Journal of Positive School Psychology
2022, Vol. 6, No. 3, 4492–4500 http://journalppw.com

Artificial intelligence and lean in the service of patient comfort: Modelling Healthcare process (Hospital 4.0)

EL SABROUTY Rihab[1], ELOUADI Abdelmajid [2]

[1,2] *Ibn Tofail University*
[1]*rihab.elsabrouty@uit.ac.ma*,[2]*abdelmajid.elouadi@uit.ac.ma*

Abstract

Covid-19, which first appeared in Wuhan, spread worldwide. In Europe, Italy and Spain were the first to be hit, before the entire continent was. This health crisis has affected the whole world and at all levels (hospital capacity, number of health workers, shortage of medicines, ...). With 5,318,216 deaths worldwide as of December 16, 2021, the disease has shown that the health-care system is not sufficiently prepared to cope with the coronavirus.

COVID 19, like any other disease, requires a follow-up of its evolution to reduce its harmful effects. In order to ensure the comfort to the patients by offering them a care path adapted to their situation, the exploitation of artificial intelligence within the hospital is necessary and this by approaching the human cognition in the analysis of complex medical data.

The objective of this study is to generate the patient's care pathway from his initial state at the first consultation with the physician.

To do this, we will have to optimize the hospital supply chain by modeling the patient's care pathway.

First, we will proceed by identifying all the entities contributing to the hospital logistics chain.

Then, the supply chain will be optimized thanks to the use of lean to deliver to the patient what he needs when he needs it to accomplish its care.

Finally, the Multi Agents method will be used to model all the parts concerning the course of the treatment (radiology, surgery, pharmacy, accounting, ...) and to show the interactions that can take place to make them as effective as possible.

Keywords— Artificial Intelligent, Lean, Hospital 4.0, Multi Agent System, Petri Network

I.INTRODUCTION

The internal organization of the public hospital and its decision-making chain are based on bodies defined by law "Hospital, Patients, Health and Territories", which radically modifies the management criticized for a long time, in particular because of complex and often multiple processes where the entanglement of powers between the director, the board of directors and the medical board of establishment led to there being no real person responsible for the good or bad functioning of the hospital.

Based on the principle of respect for the person, shared decision-making was initiated by the Law of 4 March 2002 on the rights of patients and the quality of the health system, known as the "Kouchner Law". During this exchange, the doctor explains to his patient the different options possible based on both medical and scientific data and professional experience.[1]

Depending on the case, he/she will inform the patient of the percentage of risk of complications of a particular surgical procedure, of possible alternatives with their usual success rate, of the mode of action of the new drug he/she is proposing.

The patient, for his part, uses this meeting to describe his symptoms, his living conditions, express his moral, religious values and his preferences.

In order to facilitate this decision-making, this work is based on the modeling of the care pathways which allows the hospital to propose to the patient the most comfortable and effective pathway to treat him, taking into account the different parts which contribute to this pathway.[2][3][4]

The contribution OF AI in HEALTH CARE SYSTEM

The importance of the network at the heart of the health infrastructure has never been more evident than since the onset of the COVID-19 pandemic. The increase in hospital admissions and remote consultations has led to unprecedented demands on the network, accentuated by the adoption of telemedicine or remote patient monitoring applications.

In addition, health stakeholders are increasingly relying on IoT technologies. Remote consultations are automated thanks to chatbots. New advanced analytics and artificial intelligence (AI) applications are also being explored, to refine diagnostics and treat patients more effectively.

Many actors quickly realized that their current infrastructure could no longer meet these new requirements, as their network no longer met the levels of reliability and performance needed to ensure a good level of service.

The goal is not just to increase bandwidth. Healthcare stakeholders are also looking for more flexibility, agility, security, and better cost management. They want to be able to anticipate and adapt to changing needs over the long term. The infrastructure must not only support clinical workflows and patient experience, but also ensure compliance with data regulations and ensure the security of patients' personal information. [5]

The need to modernize IT infrastructure in the health sector affects all of Europe. According to an IDC study, by 2023, connected health alone will account for a 70% increase in IT spending by life sciences organizations and 31% of EU healthcare providers consider workflow modernization a top priority to improve operational efficiency. [6]

According to a June 2021 WHO report [7], artificial intelligence "has immense potential to improve the health of millions of people around the world." Assisting with screening, treatment development and administration, outbreak surveillance, health systems management…

The report "Ethics and governance of artificial intelligence for health" is the result of two years of consultations by a group of international experts appointed by WHO.

"Like any new technology, artificial intelligence has immense potential to improve the health of millions of people around the world, but as with any technology, it can also be misused and can have harmful effects," said Dr. Tedros Adhanom Ghebreyesus, WHO Director-General.

Innovations related to artificial intelligence have very specific uses within hospital services, from cancer management to risk prevention. Sometimes it is "enough" to allow programs to cross-reference a multitude of data to get valuable help. [8][9][10]

Hospital 4.0 definition

Hospital 4.0 is a strategy that aims to facilitate decision making. It concerns all the actors in a medical structure whatever its nature and its constraints.

It is based on the digitalization of all the information flow in order to simplify the analysis of data and draw conclusions that will allow to respond efficiently to problems like shortage of a drug, a vaccine, etc...

Hospital 4.0 or otherwise known as Digital Hospital is:

- A communicating hospital for all internal and external stakeholders, including the areas of hospital information systems (HIS) and e-health, [11]
- A smart building with the ability to track goods and people, organize processes, streamline routes, and inform, alert in case of drifts or risks,
- Medico-technical production (laboratories, operating rooms, sterilization, pharmacy) and robotized and automated logistics: minimizing human interventions, accelerating flows, transport, and generating strong productivity gains,

- Better management of the building life cycle: a more energy efficient and easier to operate hospital.

Therefore, Hospital 4.0 makes the structure more flexible and more capable of serenely managing unexpected events.[12]

USING LEAN IN hospital

The deployment of lean management in hospitals and, more generally, in public services is in line with that of new public management, which has resulted in the implementation of management tools from the private sector in the public sector.[13]

Like the new public management, lean management is seen as a way to rationalize the organization of hospitals by eliminating losses and waste (for example, interruptions, delays, errors...) in order to improve the flow of patients, information and goods.

In France, lean management is presented as an essential link in the savings plan, within the hospital system.[14][15]

It began to be installed in hospitals in the early 2000s. The University Hospital Centers (CHUs) in Lyon, Toulouse or Grenoble or the Paris Public Hospital Assistance are among the establishments that use it. [16][17]

A. Standardization:

Standardization is the practice of setting, communicating, following, and improving standards. It facilitates measurement and promotes consistency in application through uniform criteria and practices.

The process of continually improving the standards is the path to reliable methods. Everyone must practice the standards consistently before standardization truly exists. Consequently, standardization depends on user-friendly language, pictures, or symbols to communicate the standard. It must be easy to see and understand what the standard is so that everyone can learn to practice it.

B. Standard Work:

Standard work is an agreed-upon set of work procedures that establish the best and most reliable methods and sequences for each clinician and support staff member It is also a method that helps determine those methods and sequences.

Standard work aims to maximize performance while minimizing waste in each person's operation and workload.

PROBLEM: Definition, methodology and findings

A. The health care service production process:

The main purpose of the care process is to transform the patient from an unhealthy to a healthy state and this is achieved through a series of medical and other care operations.

Figure 1 illustrates the health care process as a network of process and operation. To clarify the difference between process and operation: the process is linked to the patient flow and the operation represents the work performed on patients by clinicians and support staff. Knowing the difference between these two concepts allows us to analyze them separately in order to know what we are acting on: the hospital's capacity to absorb the flow of patients or the capacity to provide the necessary care. [18]

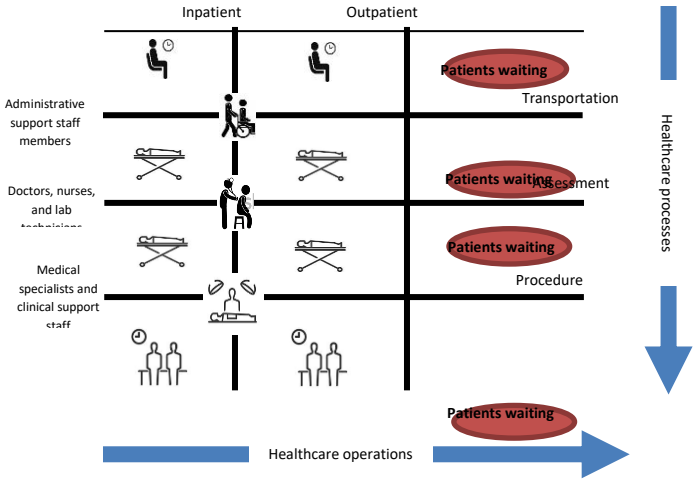


Figure 1. The health care service production process

The objective is reducing the patient waiting that's why we must identify wastes healthcare operation and administration which cause a prolongation of the treatment process,

To do that, we're going to use flowchart to represent in which phase of the process, the patient has to wait without added value.

Figure 2 represents the care pathway that a patient follows for chemotherapy sessions, it is

not an emergency room visit, otherwise the pathway would be different.

It is a treatment well prepared in advance to check the availability of drugs, it can happen to have a shortage of drugs or a delay in delivery, depending on the condition of the patient, the doctor will have to find another alternative.

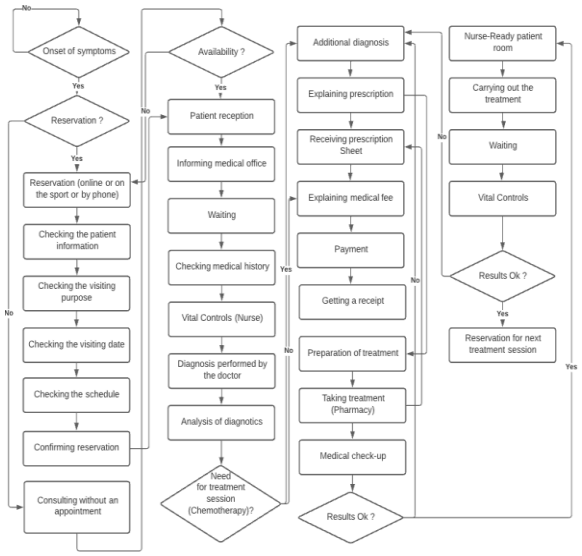


Figure 2. Flowchart of healthcare pathway

The losses that can be found in this process are presented as follows:

- **Overproduction:** Producing more, sooner, or faster than is required by the next process…
- Waiting: Time delays, process idle time
- **Transportation:** Unnecessary handling or transportation; multiple handlin…
- **Overprocessing:** Unnecessary processing, steps, or work éléments/procedure…
- **Inventory:** Producing, holding, or purchasing unnecessary inventory…
- **Motion:** Excessive handling, unnecesary steps, non-ergonomic motion…
- **Defects:** Rework, correction of errors, quality problems, equipment problems…

To eliminate those wastes we are going to use standard word, to do that, five steps are applied as follows:

✓ Step 1: Conduct a Running Time Observation

The goal of a running time observation is to determine the daily tasks in the right order and indicate the time spent on each task. This will allow us to evaluate the time spent on each operation and see if it adds value in relation to the time spent.

✓ Step 2: Create A Standard Work Sheet

The Standard Work Sheet includes cycle time, work sequence, SWIP inventory and other information on standards in that work area.

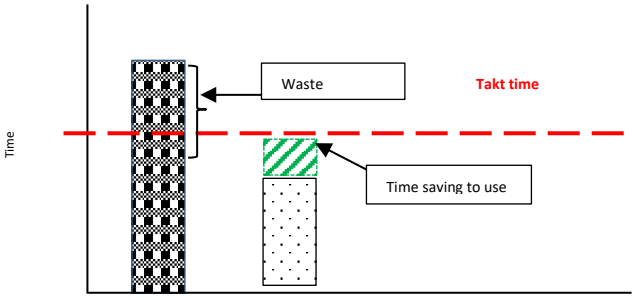
As its name indicates, the standard work sheet gives a work rhythm to be followed by the entire medical staff, otherwise there is no point in applying it. To achieve this, it is necessary to gather all the staff to agree on its application and to often check its erasures and if it needs to be updated. It is important to note that this document is evolving, so it must be reviewed quite often and adapted to new constraints (e.g.: appearance of a new regulation...)

✓ Step 3: Percent Load Chart

The Percent Load Chart takes the information from the time Observation Form by adding up the total duration of the operations by trade of the same nature (we cannot apply this for a computer scientist and a nurse for example). Our reference is the takt time which is defined by:

$$Takt\ time = \frac{\text{Net time available to work during the period}}{\text{Demand (customer demand) during the period}}$$

It represents a base that allows us to see if we are not losing time (we are above the takt time) or not (we are below the takt time).



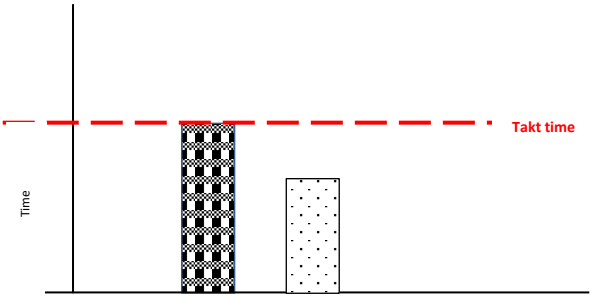
Operator	Doctors	Lab members	
Cycle time	t_1	t_2	

Figure 3. Percent Load Chart (Before Improvement)

✓ Step 4: Create a Standard Work Combination Sheet

The Standard Work Combination Sheet identifies opportunities to improve the work of staff members using Percent Load Chart.

It allows us to review the time wasted on each task and bring them closer to the takt time.



Operator	Doctors	Lab members	
Cycle time	t'_1	t'_2	

Figure 4. Percent Load Chart (After Improvement)

Figure 4 illustrates the impact on time after the optimization of certain tasks. It is necessary to see if the task only meets the need or if it includes other things that can cause a non-visible and non-necessary over-quality for the care of the patient.

✓ Step 5: Standard Work Instruction Sheet

The purpose of Standard Work Instruction Sheet is providing on the one hand explicit instruction for new workers so that they will pick up the methods quickly and correctly and on other hand a well-structured framework for all employees to follow in order to meet the needs of patients.

Figure 5 details the essential tasks that a nurse performs when welcoming a new patient for a chemotherapy session. [18]

The objective is to treat 16 patients in a working time of 8 hours.

Hourly rounds of medical staff		Date: 30/09/2021
Department who must adopt: Oncology	Operator who must adopt: Nurses	

Task	Task description	Task time
1	Greet patient and confirm identity	*30 sec*
2	Check the blood test brought by the patient	*30 sec*
	Explain to the patient their treatment and length of stay	*300 sec*
4	Put the patient in his room	*300 sec*
5	Moisturize the patient by putting a serum through a pulse irrigation system	*240 sec*
6	Administer medications to prepare the patient for the treatment session (chemotherapy)	*420 sec*
7	Monitor patient's vitals	*180 sec*
8	Inform the doctor of the end of the treatment session	*120 sec*
9	Give the patient an appointment for the next treatment session	*120 sec*
Takt time = $\frac{8\,h}{16}$ = $\frac{28800\,sec}{16}$ = *1800 sec*	Cycle time:	*1740 sec*

Figure 5. Example of Standard Work Instruction Sheet

After optimizing the process, we will model it using multi agent system approach to make decision easily and that's the purpose of hospital 4.0.

A multi-agent system (MAS) is a system composed of a set of agents, located in a certain environment, and interacting according to certain relationships. An agent is an entity

characterized by the fact that it is, at least partially, autonomous. It can be a process, a robot, a human being, etc.

The Multi Agent System has several roles:

1- Solving a problem in a distributed way multi-expert systems.

- The actions of the agents are transformations of objects linked to the description of a problem.
- rather rational agents

2- Simulation of complex phenomena.

- The agents simulate physical, biological, or social actions that actions which produce modifications of the represented world.
- Reactive agents.

B. Supply Chain Modeling - Multi Agent System Approach:

To build this model, we need to define:

- Environment
- Organization
- Interaction
- Agent

In this model, we have opted for the intelligent agent, because it is autonomous, able to cooperate and learn from their environment.

We relied on a model of BDI (Belief-Desire-Intention) agents distributed in an AGR (Agent-Group-Role) organization. We choose BDI architecture because we work with intelligent agents, and it is based on a known and appreciated theory of rational human action.

An agent represents an entity in the supply chain, so it has:

- System constraints: an identification, a name, and a location.
- Environment constraints: Incoming product flow and Outgoing product flow.

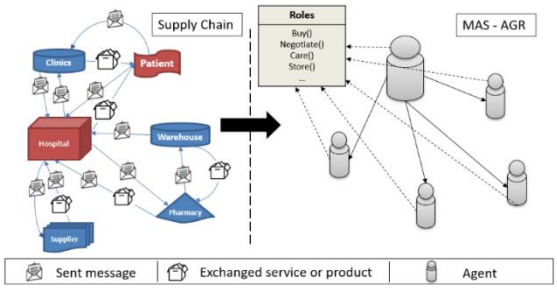


Figure 6. BDI Architecture

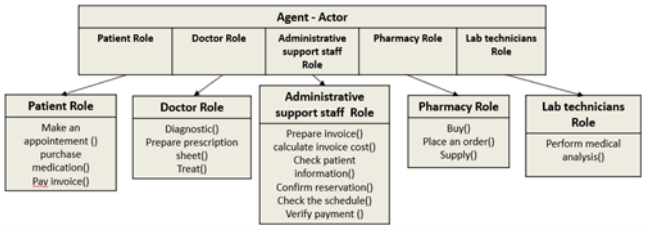


Figure 7. Roles of Agents in SMA

C. Communication between agents:

To have a functional model, agents must have the ability to manipulate a common language through either information sharing, message sending, or both.

The message exchanged is characterized by:

Parameter	Category of Parameters
performative	Type of communicative acts
sender	Participant in communication
receiver	Participant in communication
reply-to	Participant in communication
content	Content of message
language	Description of Content
encoding	Description of Content
ontology	Description of Content
protocol	Control of conversation
conversation-id	Control of conversation
reply-with	Control of conversation
in-reply-to	Control of conversation
reply-by	Control of conversation

Table 1. FIPA ACL (Foundation for Intelligent Physical Agents – Agent Communication Language) message

A FIPA ACL message contains a set of one or more message parameters. Precisely which parameters are needed for effective agent communication will vary according to the situation; the only parameter that is mandatory in all ACL messages is the performative, although it is expected that most ACL messages will also contain sender, receiver, and content parameters. [19][20]

D. Petri Network:

The use of the Petri Network allows us to model the inter-role interactions of the agents-actors, which will facilitate the identification of the relationships between all the agents despite the complexity of the organization and their impact in the decision making.

Each agent has a well-defined role within the supply chain and reacts according to the elements it has in input so that it can generate a message to be transmitted to all the agents to which it is linked.

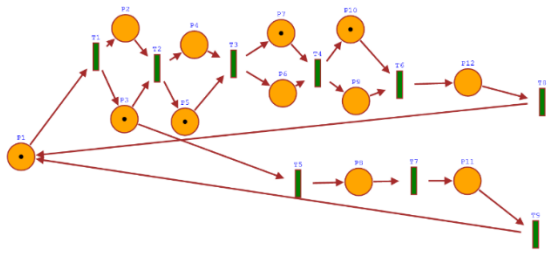


Figure 8. Petri Network

Transition	Signification
T1	Appointement taken
T2	Control of Patient information
T3	Diagnostic made
T4	Payment verification
T5	Schedule availability
T6	medication purchased
T7	Operation carried out
T8	Healthy patient

Table 2. Signification of different transitions represented in Figure 8

Figure 8 shows that if we add several patients at the beginning, we can know if the hospital will have the capacity to handle all patients within the waiting time without making them wait for a long time. If not, this model can help us detect where congestion will occur and plan to add physical and/or material resources. And that's not all, because the objective of our study is to ensure a good quality of the patient's care pathway, so with this model we will also be able to identify the entities that are saturated first in order to intervene and fluidify the flows at that level and meet the patient's need as desired.

Discussion

During the development of this work, we were forced to face several difficulties, mainly inaccessibility to hospitals during the COVID 19 period. This work was also characterized by an important theoretical layer; The exploitation of AI to deal with the coronavirus is not sufficiently developed, and this is justified by the fact that every effort is made to treat and combat this virus in order to regain a normal rhythm of life.

For the rest of our research, we plan to integrate the simulation into a robotic system to provide patient support without using nurses. Using a robot will reduce the demand on the doctor in the event of the appearance of changes in the pathway care and it will give a new modeling if the disease develops.

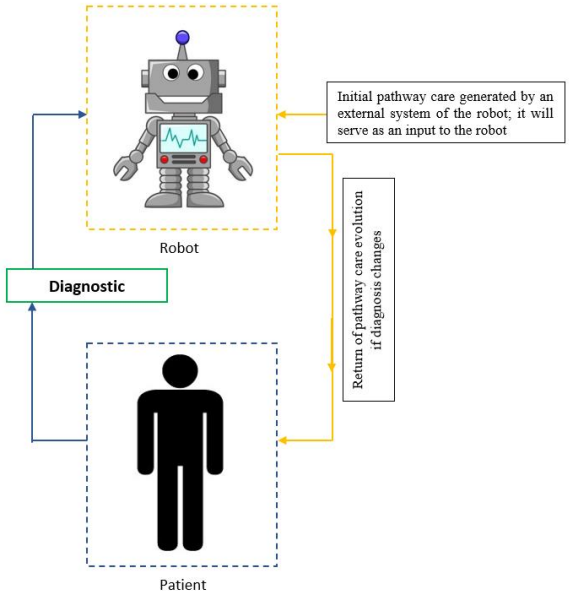


Figure 9. Integration of pathway care simulation in a robot

The aim is, first, to integrate all constraints that can impact the care pathway and all the parties involved, before moving on to an experimental program, based on AI software tools, which, after implementation on a study sample, should provide information on the feasibility and contributions of this technology. In concrete terms, the experiment would consist in analyzing a concrete case of a patient followed by the hospital and comparing the effectiveness of the care path adopted with that which could be chosen without using this modeling. This would be especially true for patients who initially suffered from chronic diseases. Second, the goal should be to expand the experience of new, more serious diseases such as cancer, especially in the most fragile patients. This transition to other disease categories will be made, in part, by the system itself, as new pathways of care and particularities are discovered, massive amounts of data are processed, and many differences in outcomes are identified. This tool, integrated web and mobile, would have a connected technology of integrated machine learning which, after the first profiling phase, and after little feedback

with the user (patient/healthcare professional) would process the data in other processes to develop new learning processes, becoming smarter and more accurate with time, and, inside, suggesting the appropriate care path each time

Conclusion

Having a flexible hospital is not a simple step to take, but it is a way to be armed against pandemics like COVID19.

Technology is changing, and sadly new disease appears.

It is therefore essential to use technology in the health system to reduce the impact and exposure to diseases.

Hospital will remain a human industry, patients will always need physical contact with their doctor and nurse to be reassured. Hospital 4.0 does not exclude this contact on the contrary, it frames it in such a way as to intervene when it really needs (Just in Time).

The objective of this work is to facilitate decision making and to involve the patient more and more so that he can participate in his care. This allows the patient to be reassured throughout the process and to be prepared in advance in case of complications.

The exchange between the two parties helps to position and choose what is appropriate and adapted to the patient's situation.

This work is based on two pillars that cannot be separated, namely artificial intelligence and Lean, to have the most optimized care pathway in terms of cost, time and better quality.

The role of artificial intelligence is to simplify the understanding of the care pathway by the patient, even if he has no knowledge in the health field, it helps to advance his care because he will be aware of the importance of following this pathway and not another. Therefore, he will be more autonomous and confident during the care period. It is a kind of awareness for the patient that serves to reduce unnecessary medical solicitations, we can take the example of childbirth preparation courses that allow the woman to learn the difference between the beginning of labor or false contractions. This helps her to avoid going to the maternity ward 15 times a day. In our study, it is exactly the same purpose that we are looking for but directed towards diseases that mobilize more resources from different parts.

Lean in this study is used to reduce as much as possible the waste of time that the medical staff can have in performing their daily tasks. Lean should never be used as a means only to reduce the number of devices, beds without considering the need that we can have, and this is what happened in France at the beginning of the pandemic of COVID 19 with the application of lean for some years, hence, the interest of associating it with other constraints to properly assess the need to cope with the unexpected.

REFERENCES

1. Haute Autorité de santé, “Patient et professionnels de santé : décider ensemble.”October 2013, accessed 18 February 2021 ,<https://www.has-sante.fr/upload/docs/application/pdf/2013-10/12iex04_decision_medicale_partagee_mel_vd.pdf>
2. C.MAILLARD, “Histoire de l’hôpital de 1940 à nos jours,” Dunod, pp. 97-109, January 1988.
3. JM. BUDET, “Covid-19, and after." Hospital management”. January 2021, accessed 14 March 2021 <https://gestions-hospitalieres.fr/dossier/covid-19-et-apres/>
4. Haute Autorité de santé, “Éléments pour élaborer une aide à la prise de décision partagée entre patient et professionnel de santé.”March 2018, accessed 15 March 2021,<https://www.has-sante.fr/jcms/c_2838959/fr/elements-pour-elaborer-une-aide-a-la-prise-de-decision-partagee-entre-patient-et-professionnel-de-sante#toc_1_4>
5. C. MILCENT, “Towards a digital integration in health systems.” Hospital management. July 2021, accessed 25 July 2021, < https://gestions-hospitalieres.fr/vers-une-integration-du-digital-dans-les-systemes-de-sante/>

6. J. DESPATIN, “Digital innovation in the hospital.” Hospital management. April 2021, accessed 30 December 2021, <https://gestions-hospitalieres.fr/linnovation-digitale-a-lhopital/ >
7. World Health Organization, “Growing use of AI for health presents governments, providers, and communities with opportunities and challenges.”. Jun 2021, accessed 30 November 2021, <https://www.who.int/fr/news/item/28-06-2021-who-issues-first-global-report-on-ai-in-health-and-six-guiding-principles-for-its-design-and-use>
8. World Health Organization, “E ETHICS AND GOVERNANCE OF ARTIFICIAL INTELLIGENCE FOR HEALTH,” Dunod., p. 4-15, 2021.
9. Hospital management. July 2021 accessed 25 July 2021, < https://gestions-hospitalieres.fr/vers-une-integration-du-digital-dans-les-systemes-de-sante/>
   Ordre national des médecins. “médecins et patients dans le monde des DATA, des Algorithme et de l’intelligence artificelle, pp.8-26, January 2018
10. IDC, “The IT Network Infrastructure Revolution in Healthcare.” February 2021, 27 April 2021,<https://www.juniper.net/content/dam/www/assets/infographics/us/en/the-it-network-infrastructure-revolution-in-healthcare.pdf>
11. T. JELLOULI, “Hospital Information System (HIS).” Hospital management. September 2016, accessed 26 February 2021 < https://gestions-hospitalieres.fr/systeme-dinformation-hospitalier-sih/
12. Complémentaire retraite des hospitaliers, “L’intelligence artificielle à l’hôpital, au service des patients et des agents.” October 2021, accessed 2 Decemeber 2021 ,<https://crh.cgos.info/informations/l-intelligence-artificielle-a-l-hopital-au-service-des-patients-et-des-agents>
13. JM. BUDET, “What Is Lean Healthcare?” NEJM Catalyst. January 2021, accessed 27 April 2018, <https://gestions-hospitalieres.fr/dossier/covid-19-et-apres/>
14. G. Paché, “Why logistics is at the heart of the coronavirus crisis.” Harvard Business Review. May 2020, accessed 26 January 2021, <https://www.hbrfrance.fr/chroniques-experts/2020/05/30124-pourquoi-la-logistique-est-au-coeur-de-la-crise-du-coronavirus/>
15. G R LEDLOW, KB MANRODT, D SCHOTT, “HEALTH CARE SUPPLY CHAIN MANAGEMENT,” Jones & Bartlett Learning, pp. 10-50, Jun 2016.
16. Staff, “How to Get Hospitals to Think 'Lean': 5 Key Principles.” Hospital Review. July 2012, accessed 10 January 2021, < https://www.beckershospitalreview.com/strategic-planning/how-to-get-hospitals-to-think-lean-5-key-principles.html >
17. The Conversation, “Le « lean management », une voie à suivre pour les hôpitaux?.”August 2018,accessed 30 Jun 2021,<https://theconversation.com/le-lean-management-une-voie-a-suivre-pour-les-hopitaux-144450>
18. T. L. JACKSON, “Standard Work for Lean Healthcare,” Taylor and Francis Group, vol. 1, pp.9-12/54-69, July 2011. C.MAILLARD, “Histoire de l’hôpital de 1940 à nos jours,” Dunod, pp. 97-109, January 1988.
19. T. L. JACKSON, “Standard Work for Lean Healthcare,” Taylor and Francis Group, vol. 1, pp.9-12/54-69, July 2011.
20. Badr Benmammar, “Systèmes Multi-Agents. Engineering school. ”, HAL, cel-00660066, pp.3-40, 2009.