# Systemic modeling in telemedicine

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## Modélisation systémique en télémédecine

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**KEYWORDS**
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**Summary** The complexity of the health care system is a particularly notable framework for the development of telehealth and telemedicine. It is therefore necessary to try to answer the relevant question that can be summarized broadly as ''How to manage this complex system?'' We will discuss here the relations between system engineering and telehealth, or more specifically how systems engineering can be applied in the design of a telehealth system, and what benefits it can bring in its development. This naturally leads us to think of methods you can use to understand the difficulty of decision-making and the conceptual perspectives. It has been an accepted fact that this first requires modeling, i.e. to construct a representation of the perceived reality through symbols and relevant rules, then to verify or validate in absolute terms this representation, model, so as to improve or be able to use it. The importance of this modeling and the rigorous analysis of the requirements of telemedicine systems are even more apparent since the recognition of the generic representation declined in two meta-models: the first covers the activities of teleconsultation, teleexpertise and teleassistance; the second concerns telemonitoring.

**MOTS CLÉS**
Télémédecine ;
Approche centrée sur le patient ;
Holisme ontologique ;

**Résumé** La complexité du système de santé constitue un cadre particulièrement marquant pour l'essor de la télésanté et de la télémédecine. Il est donc nécessaire d'essayer de répondre à la pertinente question qui peut se résumer globalement ainsi « Comment mieux maîtriser ce système complexe? ». Nous allons donc étudier ici les rapports que peuvent entretenir l'ingénierie système et la télésanté, ou plus concrètement comment l'ingénierie système peut s'appliquer lors de la conception d'un système de télésanté, et quels bénéfices elle peut apporter dans son développement. Ce constat nous amène naturellement à réfléchir aux méthodes que l'on peut employer pour appréhender cette difficulté d'un point de vue décisionnel, d'une part, et

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conceptuel, d'autre part. De manière communément admise, cela nécessite de modéliser tout d'abord, c'est-à-dire de construire une représentation du réel perçu au moyen de symboles et de règles pertinents, de vérifier ensuite, voire de valider dans l'absolu cette représentation, ce modèle, de manière à l'améliorer ou à pouvoir l'utiliser. L'importance de cette modélisation et l'analyse rigoureuse des besoins des systèmes de télémédecine sont encore plus évidents depuis la reconnaissance des projets prioritaires dont la représentation générique se décline en deux méta-modèles : le premier porte sur les activités de téléconsultation, téléexpertise et téléassistance ; le second concerne la télésurveillance.

## Introduction

From the perspective of systems engineering, the health program is complex. Its operation is the result of multiple equilibriums arising from interactions between many elements and processes. It is itself interacting with all levels of modern society, e.g. an economic or legal point of view, but also with all sources of health risk issues associated with medical practices and the development of the regulatory and institutional context in Europe. Acting on the health system means changing balances or seeking new ones. Introducing telemedicine is making new interactions possible between patients and caregivers, creating new interfaces.

There is room to improve the healthcare system for patient management, although any changes here must not affect the existing balances between the system components. In other words, all telemedicine policies should aim to reduce territorial disparities and at least preserve existing balances or create news ones within the healthcare system.

### Systemics and complexity

For decades, a concept has emerged that can help to solve complex problems in various fields by strong abstraction mechanisms and a number of interesting concepts of generic representation. The systemic approach has complemented if not replaced in some areas the traditional Cartesian approach that has shown its limits.

The system definition adopted in this manuscript is that given by [2]:

> *''A system is a set forming a coherent and autonomous unit of real or conceptual objects (hardware, people, actions...) organized around a goal (or a set of goals, objectives, aims, projects...) by means of a set of relationships (mutual interactions, dynamic interactions...), all immersed in an environment''.*

A common characterization of the systems is to distinguish those that are complicated from complex ones. A complicated system cannot be understood at first by a person who considers it in his analysis. However, a minimum of information, time and Cartesian approach effectively allows understanding and control of it. For example, a machine that uses the wind to drive pumps, remote control or some intelligent processors can be complicated to use. On the contrary, a complex system [3] cannot be, at any given time, known exhaustively. For example, a healthcare system or even a living organism can never be fully described because it is composed of heterogeneous elements, behaviors and interactions with each other and their environment still unpredictable as they emerge from this contextual organization of the system. This means that a large part of the requirements and knowledge of the system escapes the one who believes. Systemics presents itself as the most excellent way to address the complexity, since it helps to organize the methodology for dealing with a largely unknown system from a person who considers it. Systemic concepts break down traditional disciplinary barriers and provide design research to be relevant to policy-making in complex environments.

### Systemics and totality principle

The systemic approach [4] is to apply this system concept definition and the resolution of the problems posed by it. For this purpose, this approach seeks to link together instead of isolating as a Cartesian approach would, it is therefore based on the overall perception rather than a detailed analysis, considering the interactions rather than the elements and emphasizing the study of transactions taking place at the interface points between the system and the environment. Finally, it provides a focus on the dynamic and interactive aspects that sets up the vision reality. The totality principle therefore occupies a place in systems thinking. It states that a system cannot be reducible to its parts. Concretely, this means that it is essential to know the system requirements to consider the relationships linking its elements. Based on this principle, there are summative and constituent system requirements. Summative requirements of a system are the sum of the requirements of the different elements that constitute it. The component requirements include summative but also those resulting relationships linking the elements requirements. The difference between summative and constituent requirements of a system is what is sometimes called the concept of emergence or the ''system effect''. This concept is often found as a key study and progress in many fields (biology research, service engineering, psychology, artificial intelligence, etc.). In particular, its application to a complex system of services shows patterns

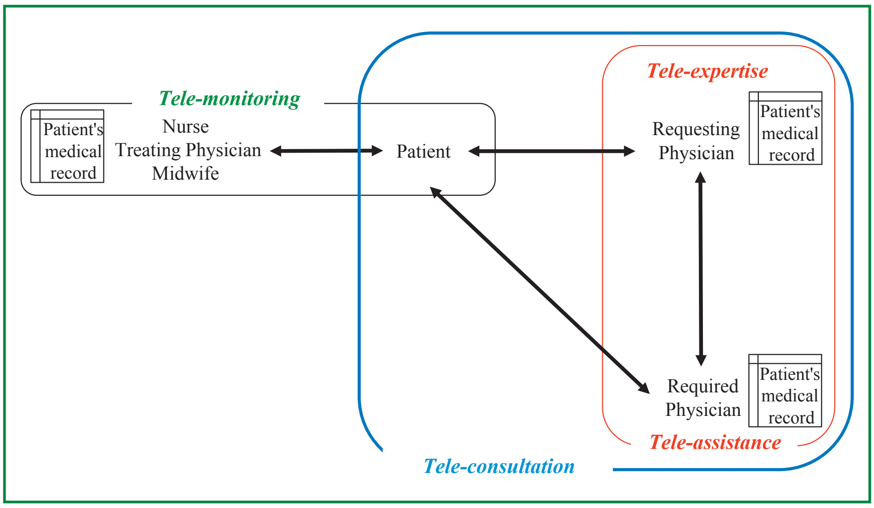


**Figure 1.** Characterisation of telemedicine activities.
*Caractéristiques des activités de télémédecine.*

of organizations that emerge from all these interactions between system components. These emerging organizations then allow the system to behave with a very effective and consistent ability to adapt and produce innovative solutions. In the next section, we present a system that provides the basis for our study of telemedicine.

## Telemedicine: a complex domain

### Definition of telemedicine activities

According to the French regulatory documents (decree-Law n° 2010-1229 of 19 October 2010), telemedicine is a remote medical practice which utilizes advanced telecommunications and information technologies for the delivery of healthcare and the exchange of health information across distances, including the following medical activities (Fig. 1):

- teleconsultation, a procedure whereby medical professionals can consult a patient remotely and interpret the necessary data remotely for medical follow-up;
- teleexpertise, whereby a medical professional can seek remotely an opinion of other medical professionals who have the relevant training or skills;
- teleassistance, a procedure which enables a medical professional to assist remotely another healthcare professional during the realization of a medical act;
- telemonitoring, the ability to monitor and supervise patients remotely.

What conceptual and methodological frameworks to implement to try to capture at least part of the complexity of telemedicine activities? From this point of view, the systemic modeling seemed to be a useful theoretical and conceptual basis for an effort to integrate the notion of complexity, which implies unpredictability and uncertainty. It, therefore, has an important place in our scientific research, especially as we observed that ''modeling is the main — perhaps the first — tool for the study of complex systems'' [5].

### Characterization of key features of telemedicine domain

In line with the practices of collaborative processes of telemedicine, preparation includes studies, meetings, information activities, publications, management on informatic tools, systems and networks for the exchange and processing of information. Telemedicine activities are effective (in terms of being cost-effective and increasing population reach) medical practices, which are promising for and the organization of healthcare in various medical domains (pediatrics, geriatrics, cardiology, diabetology, etc.) with some and advances in urban and rural healthcare delivery around the world [6—16]. There is concern about the appropriateness of methodologies for assessments of telemedicine [17] in general and particularly, the measurement of patient satisfaction with telemedicine [18]. The key factor behind this telemedicine is a correct description in the formulation of the question used to determine the situation's medical background. Other factors affecting the procedure of such telemedicine activities are the purpose, the context and expected results for which the telemedicine is being carried out. The selection of the medical questions examined is determined in the planning stage, and should be strongly influenced by the nature of the telemedicine being requested and by the expected use of the telemedicine results. A preliminary process evaluation reviews telemedicine project and examines project actions to assess whether the results or outcome of the work may be affected by a technological obstacle or barrier.

Therefore, the management of interorganizational and interprofessional collaboration practices is influenced by the context in which it is implemented: the human factors, the issues relating to the procedures and the deployments, the legal framework, the prioritized intervention strategies, and the resources that are mobilized to support the intervention by medical professionals [19].

The first step to take when considering these questions is to determine the background and explanatory information of the planned telemedicine in order to enhance our knowledge and understanding of medical situation and to identify key issues paying particular attention to the associated risks. So, it is fundamental to get a deep understanding of the relationships between telemedicine actors and the organizational controls required to support telemedicine services [20].

This collected information aims to ensure the proper identification and consistent determination of the following elements associated to any telemedicine activity:

- the purpose of the telemedicine: it is at this stage that the collaborative medical team must analyze the needs and identify the objectives to be set in order to fulfill the requirements of and commitments to the patient. The requesting physician must present the situation and formulate the expertise requested clearly and precisely. He could provide the required physician with the elements they used as a basis to formulate the request contained in their communication. The purpose and impact, as well as the arrangements for the planned use of expertise outcomes may also be specified as conditions of telemedicine;
- the nature of the telemedicine: remote medical service involvement depends essentially on the nature of the expertise required and on the conditions of the studied situation. The approach for telemedicine depends on the required physician's expertise, the advice solicitation for diagnosis, treatment or monitoring, the nature of the disease, patient characteristics and patient choice. The subject matter dealt with by telemedicine requires relevant evidence from the contextual medical constraints, case study analysis and key informant analysis to assess and provide meaningful advice or orientation;
- the documentation for traceability: a precise formulation of the expected outcomes may be issued for all telemedicine requests for which the resources and the deliverables of an expert medical demand are defined by their inbox and outbox parameters. The produced deliverables must give some indications about its content to the interpretations, findings and recommendations based on the associated professional expertise. The expert report may consists of several elements, containing a written document, sound recording, videotape, file, photograph, chart, graph and information recorded or stored by means of any device. Instructions for an exploitation which meets the requirements for organizational, conceptual or technological interoperability must be given in the documentation supplied with the final report;
- the available data: participating experts also examined the availability of data concerning telemedicine and agreed that a knowledgeable analysis helps to point to the most efficient implementation path towards the target medical goals (treatment of cerebral edema in cases of ischemic brain infarct or normalization of blood sugar in cases of diabetes mellitus). Further details and the suitable modalities of remote access to available data enable physicians to collaborate with each other by sharing data sets, expert environments and tools. Each health care service must also lay down specific provisions regarding secure access to its medical data and documents in its information system by means of the communications protocols or internal operating procedures;
- the risks associated with the telemedicine: the engagement of remote expertise requires that the telemedicine management identify and properly manage the principal risks related to their medical procedures. A telemedicine scenario must include the appropriate risk management measures and operational conditions that, when properly fulfilled, ensure that the risks from the practices of the remote expertise are adequately controlled. The challenges faced in designing, installing and operating remote health care systems are multi-faceted e.g. administrative, organizational, technological or medical, either positive or negative. A thorough understanding and consistent application of the criteria for characterization of the risks would be based partially on assessments or judgments that may change due to professional uncertainties and expertise-related hazards;
- the requirements or constraints related to the telemedicine: the practice of telemedicine should integrate new standards and regulations and take recent scientific and technical knowledge into account. They are some requirements or constraints which are necessary in order to ensure the security of the telemedicine and the authenticity of the shared documents. Numerous important measures have been taken to guarantee a level of protection of medical data. These measures include the preparation of technical standards or rules. The management also contains requirements regarding practices and the competencies of the concerned healthcare professionals that the type of telemedicine must provide to potential patients. The telemedicine may be individual, plural, or collective, but in all cases it must be proportionate in order to achieve the target objectives.

## Modeling

### Definition

In the scientific community, the concept of modeling was initially defined by mathematics, such as the construction of an abstract description interpretable but whose goal is to better represent reality. Significantly restrictive definition of which we prefer a much more constructive sense of Jean Louis Le Moigne defines modeling as follows:

> ''*An action of development and intentional construction by composing symbols with models that make sense of a complex phenomenon seen, and amplify the reasoning of the actor throwing a deliberate action within the phenomenon, including reasoning to anticipate the consequences of these actions possible projects*'' [1].

We can thus look through modeling to describe, understand, summarize and explain a system considered, in order to better decide or analyze its behavior in response to different determinants, but also to find the information needed to make changes and extensions. Significantly, the systemic modeling with its tools (mapping, analogy, etc.) provides a fruitful reading grid to understand complex situations for analyzing properties and action levers are required for the continuous improvement.

*''Model or theory, we all know, however, that we still are facing both old and familiar problems: on the one hand do we have some good methods to find or build, and the other hand to validate or legitimize them?''* [1].

The target scope is the modeling of telemedicine activities, but it seems clear that the concepts developed in this paper can be varied in many ways in other application fields.

## The process of systemic modeling

Daniel Durand describes the process of systemic modeling into four modules [21]:

- the first module is to define the field of modeling and it has two components. The first element is to establish the purpose of the model, which may be limited to get a good understanding of a system or phenomenon. If this goal can be specified during the modeling process, it is different from the second element: the boundaries. These must be defined from the outset to locate the exchanges between the internal components of the system and its environment;
- the second module consists of the design of the model. This is being fulfilled, since the identification of significant elements that will compose the model, including the precision of their characteristics (inputs, outputs, specific relations), through the research of their arrangement and the establishment of their connections;
- the third module of the modeling process is to check the behavior of the model, that is to say, to identify invariants and variables, and constraints related to the application of the model to clarify the operation of the system and its dynamic evolution;
- the fourth and final module is finally developing scenarios for the application of the model in fields related to the studied system and implement means of validation for qualitative or quantitative development.

Daniel Durand also relies on four precepts defined in [4] and which are based on systemic modeling: the relevance of which is defined in relation to the modeler; globalism which considers the studied system as a part included in a larger whole, teleology, which is to analyze the model in terms of its purpose and finally agregativity used to connect the components of the model, all of which is a simplification of reality. Similarly, any modeling approach being in the context of systems theory must take into account the systemic expert knowledge. This especially as systems theory provides an informal generic knowledge highlighting the aspects common to several models. This generic knowledge defines, for example, the concepts of flow and nature of flow and processes elementary transformations [22]. This knowledge has been reused in work in different areas (e.g. physical and information systems) but with a common goal to help the modeler in a process of systemic modeling by using common concept of flows (Must-Do, Want-to Do, Know-How and Can-Do) proposed by [3].

## Different modeling views

Just as a photograph of an object takes different aspects depending on the angle of view, the complex system can be defined differently depending on the observed appearance. Systemic triangulation [4] (Fig. 2) observed the system in three different but complementary aspects, each associated with a particular aspect:

- the functional aspect is especially sensitive to the purpose or purposes of the system. We spontaneously seek to answer the following questions in a transparent manner: What is the system in its environment? What is it?
- the structural aspect is to describe the system structure, the arrangement of its various components. The focus is much more on the relationship between components than on the components themselves, on the structure more than on the element;
- the behavioral aspect (historical or genetic) is related to the evolutionary nature of the system which has a memory and a project capable of self-organization. Only the history of the system will often reflect aspects of its operation.

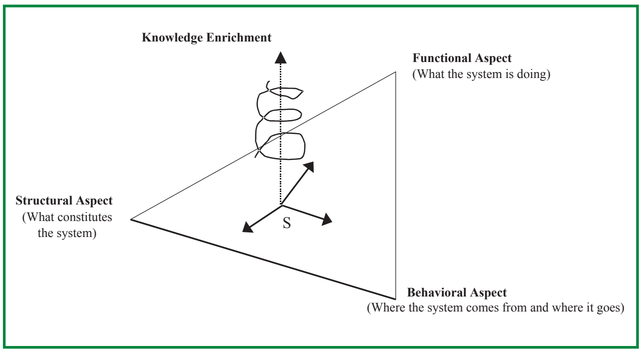


**Figure 2.** The systemic triangulation [4].
*La triangulation systémique [4].*

Naturally, systemic triangulation grows by combining these three approaches. More precisely, it moves from one side to another in a spiral process which allows, at each passage, to gain a better understanding, but without that we cannot believe that we have exhausted this understanding. The previous three aspects, we often add the informational component to describe the data used and generated by the systems. These data (which can be interconnected) need to be understood, manipulated and managed. Meticulous decisions must be made to determine the nature of information that the system can represent and make that information carried by the system can match the real phenomena that we are trying to represent. In practice, taking into account the various aspects simplifies the management of complexity, facilitating human understanding and communication.

## Generic functional models for French telemedicine

In the French national context, different medical use cases associated with five priority projects that can be summarized in two generic functional models [23]:

- a first generic model (Fig. 3) covers cases of teleconsultation, teleexpertise and teleassistance with the priority projects of ''Permanence of care in medical imaging'',

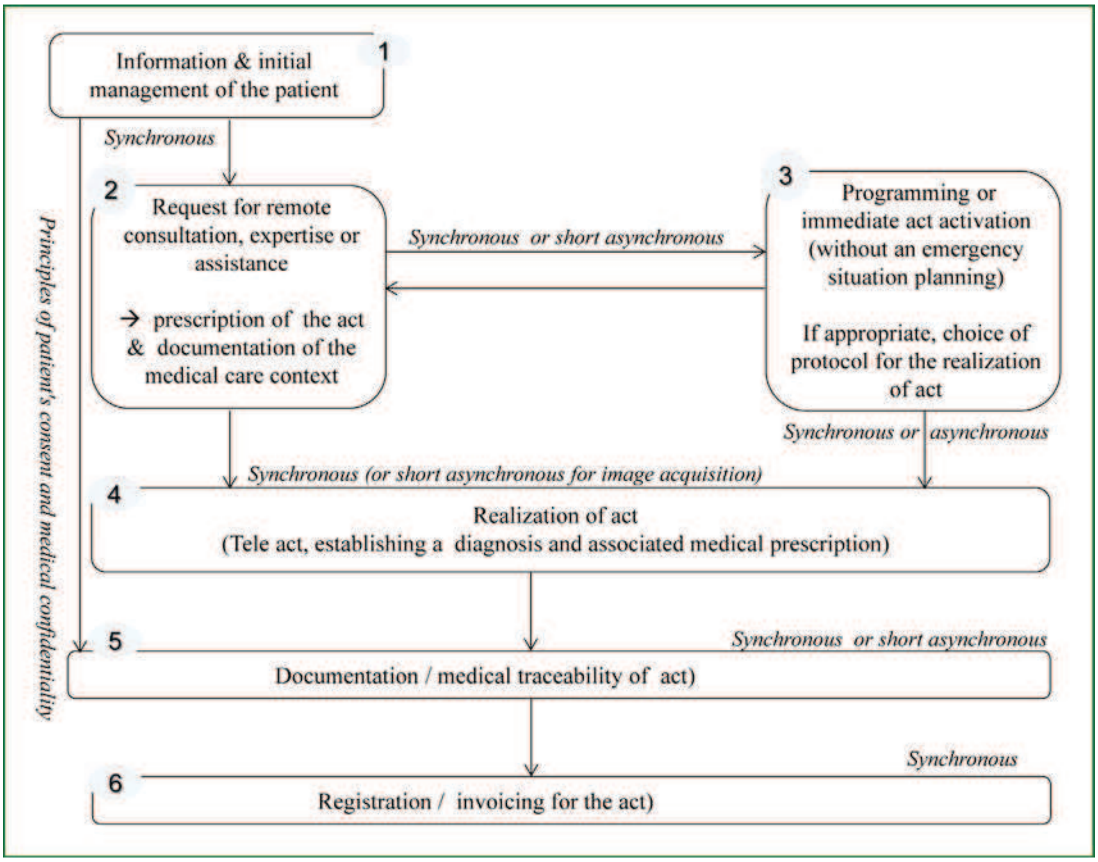


**Figure 3.** The functional model for teleconsultation, teleassistance and teleexpertise.
*La modélisation fonctionnelle pour la téléconsultation, téléassistance et téléexpertise.*

''Management of care for stroke'', ''Health of detainees'' and ''Care in medical-social structures or home hospitalization'';

- a second generic model (Fig. 4) is devoted to the cases of telemonitoring, which mainly correspond to the priority project of ''Management of Chronic Diseases'' (teledialysis, telemonitoring of diabetes, telemonitoring of heart failure, telemonitoring of chronic respiratory failure, follow-up of chronic wounds...).

In addition to the two typical situations previously described, an integrated approach will be adopted to discuss the borderline or problematic cases. For instance, telemonitoring activities can be coupled with a teleconsultation, teleexpertise or teleassistance. In case of actual or perceived life-threatening emergency, a protocol may include the option of calling an emergency service, then the medical professional responsible for telemonitoring, allowing it to provide the additional information and relevant comments to the emergency physician. This collaborative telemedicine helps the health care providers to improve the management of the patient on the satellite site and reporting processes to determine its orientation (teleexpertise).

Within the first generic functional model which covers most of the priority areas with the exception of cases of telemonitoring, the main differences between them depends on the operational context and the considerations of temporality:

- operational context: nature of needs/pathologies concerned and, by extension, the types of actors involved, to contextualize according to the concerned medical domain:
  - thus, for emergency situations, the ''request for consultation, expertise or remote assistance'' is performed by an emergency physician (applicant) to a radiologist on duty in the case of the ''permanence of care in medical imaging'', a medical expert of neurovascular unit in the case of a ''stroke management'',
  - regarding the areas of ''Health of detainees'' or ''Care in medical-social structures or home hospitalization'', it is the qualified health professional (doctor, nurse, counsellor, etc.) in the patient's location (detention centre or a health care facility) who makes this request to a specialist located outside (psychiatrist, dermatologist...);
- considerations of temporality:
  - the areas ''stroke management'' (in its acute phase) and, to a lesser degree, ''Permanence care imaging'' are primarily characterized by the acute care setting, requiring the implementation of acts of teleexpertise in real time (the medical acts are not scheduled, immediate care for people who are affected by the diseases is a key element),
  - in contrast, a teleconsultation of a remote specialist (projects the ''Health of detainees'' or ''Care in medical-social structures or home hospitalization'')

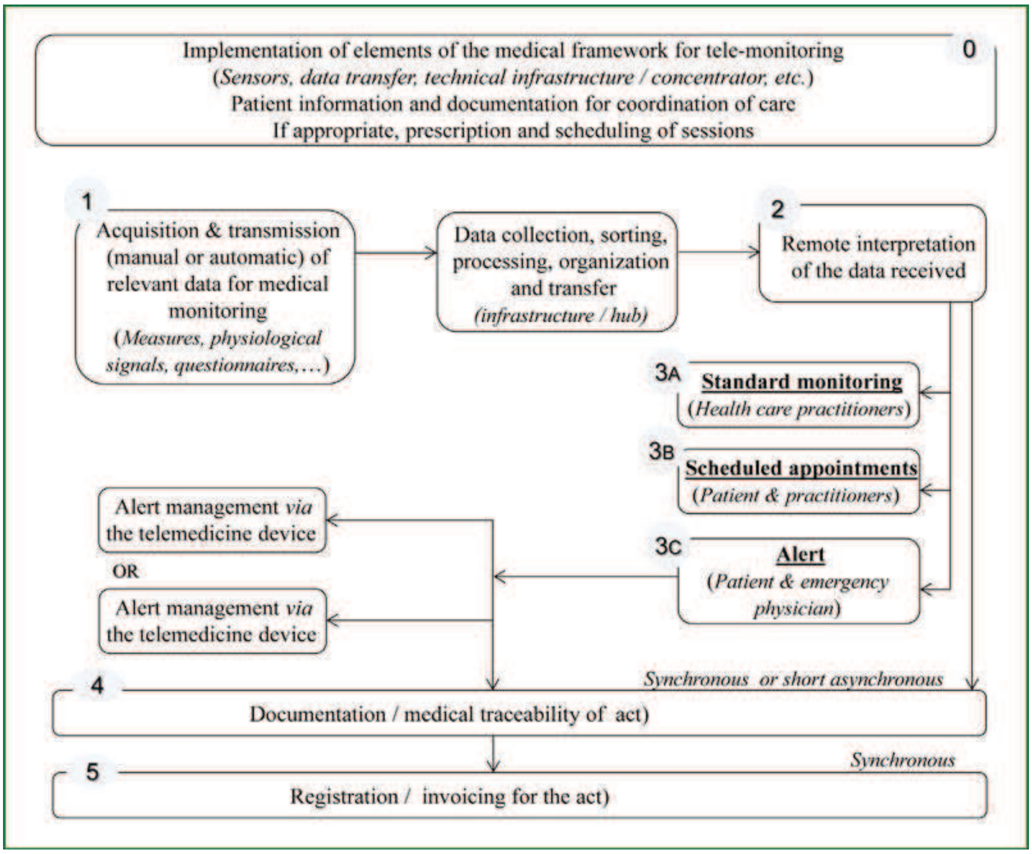


**Figure 4.** The functional model for telemonitoring.
*La modélisation fonctionnelle pour le télémonitoring.*

covers mostly primary care, which may be delayed with reference to the moment of the initial request for new medical services (planning the proposed act at a later date),

- likewise, certain acts of teleexpertise (multidisciplinary coordination meetings in the cases of strokes) may be delayed when they do not necessarily concern emergency situations. This is especially the case of ''ministrokes'' that are very small hemorrhages in the brain, which appeared not to have triggered any symptoms when they happened, but an indication that they did certainly occur is obviously observable when ordinary brain imaging is done at later times.

## Ethical implications of the use of information systems in telemedicine

New information and communication technologies (ICTs) play a key role in ensuring the development of telemedicine applications. ICTs give health professional and medical professional quick access to up-to-date clinical and administrative data. They support collaborative activities in a number of key medical areas, addressing generic situations such as teleconsultation, teleassistance and teleexpertise. These technological evolutions lead to behavioral changes among stakeholders. Today, we must manage the information systems with ethical conditions incorporated in information modeling processes, in accordance with the standards of current medical rules and professional ethical codes. Such codes or rules may take various forms such as health legislation, a code of professional practice or accepted medical ethical principles. Bioethical principles [24] can usefully be applied to telemedicine in particular. The ethical guidelines associated with the practices of telemedicine must be grounded in the four ethical principles of the universal human rights [25]; namely, the Principle of Autonomy, the Principle of Beneficence, the Principle of Non-maleficence, the Principle of Justice (Table 1).

The ethical principles only make sense if all four of these elements are taken together and if none of them prejudices any other. Frequently and strongly articulated views of autonomous individuals are considered to permit the advancement of these principles without damaging others in the society. The needs of people must be balanced with the requirements of operations, ensuring the best possible care. Faith in ethical safeguards and the fairness of electronic data processing techniques operate so as to strengthen the confidence in telemedicine [26]. The deployment of telemedicine applications would be consistent with international human rights norms and standards if they comply with the described ethical principles [27]. Besides, observance of these principles would also be in compliance with the laws in effect in the country or territory.

**Table 1** Bioethical principles for telemedicine.
*Les principes bioéthiques pour la télémédecine.*

| Principles | Definitions | Rules |
|---|---|---|
| Autonomy | Respect for individual rights and free choices and associated decisions (human dignity and human rights) | To tell the truth about all medical activities<br>Respect for private life<br>Protection of the confidentiality of personal information and records<br>To obtain informed consent |
| Beneficence | The duty to do good to individuals and society (social responsibility and sharing of benefit) | Prevention of disease<br>To get rid of the problem at the source<br>To promote the existing and future well-being of the people and communities of the settlement area |
| Non-maleficence | The duty not to harm others (solidarity and cooperation) | To consider the possible harm that any intervention might do |
| Justice | The duty to treat people equally and fairly (with equity). This makes it possible to deal with the same cases in the same way (respect for cultural diversity and pluralism, non-discrimination and non-stigmatization) | To give each person due consideration based<br>equally deserving of the time and attention<br>according to their needs<br>by the measure of its endeavor<br>on the basis of its contribution<br>on its merits |

## Conclusion

In the early stages of the development of complex systems, such as telemedicine, process modeling is an element that can contribute significantly to the quality and reliability of activities and services developed. In addition, the resulting documents are regularly consulted and operated, from the development phase of the system to maintenance, through formal verification and validation [28].

The nature of the questions addressed in telemedicine makes it essential to have a coordinated, multidisciplinary and systemic approach involving the various components needed for appropriate analysis of specific characteristics of telemedicine domain. The challenges include [29]:

- the difficulty in reconciling the organizational, financial, medical and technical objectives having various methodological frameworks that are managed by different responsibilities (health care professionals, public or private health institutions and agencies);
- the prerequisite to take into account not only the practical aspects of collaboration, but also the various risks involved - including cultural, ethical and legal factors and the surrounding context;
- the need to consider experience and learning capacity among the actors involved in telemedicine activities;
- the importance of placing telemedicine devices consistent with the urbanization of health information systems in a dynamic and ergonomic way.

The importance of this modeling and rigorous analysis of the requirements of telemedicine systems is even more apparent since the recognition of the generic representation declined in two meta-models: the first covers the activities of teleconsultation, teleexpertise and teleassistance; the second concerns telemonitoring.

The applications of telemedicine seem justified and have a promising future, but it is important to prevent or control any impacts of the development of intelligent information systems with computerized processing of medical elements (data, images and sounds) [30]. Indeed, we must be able to manage the undesirable effects of automated reasoning [31—34] and contribute to systemic solutions driven by ontologies [35] to protect the fundamental principles relating to individual rights, freedom, justice and medical deontology. Indeed, apart from the intrusion of privacy that the doctor would answer, medical confidentiality may be violated by telemedicine, in situations where several non-practitioners are involved, since they would not be bound by medical confidentiality. To be as rigorous as possible, it is always necessary to specify that anyone attending activities of telemedicine shall be bound by medical confidentiality with regard to the information and/or documents to which they have access in the performance of their duties [36—40]

## Disclosure of interest

The author declares that he has no conflicts of interest concerning this article.

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