APPLICATION OF CYBERNETICS TO THE HEALTH SCIENCES AND ITS ETHICAL IMPLICATIONS

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Abstract

The question bothering on the application and implication of cybernetics to the health sciences have not only been of special interest to academics but have also received myriad of interventions by scholars from different academic backgrounds. The present paper contributes to this growing scholarship by exploring the benefits of cybernetics in the promotion of global health and the bioethical implications of such benefits. The paper claims that as cybernetics evolves, physicians have appropriated support systems with intelligent and adaptive features to help them in many diagnostic and treatment tasks. These artificial systems, the paper contends, use very efficient arti? cial neural network and fuzzy logic algorithms that have tremendously assisted physicians and their patients around the world. Specifically, these improvements have helped clinicians in decision-making, to offer an accurate diagnosis or to deliver a better treatment resulting in the possibility to develop new approaches for a higher quality in healthcare systems. However, as is usually the case with high-technology developments, the application of cybernetics to medicine has also given rise to many ethical issues. Based on this, this investigation will follow the following course of actions: identify some of the bioethical issues generated by the application of cybernetics to medicine and recommends that while the increasing application of hi-tech machine in the promotion of health is a welcomed development, it is also crucial to address the bioethical concerns that surround these applications.

Introduction

The recent and perhaps the truest account of cybernetics as it has come down to us, associates the development of the science with the pioneering work of the American Mathematician Robert Wiener. According to this account, during the Second World War, Wiener was working in a military program for the American Government when he and his associate, Julian Bigelow conceived a science that could predict behaviours and control processes. This science eventually come to be known as cybernetics. With the establishment of cybernetics, a different point of view to approach the way of studying systems was provided, and rapidly, many disciplines adopted principles proposed by this new science.

Since its invention, J. Markoff believes that one area that cybernetics has found its most important application is in the health sciences. This achievement is brought about by a number of contributions. In 1965 Lotfi Zadeh established the theory of Fuzzy sets and systems as a “generalized system theory” basing on his former research in cybernetics, system theory and information theory. Already four years later A. Zadeh expected that this new theory could be used in the life sciences and particularly he himself proposed the medical sciences as a field of its application to assist physicians in medical decision-making and in their patient care(pp.358-388). Today, medicine and healthcare have advanced in its application of cybernetics mechanism. This include adopting supporting systems constituted by concepts and principles derived from cybernetics. These systems use Arti?cial Neural Networks (ANNs) and fuzzy logic (FL) approaches composed of intelligent algorithms and adaptive characteristics to apply them mainly for decision-making. Moreover, new therapeutic options have been developed thanks to cybernetics; for example, robotic exoskeletons have provided a new hope for patients that need prosthesis to recover a limb's functionality. Also, A. Zadeh stated that e-health has been introduced as a proposal for making healthcare systems more ef?cient because this approach could reduce costs and bene?t patients by making them active participants (pp. 29-37).

Nevertheless, in spite of these benefits, the use of cybernetics in the medical ?eld has many bioethical questions about responsibilities and ethical issues deriving from machines and devices that are used in daily clinical encounters. Also, decision-support systems have generated ethical issues, such as the purpose and moment when these systems must be used, the individual who is responsible for management of the system, etc. Furthermore, A. L Caplan affirm that the bioethical principles (autonomy, bene?cence, non-male?cence, and justice) can be outrageous from some points of view, when clinical trials are performed, new technology is used, or some researches are conducted (pp. 225-230). In this paper, we shall follow the historic development of cybernetics to highlight some of the important achievements in the application of cybernetics in the promotion of the health sciences. Ethical challenges that lurk behind these achievements are assessed and some recommendations underlined.

Conceptual Framework

Back in ancient Greece, Plato applied the word cybernetics to refer to how governors ruled and directed society. In other words, *cybernetics* was first used in the context of "the study of self-governance" by Plato in *The Alcibiades* and signified the governance of people (p. 2). Similarly, but not directly connected to this Greek derivation, the French Physicist and Mathematician, André-Marie Ampère was the one who first coined the word "cybernetique" in his 1834 essay *Essai sur la philosophie des sciences* to describe the science of civil government (p. 5). In other words, for Plato as well as for Ampere, cybernetics portrays the independence or ability political leaders or governors exercise over their cities or subjects. It is similar to what we mean today when we use the word, sovereignty.

Etymologically, cybernetics has a meaning similar to the way it was used by Plato and Ampere. The term stems from the Greek noun, κυβερνήτης (*cybern?tēs*) and refers to "steersman, or more precisely, to governor, pilot, or rudder." It pertains to all that are pertinent to the Greek verb, κυβερνάω (*cybernáō*), the latter meaning "to steer, navigate or govern." Therefore, the Greek noun, κυβέρνησις (*cybérnēsis*), meaning "government", is the government while κυβερνήτης (*cybern?tēs*) is the governor or "helmsperson" of the "ship". Here again, the term expresses the ability of governors or captains of ships to make independent decisions.

The formal and most widely accepted de?nition of cybernetics was proposed by N. Wiener as "the science of control and communication, in the animal and the machine"(p. 2). Bearing this in mind, cybernetics can be de?ned as the science that studies the communication and interactions between autonomous complex systems (machines and living organisms) through the use of information and the control of their processes. For this reason, it is a multidisciplinary science complemented by different sciences or disciplines such as biology, engineering, sociology, and psychology, among others. This science mainly focuses on the functionality of the system for the achievement of its goals rather than its components.

In addition, it is important to understand what a system is, and according to Hass and Burnham a system is a "combination or assemblage of interdependent, interrelated, or interacting elements which perform a set of functions"(p. 9). Therefore, what really matters to cybernetics is how things behave and function. It offers a form of organization on how systems may be conducted, related, and conceived in such a way that William Ross Ashby thought of the signi?cant applications in the biological sciences. Likewise, Ashby considered that cybernetics could generate "parallelisms," for example, between machines, brain, and society, making the application of a common language to discoveries possible, where they can be interchangeably used in different ?elds. One of the most important features is that cybernetics offers methods for studying and controlling complex systems; therefore, it offers ideas on how to approach the complexity of systems (p. 9).

For the control and regulation of complex systems, cybernetics proposes a series of processes that applies feedback and feedforward as well as buffering. Feedback and feedforward are controlled and regulated through actions generated by the system, counteracting or inhibiting the effects of variations. Speci?cally, feedforward exerts actions before there is affection to the function of the system. In other words, it anticipates before something happens. Otherwise, the feedback process deals after something has happened, so it counteracts the errors. That is why it is also known as error-controlled regulation. Besides, there are negative and positive feedbacks that preserve stability and allow growth, the same as self-organization. In contrast, buffering is referred to as the way of reducing changes, so it can be considered as a stable equilibrium. This shows a very important contribution of cybernetics to complex systems and the importance of its application to the health sciences.

Theoretical Framework

Certainly, when dealing with medical bioethics, physicians are forced to face several moral theories in order to get a better approximation about speci?c problems and to generate solutions based on a bioethical re?ection process. One of those moral theories, and seemingly the most popular among physicians and the one to guide this research is principalism. This term refers to the four basic principles: autonomy, bene?cence, non-male?cence, and justice, in order to enhance moral assessments in the daily practice of healthcare providers.

To understand these principles, a brief de?nition of each one of them is exposed. Autonomy can be understood as the way a moral subject rules his own life and chooses the best options for himself without any external constraint. Bene?cence points out that every single decision must be made by the person confronting an issue, because only the subject knows exactly what he wants for his own bene?t. Non-male?cence implicates the response of an external moral agent; it deals with the concern that nobody should do any harm to another subject. Finally, A. L Caplan justice can be understood as the equal consideration and distribution of bene?ts in a society (p.225).

These four bioethical principles will be used in this research to show that there is need to develop a framework that will balance the application of cybernetics in medicine with the rights of patients, professional caregivers and the demand for justice in society.

History and Development of Cybernetics

As already hinted, Plato was the first to apply cybernetics to refer to how governors ruled and directed society. Similarly, the word, which means "steersman," made reference to the person who was in charge of the steer in large ships in old Greece and who controlled the ship's destination course. But it was not until the publication of the Essai sur la Philosophie des Sciences by the French André-Marie Ampère in the nineteenth century that the word "cybernetics" was used as it is known nowadays. Despite the meaning given to this term later, Ampère used it to describe the science of government. However, in the twentieth century, the American mathematician Norbert Wiener in his widely known book *Cybernetics: or Control and Communication in the Animal and the Machine*, established an innovative theory for the organization and control of systems and, more importantly, the development of a new science called cybernetics

During the Second World War, the American Government was trying to ?gure out a method to predict the exact position of the military alliance's (Axis) airplanes in combat for a more effective attack. Therefore, the government created a classi?ed military program, which was in charge of R. Wiener an American Engineer and Mathematician who graduated from the Massachusetts Institute of Technology (MIT) with experience working in companies such as the International Business Machines Corporation and Sperry Corporation. The purpose of the program was to employ computational methods to predict airplanes' ?ight. It was while carrying out this research that Wiener found his field of scientific activity, namely the development of fire control systems and anti-aircraft weaponry. Later A. L Caplan wrote:

> At the beginning of the war the only known method for tracking an airplane with an anti-aircraft gun was for the gunner to hold it in his sights by a humanly regulated process. Later on in the war, as radar became perfected, this process was mechanized. It became possible to couple directly to the gun the radar apparatus by which the plane is localized, and thus to eliminate the human element in gun pointing. However, it does not seem even remotely possible to eliminate the human element as far as it shows itself in enemy behaviour (p. 230).

It was clear to Wiener that the computations needed for the control apparatus on the antiaircraft battery had to be built into this apparatus. In his autobiography, O.C Hass recalled:

> These were rendered much more difficult by the fact that, unlike all previously encountered targets, an airplane has a velocity which is a very appreciable part of the velocity of the missile used to bring it down. Accordingly, it is exceedingly important to shoot the missile, not at the target, but in such a way that missile and target may come together in space at some time in the future. We must hence find some method of predicting the future position of the plane (p. 1).

Since they did not think they could solve the problem psychologically, Wiener and his associate, Bigelow attempted to think both like a gunner and like a pilot and to imitate their behaviour mechanically. They recognized that both the pilot and the gunner were aware of particular patterns of behaviour and were trying to avoid making the same errors in the future. This resembled the control method of the controllers that they knew from electric circuits and that were used in servo mechanisms, the so-called feedback principle Ross Ashby believes

> However, this improvement in behaviour does not continue indefinitely, for after a certain stage, with a large measure of amplification in the feedback, the apparatus will go into spontaneous oscillation and behave in such a wild way that we have decreased rather than increased the load independence of the apparatus. We expected that if human control also were to depend on feedback, there would be certain pathological conditions of very great feedback, under which the human system, instead of acting effectively as a control system, would go into wilder and wilder oscillations until it should break down or at least until its fundamental method of behaviour should be greatly changed (p. 2).

The team was completed by the Mexican neurophysiologist Arturo Rosenblueth who was at that time conducting research at Harvard Medical School. Wiener has this to say on what becomes their orientation when Rosenblueth joined the team. The specific question we put was:

> Are there any known nervous disorders in which the patient shows no tremor at rest, but in which the attempt to perform such an act as picking up a glass of water makes him swing wider and wider until the performance is frustrated, and (for example) the water is spilled? Dr. Rosenblueth's

> answer was that such pathological conditions are well known, and are termed "intention tremors"; and that very often the seat of the disorder lies in the cerebellum, which controls our organized muscular activity and the level on which it takes place. Thus, our suspicions that feedback plays a large role in human control were confirmed by the well-established fact that the pathology of feedback bears a close resemblance to a recognized form of the pathology of orderly and organized human behaviour (p. 251).

Finally, in 1943, all the concepts and principles were put together and the paper titled Behaviour, Purpose and Teleology by Wiener, Bigelow, and Rosenblueth was published in the Philosophy of Science. This work laid the foundations of cybernetics and marked the path that it would follow. On the whole, the core of this interdisciplinary approach is the hypothesis that the behavioural mechanisms in machines and in living organisms were – at least roughly – the same.

In addition, Wiener continued developing cybernetics in the following years and suggested that the way to control systems was to regulate feedback through the transmission of information. This approach was based on the work published by Claude Elwood Shannon, *A Mathematical Theory of Communication*, which describes how information ? ows in a communication system. As a result of this, Wiener wanted to create a new perspective on cybernetics, considering it useful in the application for different sciences (i.e., physiology, biology, social sciences, etc.). He correlated cybernetics with other points of view in Mathematics, Thermodynamics, and Logics in order to give a wider point of view to this new evolving science.

It is important to point out that the general systems theory (GST) founded by the Austrian Ludwig Von Bertalanffy has been taken into account by cybernetics. This theory studies the systems from multiple angles; despite the fact that cybernetics focuses mainly on functional systems, both GST and cybernetics have helped for the development of systems. Wiener beleives the entire trajectory that cybernetics took led to the consolidation of a variety of disciplines and the development of other ? elds such as computer science, arti? cial intelligence (AI), neural networks, control engineering and most importantly in medicine (p.252).

Cybernetics in Medicine

Throughout history, cybernetics has followed two trends; thus, it is imperative to emphasize them. During the foundation of cybernetics, the attention was centered in a mechanistic approach; conversely, in the 1970s, Wiener upholds there were concepts and principles that were strongly highlighted such as autonomy, self-organization, cognition, and the possibility of modelling systems. This transition of cybernetics was known as the second-order cybernetics (p. 253). As a result, there was a signi? cant number of sciences and disciplines that implemented these concepts and principles to adapt systems into their ? elds in order to enrich them (i.e., medicine and healthcare).

For instance, Heylighen and Joslyn in the history of medicine, discoveries have led to the generation of a great amount of knowledge, and for this reason, medical physicians have resorted to support systems with intelligent and adaptive features to help them achieve many diagnostic and treatment tasks. Moreover, these systems have helped clinicians in decision-making, to offer an accurate diagnosis or to deliver a better treatment, resulting in the possibility to develop new approaches for a higher quality in healthcare. The systems include software and hardware that have to ful?l some special characteristics, as the ones previously mentioned, in order to provide that kind of actions. Thereby, intelligent systems must be able to learn to transform their processes, when needed, based on the environmental conditions. This property of arrangement is called "adaptation," which consists in the internal reorganization within the system to change its operational dimensions. These two properties are essential to satisfy the goals and functions of a system.(p. 13).

The software-based systems are composed of several kinds of algorithms designed to be intelligent and of course to permeate an adaptive nature. Therefrom, the systems must be "trained" with historical or expert data that correlate situations or conditions to generate knowledge with the objective to create an illustrative model. The main examples of intelligent and adaptive systems are arti?cial neural networks (ANNs) and fuzzy logic (FL). However, heterogeneous and complementary systems can be built up from these two main categories. For instance, the mixed systems are neurofuzzy (NF), adaptive neurofuzzy inference system (ANFIS), and fuzzy cognitive maps (FCM) (p. 15).

Likewise, Hass and Burnham stated for the design and inception of the intelligent systems, human behaviour and physiology have been the main insights for the designers. This last idea can be clearly exempli?ed by systems using ANNs, because they were developed based on how neurons function. Additionally, the development of the systems is constantly improving and algorithms are trying to incorporate biological and AI principles to re?ne them. There are many signi?cant applications of intelligent and adaptive systems in medicine that have been used to diagnose or to treat pathologies such as cancer, pulmonary embolism, coronary disease, etc (p. 42).

Furthermore, as in medicine and in the healthcare system, the management of information is immense; mechanisms for processing information have to be present in the systems to select the correct data and provide the best options. Depending on the necessities, three different approaches for processing information have been created. For example, the integral-differential approach uses numbers to formulate mathematical integral and differential equations in order to explain how a process functions but is rarely used in the medical ?eld. Another example is the empirical-data approach, which uses tools to calculate nonlinear functions. Therefore, this approach is able to predict outcomes of systems, based on their behaviours. In order to reach this goal, systems must be previously trained with the correct data. Hence, this kind of approach is used by ANN to create relationships between sets of data, and consequently, it can readily be applied to medicine. Finally, the linguistic approach uses tools that facilitate the utilization of words in computers. Thus, FL-based systems are used for this approach. Some FL systems used by clinicians assist them to make inferences or deductions taking this approach into account. Because factual situations use a diversity of information, the modelling of systems must consider these three types of approaches in order to produce a ?exible ef?cient system (p. 8).

Cybernetics and Decision-Making in Medicine

The basic element of an ANN is an arti?cial neuron capable of simulating what happens in a physiologic environment. Thus, this neuron mimics to receive an electrical impulse to reach a particular threshold in order to bring forth certain actions. In the arti?cial neuron, numerical values are provided to the input, as an analogy of an electrical impulse. Then, these values are summed up and pondered to give a particular activation function that is later transformed into an output signal. Also, A. Dourado, J. Henriques, & De P. Carvalho up hold that ANN can be arranged as a network organized in series or parallel in order to create a model with nonlinear relations between a set of inputs and outputs, for example, the multilayer feed forward neural network and the radial basis function neural networks (pp. 127-146).

Concretely, ANN is used to make relationships between two sets of data, the input and the output. In order to make accurate relationships and to get the ef?cient working of ANN, the training phase is one of the most essential steps. This phase is achieved by presenting a series of inputs to the network in order to generate an output that is desirable, in other words, a goal outcome. For this task, a training algorithm is in charge for minimizing the errors by using degrees of freedom to ?nd the most accurate output, based on the criteria previously assigned to the network. In order to minimize the errors, the network manages its control and regulation by using feedback or feed forward processes. Finally, when the network is trained, it can prognosticate a behaviour or it can give different solutions based on new inputs. So it is important to point out that when more quality of the inputs is provided to the ANN, according to a speci?c situation, a more experienced network will be available (p. 42).

For instance, as it is mentioned before, ANN can be applied to medical decision issues. First of all, signs and symptoms are provided to the input of the network as numerical values, which correspond to a precise diagnosis. Then, the values are summed up and pondered by the network in order to produce an output with the accurate diagnosis, also represented by a numerical value. This function of ANN resembles how physicians are trained during all their clinical encounters. When medical students are in their clinical clerkships or rotations, known cases with speci?c signs, symptoms, and diagnosis of pathologies are reviewed in order to prepare these physicians to give an accurate output when they encounter a patient with similar characteristics (p. 159).

Moreover, there are particular applications of ANN in medicine seen in the daily practice. In prostate cancer, for example, the prostate-speci?c antigen (PSA) secreted by epithelial cells of this gland is produced over normal range values in prostate hyperplasia or cancer. Therefore, there is a correlation between high levels of PSA and prostate cancer. In order to analyse this correlation, a computer-assisted diagnosis for prostate cancer is available under the brand name of Prost Asure. This system uses ANN, and based on different parameters of PSA, it can assist the diagnosis of prostate cancer. Also, the application of an ANN system can be used to make a more accurate diagnosis for breast cancer. For this task, a computer-assisted diagnostic system based on radiology studies assists physicians to detect suspicious lesions in order to denote a more precise diagnosis for this pathology (p. 162).

In addition, FL deals with a wide scope of true and false statements; in other words, a system that uses FL does not consider that there is a completely “true or false” outcome. First, it is important to point out that FL systems function through a set of rules that are previously assigned and clustered, named fuzzy rules. These rules are the knowledge (i.e., symptoms, signs, tests, etc.) for diagnosing pathologies, to have a clear idea of how this system works, it is easier to exemplify an application in the medical ?eld. Thus, after the rules are set to the system, the input values are presented as symptoms or level of health of a patient's case provided by numerical values and then transformed into linguistic variables. Afterward, the inputs and the fuzzy rules are combined and relationships are made of each case. The result is the diagnosis of the case based on the relationships generated between the inputs and the fuzzy rules assigned. In brief, FL systems permit the clarity between knowledge and decision-making; hence, they are helpful as decision-support systems.

Robotics: A Bridge to a Therapeutic Option

Many disciplines were developed due to the foundation of cybernetics. One of them is robotics, a branch of AI which nowadays has been introduced to many ?elds, such as medicine. An interesting application of robotics in medicine is wearable robots. This refers to person-oriented robots, which an individual can manage in order to support or supplant a function. M. Fisher provides therapeutic options for patients who have suffered amputations or dysfunction of their limbs; thus, these robots offer tools to supplement, back up, or augment limb functions (pp. 283-288).

Furthermore, J. L Pons wearable robots can be classi?ed as empowering robotic exoskeletons, orthotic robots, and prosthetic robots. Empowering robotic exoskeletons are the robots that offer a “magni?ed function” for a speci?c anatomic part; in other words, the function is not the natural one. The orthotic robots are mechanical devices that help to restore physiologic functions especially in neurological pathologies. And ?nally, prosthetic robots are electronic and mechanical structures that supplant an anatomic part for amputated limbs (pp. 2-5). This classi?cation portrays many applications of robotics into medicine, but more importantly, it provides a new hope for patients.

E-Health: A Proposal for the Improvement of Healthcare Systems

Nowadays, healthcare systems deal with high costs, expenses, and an immense demanding on patients. Hence, new proposals and strategies are being adopted in order to reduce these issues without jeopardizing the quality of care. These proposals and strategies are directed to outpatient services to use technology in order to reach speci?c goals. For instance, e-health offers a strategy that uses advanced telecommunications, such as networks, devices, the Internet, etc., for the transformation of the medical care and its delivery. Moreover, e-health provides a new method for supporting healthcare processes, empowerment to patients to be active in their health, and also, new perspectives for decision-making (p. 9).

There are a variety of devices that e-health may be used for prevention and to monitor vital signs or other parameters. These two approaches may be the key features for anticipating diseases and, if necessary, to provide an early treatment. Also, G. Demiris believes that e-health could be a strategy to overcome the borders of territories for healthcare systems to reach a massive population and to provide a quality of care at all levels. However, the policies and ethical framework of e-health are not well established; thus, for implementing this way to reach patients with so "inmost relationships" between care providers and people, these issues must be discussed (p. 34).

One current application of e-health is the home healthcare which offers a combination of care services to patients, families, and caretakers at their homes. In this setting, issues previously mentioned such as high costs and reaching a vast population could be approached. Two ways in which home healthcare can comply with these objectives are telehomecare and smart homes. Telehomecare uses telemedicine systems installed in patients' homes that enable communication for patients and care providers. This way to approach patients can be affected by a variety of factors such as the correct primary diagnosis giving to patients, the induction of them to use this kind of system, and their physical limitations, among others. Additionally, smart homes can be a new approach that can help to prevent diseases and to promote a healthy life by installing monitoring devices, not only for measuring vital signs, but activities that people do in a daily basis. Speci?cally referring to smart homes, the transfer and management of patients' information is the main concern, because privacy policies are not well established and this information could be used for other purposes, with the risk of jeopardizing ethical issues.

Evaluation

In the last 25 years of the twentieth century, bioethics has evolved enormously, thanks to the collaboration of many disciplines. This evolution has been possible, mainly, due to the development of new technologies in the medical ?eld. Therefore, bioethics has provided a framework with a multidisciplinary perspective to locate the problems that compromise the principles that support this discipline, as well as to try to ?nd the best solutions for daily encountered issues. Moreover, as science and technology progress, healthcare professionals' dreams of curing fatal diseases and enhancing human capacities could become real. For instance, prosthesis and mechanical substitutes are a perfect approach to reaching this goal. However, as Miller and Goodman pointed out, ambiguity and controversy sometimes arise in the resolution of the issues (p.56). The use and research that surround this kind of devices have given rise to ethical issues that can be extended to other types of high-technology developments. Thus, it is crucial to address the bioethical issues that surround the application of cybernetics into medicine, such as Medical Decision-Support Software (MDSS), health informatics, intelligent machines, etc. Attempts will be made to evaluate and recommend solutions to these issues in this section.

It was previously described in this study that decision-making systems are being broadly used in medicine to help physicians make right decisions for the improvement of medical care and an accurate therapy choice. Furthermore, it has also been said by R. A Miller that these systems are software based and useful in clinical practice; thus, these kinds of systems are also known as MDSS. The constant development of technology has impacted directly to the MDSS, making it necessary to embrace a range of abilities and capabilities to solve issues found in daily clinical encounters, such as the calculation of drug doses, emission of warnings for possible drug interactions, assistance for the interpretation of arterial blood results, monitoring of patients in case of lethal arrhythmias, etc (pp. 103-112).

It is evident then, that when any of these MDSS or other systems is used to make decisions, the patients' health is involved and ethical issues emerge. One of these ethical issues addresses the purpose and moment when these support systems must be used; it is clear that the purpose of MDSS is to improve healthcare and the way to provide it to patients. Moreover, this software must be used when physicians face a problem and when the usage of this system can solve this problem ef? ciently.

Another ethical issue deals with the people who are responsible for using these systems. In order to use MDSS, there are elements that the healthcare personnel must have. Thus, they must possess speci? c quali? cations. Prior to the personnel assignment, studies must reveal the safety and ef? cacy of this kind of software in the hands of different users, as well as the level of training that they must have to use it ef? ciently. Although speci? c quali? cations are needed in order to use these support systems, in the case of advanced software, high-quality trainings have to be developed to meet the safety usage requirements by healthcare personnel (p. 34).

Another area of ethical concern is the problem of assigning responsibilities to intelligent machines. Intelligent machines have been used in medicine for many years. They have been helpful to monitor and to evaluate patients, and they also helped physicians to interpret laboratory data and to base their clinical decisions, among others. In the hospital life, it is common to adjust functions of machines in order to modify an abnormal parameter presented by a patient. But when these intelligent machines perform more complex tasks, as they are now doing in cybernetics, the judgment they apply is similar to that made by humans; therefore, ethical issues and responsibilities must be assessed.

The way of application of ethical issues and responsibilities for judgments made by machines will affect their usage. This is because physicians may trust the judgments made by the machines more than their own, and they may also rely on the conclusions made by the machines more than their own. Now, if responsibility is completely attributed to the machine, then it has to be legally de? ned by J. W Snapper who is to blame for a problem:

> The operator, the owner, the manufacturer, the designers of the machines, or the physician who trusts the judgment given. In order to reduce the impact of these ethical issues, some physicians have resisted using computerized systems to make medical decisions, mainly to control their own decisions and responsibilities (pp. 43-55)

Furthermore, in the medical ? eld, the demands made of professionals are increasingly growing and becoming more complicated. On this account, the duties have been distributed in order to focus on speci? c ones. Some of these duties have been transferred to machines, but some physicians oppose the use of these systems because they feel they leave their roles behind. A solution for reducing this feeling is that physicians preserve their traditional role combining it with the use of machines but always applying their judgment. With the globalized and constantly evolving medical knowledge that is generated every day, it is dif?cult to abandon the support system, mainly because they help us to diagnose and treat patients' ef?ciently. But, it is obvious that they only help, and that is why the physicians must never leave their judgment and responsibility behind.

Looking at these ethical challenges through the prism of the four bioethical principles discussed in the theoretical framework of this study, the following observations become necessary. The autonomy principle could be endangered when patients are to encounter "death situations," while taking part in clinical trials involving hi-tech machines. For example, when individuals participate in clinical trials, they are always susceptible to "death" probabilities or getting worse, if the therapeutic tested in this trial is not provided. Though, clinical researchers consider that the informed consent is enough for patients to accept or reject their participation in these clinical trials but with other perspective, the patients, despite knowing the possible risks and bene?ts, are constrained to accept the therapeutic because of the risk of dying or getting worse.

Additionally, bene?cence and non-male?cence could be threatened with the availability of new technologies, therapeutics, or devices in the medical ?eld. When there is accessibility of these options, questions can be raised of who are the ones in charge of choosing them for healing or improving life quality, physicians or patients? According to the bene?cence principle, the one in charge of choosing therapeutics should be the patient that is facing a health issue. However, the physicians have the knowledge and the background of the condition that the patient suffers and they know both the risks and bene?ts of the therapeutics, so they must make the decision in order not to outrage the non-male?cence principle. Moreover, there must be counterbalance between simply elongating lifetime and improving life quality by the healthcare professionals.

Furthermore, the principle of justice in medicine can be infringed with the allocation of a great amount of budget to expensive new medical technology. This idea raises questions, whether where this money should be destined for and which diseases should be prioritized and also if there is a bene?t in spending so many resources in research for medical devices that are not going to be available for all the patients. Hence, medical researchers should be focused on the development of new technologies that could be available for all patients that need the device to improve their health. In the same way, another question that may arise is whether it is right and fair to develop expensive methods, while millions of individuals die before reaching adolescence from diseases and injuries that can be already prevented at a lower cost.

Conclusion

It is evident that cybernetics has provided a framework with concepts and principles to enrich many disciplines and ?elds. These concepts and principles proposed have constructed new ways to understand complex systems and they have created support software for decision-making. In medicine and healthcare systems, support software is very important to make diagnosis and to offer therapeutics to patients, but many ethical issues have arisen because the ethical framework is not well established. Therefore, it is substantially important to address an ethical framework and policies to rule the use of support systems, research, intelligent machines, devices, prosthesis, etc., because the main goal of physicians and health professionals is the pursuit of the quality of life and patients without harming them.

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