensure the robustness of the solutions obtained in practice.

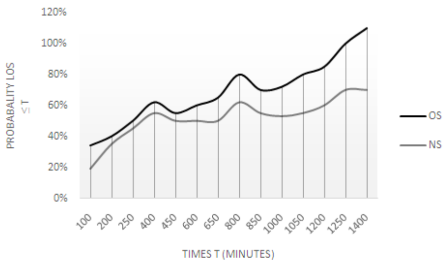


Figure 5. Cumulative distribution of the LOS between NS & OS

LOS: Represents the period that the patient spent in the service from its entry to its exit from the emergency system. Fig.5 shows a comparison of a cumulative distribution of the LOS between NS & OS situations; we note that the two distributions are very close for LOS ≤450 minutes, implying that in case of NS several patients have severity pathologies requires long care treatment or patients have a vital emergency. Otherwise LOS > 450 minutes most of patients have an excessive LOS due to the high of patient flow arriving in this period

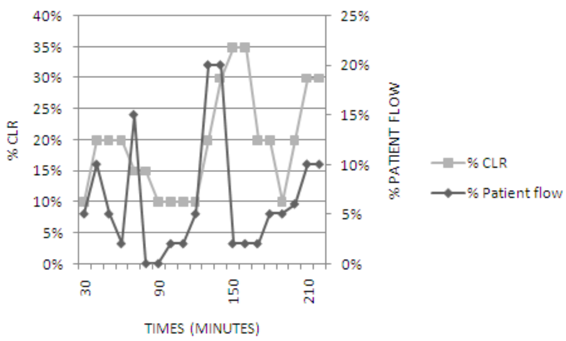


Fig 6. The CLR evolution according to the patient flow and time

CLR is the occupancy rate by the medical staff during a care treatment. The observation of the CLR curve suggests that the nature of its evolution is associated with the evolution of patient flow according to time. We note that a patient arrival flow of 5% following by another 10% in less than 20 minutes provoked a 10% increase for the CLR. This increase will last more than 35 minutes, imply that among these some of them have severity pathologies requires a long care treatment or who have a vital emergency. Then, during a 15% increase in patient flow the CLR did not increase this imply that in this new wave of patient arrived there are no severity pathologies, which attenuated the level of CLR. The same logic for the remained of points.

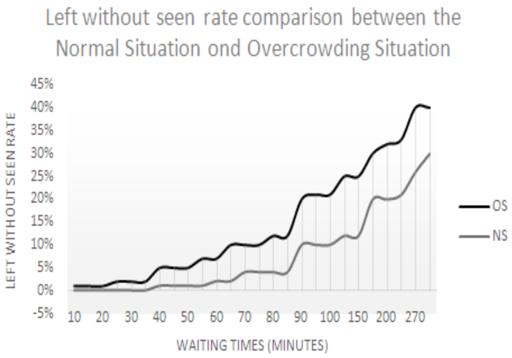


Fig 7. Cumulative distribution of the LSR between NS & OS

The LSR is the percentage of patients who leave the AED after the ROZ task and before the first medical consultation. Fig.7 shows a comparison of a cumulative distribution of the LSR between NS & OS situations. We note that the LSR in OS begins to increase from the first 40th minutes of waiting; imply that for psychological raisons, the patient observes that as more and more new patients arrive in the AED, which will become more and more overcrowded. Although in the NS, the LSR begins to increase from the 70th minutes of waiting, imply that in NS the waiting time may increase excessively because of number of urgent patients to be treated as a priority which will increase the CLR indicator and makes the medical staff unavailable.

6 DISCUSSION

Improving the performance of any health care system requires first to know how to measure its performance properly. The different made visits to AED, the observations and the discussions with clinicians and the pathway modelization prove that the chosen KPIs (LOS, CLR, LSR) are suitable to study the AED overcrowding situation. Thanks to our model and to simulations results we conclude that the patient waiting time in AED may be excessive in the two situations OS and NS, because of the massive arrival of patient in AED or/and patient arrival in a vital emergency makes medical personnel unavailable. Then we note that the chosen KPIs are strongly correlated to congestion and patient satisfaction. The selection of the appropriate KPIs has always been a controversial subject, for the whys and wherefores remain unclear. Neither the scientific community nor practitioners are able to decide about the most appropriate KPIs, as each indicators presents at the same time benefits and drawbacks. For example, the LOS gives an overview on the entire system performance but does not allow to figure out local strengths and weaknesses. Another example the measure LSR depend on external factors on which the AED has no control. We note also, that the CLR is a crucial KPIs for the critical levels of the physician workload, but it does not give any information about the remaining care operations to be done on the patients during other important steps of the process (beyond the first consultation). We will therefore review studies that combine different KPIs. We will show relevant combination of KPIs and highlight potential interdependency between them in order to focus some universal quantitative measures of AED overcrowding. To minimize patient waiting times and optimally organize the medical staff care activity we need in addition to develop scheduling and orchestration approaches in order to minimize the waiting time of the patients during the workflow execution.

7 CONCLUSION

The use of the Workflow approach to model the patient pathway in the AED at CHRU of Lille was effective in facilitating understanding of the set of flow processes in the AED. Thanks to the global model and the two sub-processes we model the complete patient pathway, so with the simulation we identify the 3 key performance indicators (LOS, CLR, LSR) that their real time control is essential especially during an overcrowding situation at the service. This paper shows the complexity of modelling the patient pathway in an emergency department as large as the CHRU in Lille as well as the importance of determining the key performance indicators. So we conclude that overcrowding situation can be represented as an imbalance between the flow of care load and the ability to take care of patients over a period of time, it causes not only an excessive waiting time for the patients but also results harmful consequences for the proper functioning of the AED.

ACKNOWLEDGEMENTS

This work was supported and funded by the Federative Research Structures Technologies for Health and Drugs (SFR-TSM): http://sfr-tsm.ec-lille.fr/

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