Medicine and Reasoning: The Diagnostic Process in Neurology

Abstract

What is the thinking process involved as physicians strive to resolve the enigma: "What is my patient suffering from?" Such is the question behind this article. Our analysis is based on real-life situations in which medical residents discuss specific cases in neurology with the aim of reaching a joint diagnosis. Our theoretical hypothesis holds that the diagnostic process has a rational component that lends itself to logical reconstruction, though it still requires the personal presence of doctors. By examining a particular case in neurology we reconstruct a cognitive process that employs the three approaches to diagnostics that are pertinent to this area of medical specialization –syndromatic, topographic and etiologic– and are used to arrive at a conclusion via a combination of abductive and deductive reasoning used to discard diagnostic hypotheses. This analysis supports the idea that clinical judgment, which dates from the 19th century and rests upon a rational medicine centered on diagnostics, is very much in use.

Keywords: medical logic, medical knowledge, diagnosis, neurology, cognitive process, abduction, deduction, induction, inference to the best explanation

Here, it is the clinic that rules.
— Neurology Service, INNN

From the very beginning, observe the dissimilarities and differences in the state of health, from those most simple to recognize, to those with the most severe effects; observe everything that can be seen. Investigate that which can be seen, touched, heard, that which can be perceived by sight, touch, listening, smelling, applying intelligence, in sum, everything that can be known through our means of knowledge.
— Hippocrates

Introduction and background

How do physicians think when they must resolve the enigma of the disease that a patient is suffering? Many have posed this question, from the patients who consult medical specialists out of necessity, to philosophers and scholars who have sought to make sense of medical reasoning by structuring it within the framework of scientific thinking. At a time when the role of technology is overwhelming and it is clear that without machines medicine could not be what it is today, is it valid to ask whether or not clinical judgment still governs medicine? If the answer is affirmative, then how is medical thinking structured?

For this study, the authors attended clinical sessions at the National Institute of Neurology and Neurosurgery (INNN) in Mexico City, which provided a unique opportunity to analyze the reality of the cognitive mechanics that neurologists follow when they need to make a diagnosis. This process –though seemingly ludic– is the supreme expression of the plenitude and elegance of the medical act.

Illness manifests itself through what are known as symptoms and signs. For symptoms we understand everything that patients *say* they feel, but these are elements that no one else can perceive because they pertain to the domain of personal experience; one example could be cephalea. Signs, in contrast, include all those indications that a doctor can appreciate *sensorially* in relation to the patient's body; for example, alterations of coordination or skin-color, an increased heartbeat or how a patient walks. Such phenomena must be explained biologically, and this entails knowledge of the medical act. Once a physician has ascertained the symptoms and signs, done a physical examination, obtained the results of certain tests and interpreted all this data in the context of the medical knowledge learned at school –all of these are aspects of the technical component of medicine– then she is in a position to make a diagnostic hypothesis elaborated as a means of resolving the problem that revolves around this key question: *What illness does my patient have*? Obviously, this process involves knowledge, but sensibility also plays a role, one that we could describe as the aesthetic or artistic component of medicine, and the one that transforms the medical act into an act of creation.

Strictly speaking, the phrases "clinical judgment," "medical logic," "clinical method," "clinical act," "medical reasoning" and "medical thinking" are not synonyms, though they all refer, in general, to the cognitive process through which the information gathered in a clinical case is sorted out and synthesized in accordance with the physician's knowledge and experience in order to diagnose and treat the patient's malady (Groves *et al*., 2002:507).

Students of the medical act have pronounced themselves in favor of two broad ways of understanding it: there are those who think that this is a mechanical process with purely nosological correlations (Montgomery 2006) that does not even require a doctor; others, however, argue that reaching a diagnostic hypothesis entails the realization of a complex scientific process (Foucault 1963; Laín Entralgo 1981) that requires absolutely the human factor. It is this second view that revolves around such phenomena as "the clinical eye," "experience," "criteria," "intuition" and even "medical knowledge." The present study develops arguments in support of this second posture, which defends the importance of the human element in the medical act; as in Goldberg's 1905 book, *How Do Doctors Think?*, which insisted that doctors cannot focus exclusively on evaluating illnesses, because illness is an entity created by humans, it is a product of the human spirit. Goldberg emphasized the significance of social and cultural aspects that, as we well know, cannot be ignored. Other scholars might say, in this vein, that we should treat patients and not illnesses (Villey 1979:209). While much could be written about the artistic component of the medical act, our chosen starting point is the thesis that developing a diagnostic hypothesis is an act of creation, and creation is a very human quality, especially in the sense that one expression of creativity is the ability to resolve problems, a capacity that is definitely one measure of intelligence.

Kathryn Montgomery, a specialist in English literature, has written a book (that, curiously, bears the same title as Goldberg's) in which she compiles the thinking of those who deem medicine to be a scientific practice. She warns that considering medicine as a science may have adverse consequences for patients, the medical profession and physicians themselves (Montgomery 2006:5). For example, she notes that while patients demand to be informed as to the cause of their problem, clinical medicine tends to simplify causality, and this reflects an attitude that is just the opposite of that of scientists, who strive to identify the exact causes of phenomena. According to Montgomery, clinical judgment is not only different from scientific rationality, but actually displaces or contradicts it. The maximum concession she makes to clinical medicine is to suggest that it follows what Aristotle called *phronosis*, or practical reasoning, understood as the ability to find the best solution in particular circumstances when universally applicable procedures fail (*Ibid*., 2006:42). According to Montgomery, such procedures can be applied easily through the use of computers.

Whatever the case, it is important to emphasize that works on the clinical act are written on the basis of theoretical reflections (Rillo 2006), not explicit situations; that is, on the basis of observing doctors while they carry out their diagnostic work, as in the present study. One study that is related, however, is by the cognitive scientist Paul Thagard (1999:117), who analyzed the cognitive processes involved in developing the bacterial theory of ulcers and other cases of the acquisition of medical knowledge. His main argument is that inferring the cause of an illness goes beyond discovering a correlation. His proposal is based on his own theory of explicative coherence, represented through complex causal networks. It should be noted that this author uses abductive reasoning in his models, though in a cognitive –not logical– approach, as we propose in this study.

Historical Context

Clinical medicine has not always played a key role in medical practice. Its golden age came in the second half of the 19th century, after the long lapse that followed the so-called Hippocratic approach. For the Greeks, the foundation of medical practice was clinical observation that, when done well, allowed the doctor to identify all the symptoms, signs and changes in the patient's condition over the course of the illness. Good clinical practice led to: 1) an accurate diagnosis that emerged from asking the question, how does this patient differ from the norm?; 2) an adequate prognosis, based on experience with other patients with similar symptoms; and, 3) a timely treatment that relied on the accuracy of the prognosis in other cases. The physician was to continue observing the patient, note any changes, and compare what he saw with his experience (Reess and Shuter 1996:24).

In the 19th century, the so-called anatomical-clinical method emerged to transform clinical medicine into science. Estañol (1996:6) writes that this was one of the greatest adventures in the history of the human spirit in the field of medicine. Though Estañol also considers that this method is perfectible and that over the centuries doctors have always identified symptoms and signs, it must be remembered that medical logic is new because the nosological entities are also new; after all, even as late as the 18th century such symptoms as fever, pain and vomiting were considered to be illnesses in themselves. At that time doctors based their diagnoses on a superficial examination of patients and prescribed treatments based on traditional formulas. In that milieu such practices as direct observation, acute perception, the search for specific or precise signs, noting changes in the patient's condition and monitoring the evolution of the illness were all considered provocative (Pinel 1980:9). Indeed, they did not come to form part of common practice until the 20th century, when advances in science led physicians to assume that each illness is specific and is distinguished by specific lesions, symptoms or signs and their causes. The mental process involved centered on matching those data with the corresponding maladies, though these had been defined just a short time before. Hence, great efforts were made to ascertain the symptoms and signs, and symptomology (the systematic study of the visible effects of organic suffering) was invented, together with semiology or semiotics; *i.e.*, the study of indices (signs) that now constitute the foundations of diagnostics (Villey 1979:117). Later, anatomical changes discovered through autopsies confirmed the clinical symptoms that the patient had manifested in life. The method of approaching a patient became ordered and the clinical act much more systematic. Any doctor who wished to be seen as an academic professional had to use anamnesis, inspection, palpation, percussion and auscultation with patients. In addition, 19th-century discoveries, such as methods for determining levels of glucose, creatinine or hemoglobin, or measuring temperature and blood pressure, were applied when examining patients almost as soon as they had been proven effective in the research laboratory (Ackerknecht 1982:157-169). At the same time, however, physicians came to realize, though only gradually, that a person could have an infectious disease or structural injury, yet show no symptoms or signs. Then reports began to appear on other kinds of afflictions, such as hereditary conditions that manifested themselves physically but had no apparent anatomical basis. This situation was disquieting because the anatomical-clinical method had functioned very well by proffering a scientific answer to the origin of diseases, in the face of which unclarified functional disorders constituted a silent but severe critique of the biomedical or clinical-pathological model (Weiner 2002:8). This dissatisfaction appeared in almost all areas of medicine, so in the early 20^{th} century medical professionals began to seek alternative models by incorporating environmental, personal, genetic and psychological factors into their explanations of the health-illness process. But this did not mean that the anatomical-pathological model lost its validity, nor the priority it had earned by transforming clinical medicine into a science.

Perhaps in no area of medical specialization has the anatomical-pathological model produced better fruits than in neurology. It was in the late 19^{th} century that the express will to erect the understanding disease and patients on firm biological foundations emerged. Two types of afflictions were particularly relevant and important in this effort: infectious and neurological diseases (Laín Entralgo 1981:104). In the area of neurological illnesses, research by Paul Broca, Jean Martín Charcot and Carl Wernicke used the tools of neuropathology to show the importance of the anatomical location and functional relation of the affected parts; in other words, the most lucid manifestation of anatomical-clinical thinking. Neurologists thus became able to predict the nature and site of lesions on the basis of physical examinations and clinical histories (Estañol and Cárdenas 1996:44).

Method

For almost two years, the authors of the present study attended clinical sessions at the National Institute of Neurology and Neurosurgery in Mexico City. Except for certain differences inherent to this area of medical specialization, the sessions at the INNN followed all the canons of general clinical medicine. Like most hospitals, the INNN holds various kinds of academic meetings, but the most important ones involve the services of Neurology, Neurosurgery, Psychiatry and Anatomy-pathology. Though the mechanics of each differ somewhat, all share a common objective: to conjointly resolve clinical problems. Once the particular case has been described, the attendees suggest diseases that might correspond to the symptomology; the most probable one (or ones) is then chosen and possible treatments are proposed and evaluated after a review and discussion of the literature on the chosen disease. The sessions at the Neurology Department were chosen as the best fit for what we wished to observe.

Each session is attended by three doctors who plan to become neurologists and who are fulfilling their residency requirement in this area of specialization at the hospital. They have graduated from general medicine and are identified as residents by the letter "R," because they reside at the hospital. Resident "one" ("R1") refers to those who have just begun, those who are in the first year of residency in neurology. A resident "three" ("R3") is in the third and final year of specialization; so their level reflects the year they are studying.

Also in attendance are pre-med and medical students, residents in internal medicine from other hospitals who spend brief periods in the Neurology Department of the INNN, and more experienced doctors who are heads of service or members of the permanent staff. With respect to the residents who lead the session, the order and importance of their participation follows a strict hierarchical order. The R3 chairs the session, while the R1 presents and then summarizes the case. The R2's role is to present the para-clinical findings and, at the end of the session, present a review of the literature on the topic according to the diagnosis reached. Following the scheme elaborated by Laín Entralgos, the sessions are structured to determine three types of diagnoses:

Syndromic: according to the symptoms and signs, clinical explorations and certain tests, possible diagnoses are suggested with the confirmatory studies they would require; members argue in favor and against the different proposals, but data may be lacking or excessive.

Topographic: members defend their diagnoses on the basis of the interrelation between anatomical location and physiological alteration. This is carried out following closely the above mentioned 19^{th}-century anatomical-clinical model. The entire group participates in this exercise, but the R3 directs most of the questions to the R1.

Etiological: the objective of this dynamic is to match the clinical data with a probable cause; on occasions, participants support their input with test results. Proposing the diagnosis is primarily the responsibility of the R2, who is also required to present an exhaustive review of what biomedicine knows about the selected illness. As her diagnosis is only a plausible one, the young doctor searches the literature for the basic or theoretical aspects of the nosological entity, its variants, historical background, subtleties and sophistications.

To conclude the meeting, the R3 gives details on the treatment and prognosis of the case. Throughout the process, the full-time doctors and heads of service resolve disagreements, clarify situations and re-orient the discussion when congruence between what the patient manifests and the theoretical concepts of a probable diagnosis seems to be lost. At the end, they offer comments that highlight specific aspects of the case, its treatment, previous experiences at the hospital, or documented cases in Mexico.

It is not possible to pinpoint the historical moment at which this ordered procedure began, but insofar as it pertains to the anatomical-clinical method, it may well date from the final third of the 19th century or the early 20th. In his *Tratado de clínica general* (*Treatise on General Clinical Medicine*, 1935), the Mexican physician Gonzalo Castañeda explained that diagnostics followed a methodology or system, the manifestations of which he called: "symptomatic diagnostics" (Castañeda 1935:91-104), the equivalent of the INNN's syndromic approach; "anatomical diagnostics" (*Ibid*., 123-138), the topographic approach of the sessions analyzed herein; and "pathogenic diagnostics" (*Ibid*., 105-122), or what the present study calls etiological. In addition, he postulated the existence of "nosological" or "psychological" diagnostics and "diagnostics of the general state of the self." Castañeda's proposal is highly didactic, similar to the one currently in use, and may be considered pioneering, at least as far as the history of medicine in Mexico is concerned. In 1941, the medical historian Iago Galdston, though without proposing any specific order, adduced that while the science of diagnostics as it was practiced in his time was quite recent, perhaps less than a century old, it was a mechanism that represented the sum total and analysis of all the deviations from normality in a sick body (Galdston 1941:372). The furthest that the physicians in the summit of the anatomical-clinical period went in terms of the logic of their diagnostic method was to follow an "anatomical order" from head-to-toe, or a "physiological order," apparatus-by-apparatus (Villey 1979:118).

Gonzalo Castañeda did not define the terms he used in his work. He only led the reader to a conclusion by providing multiple examples of the ideas he wished to convey. With respect to modes of thinking and acting in different types of diagnostics, he wrote in 1935:

> Syndromic pathology and clinical medicine are modern, they are transforming, and have to a great extent replaced earlier classics, their birth was happy and fecund and they have prospered because of their practical utility, as they imitate nature more closely, and because the syndrome, though incapable of characterizing an illness, fits very well in both general clinical medicine and practice. I know neither who first reasoned it nor the nature of the original idea (Castañeda 1935:101).

During the sessions it became clear that the young doctors usually had an impressive body of knowledge, discussed articulately the theoretical bases of their proposals and attempted to correlate them with the data, but it was also evident that their dominion of medical knowledge did not suffice. They also had to display an acute ability for analysis, synthesis and association, good use of language, a broad vocabulary and fluidity in speaking in order to adequately express the ideas they wished to convey. In addition to sharing these qualities with the younger neurologists, the senior doctors have more experience, as was evident in the discussions.

Scientific Method and Clinical Act

> Medinaveitia represented the German anatomist tendency and the direct, dry –sometimes excessively so– evaluation of clinical detail. He handled the details of exploration with unsurpassed mastery. His diagnoses were always the logical vertex of a pyramid constructed on the basis of symptoms, with no brilliant, arbitrary hypotheses or fashionable theories coming into play. Then, over the cadaver, he would read the patient's book once again, now in inverse order and with admirable accuracy. Thus he created a rather rigid school of pathological practice that at the time presupposed a revolutionary approach that could only be carried out by a man with the temper of that Basque teacher.
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> — Gregorio Marañón, 1935

As mentioned above, the objective of this study is to elucidate theoretical bases for analyzing the medical act in the diagnostic process using a concrete example from neurology. The specific case on which we focus was selected from several that were presented at the clinical sessions held in the Neurology Department of the INNN and is outlined below.

EPS patient, with antecedents of hyperthyroidism

The patient is a sixty-year-old woman who had been diagnosed several years earlier with hyperthyroidism.

Condition: She went to the hospital for a problem that began eight months earlier with difficulties in walking; initially just awkwardness that later turned into lateralization. Then she began to experience difficulty in articulating language and in swallowing solids and liquids. As her illness progressed she consulted several doctors before finally deciding to go to the Emergency Department of the National Institute of Neurology and Neurosurgery.

The general exploration revealed no alterations, but the neurological examination confirmed dysarthria[1] and dysphagia,[2] as well as a bilateral affectation of the 12th cranial nerve, dysmetria[3] and dysdiadochokinesia[4] in the four extremities, difficulty in walking due to lateralization towards both sides and ataxia of the torso.[5]

Syndromic diagnosis: the series of findings, especially the presence of dysmetria, dysdiadochokinesia, ambulatory lateralization and dysarthria, led to the conclusion that one syndrome was affecting the woman's entire brain (pancerebellar syndrome) and another was affecting the so-called "lower" cranial nerves, the ones that carry the highest flow in the entire nervous system.

Topographic diagnosis: the presence of these syndromes suggested the existence of a lesion located in the cerebellum (from the Latin for small brain); a structure found in the posterior fossa that plays a fundamental role in coordinating bodily movements. It is a reflex center that acts to regulate and maintain equilibrium and voluntary muscle tone, and is related to posture and balance. Thus, any activity that requires coordination –from playing soccer to playing the violin– depends on the cerebellum. However, the functioning of the cerebellum does not involve the cranial nerves, as their initial nuclei and trajectories are located in the brain stem. Hence, one proposal to explain the syndrome affecting the lower cranial nerves was a lesion in the cerebellum that extended towards the brain stem (the cerebellum is located on one side of the brain stem, so lesions there often compress neighboring structures; in this case the brain stem itself), or a lesion in the structures that connect the brain stem to the cerebellum.

Etiological diagnosis: several possibilities that could explain a lesion at this location were discussed, beginning with those most frequently associated with the age and gender of the patient and with the temporal profile of the evolution of her illness. Initially, tumorous lesions were suggested, but that hypothesis was rejected by arguments that such lesions show progressive growth and compress neighboring structures, while this patient showed no data to indicate an increase in intracranial pressure due to secondary hydrocephalia, a phenomenon that would be expected in such alterations, which are characterized by compression of the fourth ventricle. Also noted was the absence of headaches, a clinical datum common in such problems.

Though the patient presented no data suggestive of vascular events, her age led the doctors to consider a possible cerebral infarction or hemorrhage; though this idea was countered by the slow, progressive nature of the illness. It is well known that the main characteristic of vascular disorders is that they appear abruptly, but that was not the case of this patient, so this alternative was discarded. Other etiological options mentioned included degenerative diseases of the cerebellum, but the most common causes of the deterioration of the cerebellum are the chronic consumption of alcohol or certain medications; another situation that did not apply in this case and was thus rejected. Instead, a sub-acute or paraneoplastic deterioration of the cerebellum was considered. This is a progressive syndrome that the data on the affectation of the cerebellum would complicate, exacerbate and aggravate.

This syndrome is classified as paraneoplastic because it is caused by the remote effects of a –usually malignant– tumorous lesion.

At the conclusion of this clinical exercise, participants order the tests or studies required to confirm or reject the various diagnoses proposed. In the concrete case of this woman the results of cerebral imaging studies showed a reduction in the volume of the cerebellum, but no other lesion. This confirmed the clinical diagnoses, ruled out the presence of a brain tumor or vascular disease and supported the diagnosis of paraneoplastic degeneration. In order to confirm this, the doctors then ordered additional tests that would discard a cancerous tumor. Because of the patient's antecedents, they first requested thyroid function tests and images of the thyroid gland, and those tests did indeed reveal the presence of a thyroidal tumor, which a subsequent biopsy proved was malignant. Thus, the final diagnosis was paraneoplastic degeneration of the cerebellum secondary to a thyroidal carcinoma.

It is clear that several elements were involved in this diagnostic process: from epistemological aspects based on general medical knowledge to emotional factors of a personal nature. From a methodological perspective, the features of the type of reasoning that the doctors used to reach the diagnosis can be separated for analysis, but the diagnostic process usually involves a combination of various types of reasoning that mutually correct one another and, together, lead to the determination of the hypothesis that led to the final diagnosis. In any case, and whatever the reasoning processes involved, the diagnosis must be confirmed through other means.

In both the logic and theory of argumentation diverse kinds of reasoning can be distinguished; these include: deduction, induction, abduction, refutation, analogy, model-based reasoning, explanation and confirmation, to name just the most common and well-studied ones. What must be stressed here, however, is that the construction of a diagnosis is mainly abductive, in that the chain of reasoning proceeds from the symptoms and signs displayed by the patient to the syndromes and pathologies of which they could be manifestations though, as we shall see, other types of reasoning also play an important role in diagnostics; for example, the use of refutation to discard hypotheses.

According to René Cruchet (1955:9), we owe the origin of method applied to medicine to Descartes. For clinical medicine, Laín Entralgo (1981:242-245) mentions the deductive or logistic, inductive or statistical, and statistical-taxonomic, models, but the problem is that in real life there are no "pure" cases that clearly reveal one unique form of medical reasoning, one sole way in which physicians think in order to reach a diagnosis. In the evolution of a particular case there converge very diverse forms of thinking and the path followed is not always clear. Doubts appear, frustrations arise or, paradoxical as it may seem, the circumstances may appear illogical. The samples of clinical cases that we heard are complex even by neurological standards and thus further evidenced the conjunction of different mental approaches. In addition, they seem to show that specific cases never reproduce the classic schemes that appear in medical textbooks. Finally, each case could pertain to a particular theoretical proposal; in fact, on several occasions the doctors failed to reach agreement on one single diagnosis. In the case used here, every detail –even those that were seemingly incongruent– was taken into account. Presenting "perfect" cases would make the art of clinical medicine more romantic, but would be pure fantasy or, worse yet, falsity.

Abduction

In this section we first provide a brief introduction to abductive reasoning, to continue with an illustration of our example in neurology, within this type of reasoning. Given that there are also other types of reasoning involved in medical diagnosis, we illustrate the most used argumentative form used for refutation, namely Modus Tollens, and contrast it to abduction. Our focus on abduction, relies on our thesis that it is the type of reasoning par excellence used in diagnostic medicine[6].

In the broadest sense, abduction is a process of reasoning that builds towards explanations for surprising or unexpected observations; that is, for novel or anomalous facts. For example, if a person gets up in the morning and sees that the patio is wet, the observation may be explained by assuming that it has rained or, perhaps, that the lawn sprinklers had come on. This is an example of everyday, or common sense, reasoning. Another example of practical reasoning, and one that models the cognitive competence of physicians, concerns the construction of diagnoses. Generally speaking, a diagnosis is built up through the accumulation of observations –signs and symptoms– and then, based on knowledge of the causal relations among symptoms and signs, on the one hand, and of syndromes and pathologies, on the other, doctors construct their explanations and determine an illness.

Abduction also occurs in contexts of scientific reasoning and has been a research topic in both the philosophy of science and the field of artificial intelligence. In the former, it has been examined in relation to what is called the context of discovery (in contrast to the context of justification), in order to analyze precisely how scientific discoveries come about. In the second, though research on abduction dates back to the 1960s, it was not until the 1990s that a growing interest in this type of reasoning emerged in such areas as logic programming, knowledge acquisition, diagnostics, pattern recognition, natural language processing, vision, learning and, in general, as a means of defeasible reasoning. In all these areas, the discussion of diverse aspects of abduction has raised a conceptual challenge. It should be noted that abduction often generates confusions –especially terminological ones– with induction, another method of reasoning that is defeasible *par excellence*.

Therefore, the broad map of abduction has room for many focuses and a wide variety of applications. Here, we present the notion of abduction as it was elaborated by the philosopher who first named it and gave it logical status, Charles Sanders Peirce. The formulation of the abductive inference as initially posited by Peirce, a pragmatist philosopher, (1931, 1935, 1958, vol. 5, paragraph 189) is as follows:

> A surprising fact, C, is observed.
> But if A were true, then C would be a matter of course.
> Therefore, there is reason to suspect that A is true.

In formal academic circuits, this formulation has been expressed as follows:

$$\frac{\begin{array}{l}C\\ A \rightarrow C\end{array}}{A}$$

Where the first premise expresses the surprising fact, symbolized as C. The second premise is represented through a conditional $A \rightarrow C$. Returning to our example, if the pancerebellar syndrome (A) does indeed exist, then the signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization of walking (C) may be present. However, one cannot lose sight of the fact that the status of the conclusion "A" is only tentative; hence, abduction as a form of reasoning is only "plausible".

In addition to the fact that the abductive form of logic does not capture the surprising nature of fact C, it must also be made clear that the direction of the conditional in the second premise should, in reality, be reversed, as the chain of reasoning goes from effects (symptoms, signs) to possible causes (syndromes, pathologies); thus hereinafter we shall continue using this notation[7]:

$$A \leftarrow C$$

Which can be read: "The signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization of walking (C) *suggests* pancerebellar syndrome (A)."

Moreover, according to Peirce, in addition to fulfilling the logical form described above, two additional aspects are required: namely, *corroboration* and *economy*. The first of these terms signals the need to put the result of the abductive inference to the test. Thus, abduction provides an explanation if, and only if, it accounts for the events in accordance with the logical form shown above. It can be considered as only a suggestion until it is put to the test; in our case, through imaging studies. The second criterion –economy– involves two motivations: first, to respond to the practical problem of evaluating numerous explanatory hypotheses; and, second, the need for criteria that will make it possible to select the best explanation from among those that are subject to experimentation. This is a brief and intuitive idea of abduction[8]. Finally, then, we shall proceed to illustrate this argument form using our example:

> All patients who suffer pancerebellar syndrome present the signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization of walking.
>
> The EPS patient presents the signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization of walking.
>
> THEREFORE, it is POSSIBLE that the EPS patient may have pancerebellar syndrome.

Let us contrast abduction with deduction, especially to Modus Tollens:

Modus Tollens	Abduction
$A \rightarrow C$	$A \rightarrow C$
$\neg C$	C
$\neg A$	A

These two patterns show a remarkable similitude but are different in a substantial manner. While both forms affirm the same conditional, they differ in that while abduction affirms the consequent of the conditional (C), Modus Tollens affirms the negation of the consequent ($\neg$C). The substantive difference however, lies in the status of their conclusions. While Modus Tollens concludes the negation of the antecedent ($\neg$A) as a conclusion with total certainty, in abduction the antecedent (A) is affirmed only tentatively or as a possibility. Why is this so? In abduction, a hypothesis may be refuted when there exists, in reality, another cause that explains the data. For example, it could be that although a certain patient presents the exact symptoms described above, the cause was not pancerebellar syndrome but some other condition of the brain stem that also affects the connections between the stem itself and the cerebellum, and thus presents a unilateral syndrome of the cerebellum with aggregate signs of an affectation of the brain stem[9].

As well-known, *Modus Tollens* is naturally associated with Karl Popper's falsifiability, which is offered as a response to the problem of induction. In order to quickly probe a possible hypothesis, Popper proposes that one means of verifying a hypothesis is precisely by refuting it; that is, one can start with the idea that the explanation (read diagnosis) is erroneous; however, if the arguments –symptoms, signs– do not satisfy any other possibility than the one posited at the outset, then that one must be deemed true: *i.e.*, it is the best one we have until it is refuted. The diagnosis is still considered satisfactory and we have another argument in its favor. This procedure advances by conjecture and refutation, as Popper himself characterized it.

In the case of (enumerative) induction, a conclusion would be refuted by finding the case of a patient who does not present one or more of the signs previously identified but that did, in fact, have the described disease. Hence, induction and abduction are only tentative modes of reasoning, whose conclusions may be refuted or rebutted upon the gathering of additional data. Another important difference between induction and abduction is that in the former a general rule is inferred, while the latter leads only to a hypothesis concerning a specific case. The inductive conclusion derives from a series of instances that collectively lend support to the plausibility of the general inductive rule. In contrast, abductive conclusions are generally inferred on the basis of one case and, therefore, generate the weakest inferences of the three types. It is important to note that in the case of abduction the conclusion reached takes the form of a hypothesis, which must then be subjected to experimental testing. In the specific case we are examining, cerebral imaging studies are the tests that would lead to a confirmation or rejection of the hypothesis put forward.

As well-known, each and every form of reasoning presented here, as those presented here, aims at giving a way of reaching a conclusion of the basis of the premises, but gives neither a way to state whether these premises are actually true neither states where they come from. For example the conditional "All patients who suffer pancerebellar syndrome (A) show signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization when walking (C)", which appears as premise both in deduction and in abduction, is indeed an inductive conclusion itself: given a representative set of patients who suffer from pancerebellar syndrome and show signs of dysmetria, dysdiadochokinesia, dysarthria and lateralization when walking, we may indeed infer inductively the above conditional.

Medical judgment

> Making a diagnosis requires infinite patience in the auscultation of the patient; one must sharpen one's vision in order to perceive those symptoms that are not so clear, the hidden causes of grand effects.
>
> — *Medicina humanista* (es.geocities.com)

Medical judgment rests upon a series of implicit rules related to current medical knowledge, both general and specialized. At all times and in all cases, observation is the primordial component, the one used to perceive all that which is different, unexpected or altered, anything that strays from the norm. Strictly speaking, in order for clinical medicine to become a scientific practice, interpretation –the product of observation– must be confirmed by experimentation, which consists in manipulating nature. Is this feasible with patients? The answer is "no," at least not in the strict sense of the practical activities conducted in research laboratories; but "yes," in the sense that examining, assaying, probing and even feeling lead to a proposed treatment, and because a successful therapy means that it is possible to ascertain the cause of a disease.

When the physician reaches a conclusion concerning the specific facts of a case, the symptoms and signs no longer exist as logical variables but, rather, as randomly governed magnitudes, the presence of which varies from patient-to-patient and may be characterized by probability distributions (Laín Entralgo, 1981:242-243) that will vary from one illness to another and that in a certain sense reflect medical experience and knowledge. The starting point consists of a series of suppositions; for example, that the doctor involved is sufficiently aware of those distributions and that she/he knows the different illnesses that have been defined concretely. Diagnostics, then, means determining –with the minimum possible risk of error– which illness the patient has. But this task can never achieve absolute certainty because it involves inductive and/or abductive reasoning. Let us return to our case.

The affliction of the sixty-year-old EPS patient with antecedents of hyperthyroidism has evolved over a period of eight months, during which time she tended to lean to one side or the other when walking and, three months later, began to present dysarthria and dysphagia. After being evaluated by several doctors she was finally referred to the Institute of Neurology where was admitted after examination in the Emergency Ward. Upon neurological exploration it was found that she had a bilateral affectation of the 12th cranial nerve (hypoglossal) and pancerebellar syndrome.

Syndromic diagnosis: Pancerebellar Syndrome and Syndrome of Affectation of Cranial Nerves.

The syndromic diagnosis can be reconstructed through abductive reasoning, as described in the previous section on the three types of logical processes. Here, we introduce a series of symbols in an effort to simplify the reading and elucidation of the procedure.

Signs:
Dm: Dysmetria
Dc: Dysdiadochokinesia
Da: Dysarthria
aL: Ambulatory Lateralization

Syndromes:
SxPC: Pancerebellar Syndrome

Hence, applying abductive logic would generate the following form:

C: Dm, Dc, Da, aL
A ← C: SxPC ← Dm, Dc, Da, aL
A: SxPC

which is to be interpreted as follows: *if*, on the one hand, the four identified signs appear and, on the other, *if* it is known that they cause pancerebellar syndrome, *then* it can be inferred abductively that we may well be dealing with, precisely, pancerebellar syndrome.

Here, the neurological exploration confirmed the diagnosis of pancerebellar syndrome and, moreover, detected that the patient had an additional ailment: an affectation of the lower cranial nerves (ALCN), which suggests a second syndrome; one that affects the lower cranial nerves. This second syndrome is expressed in the following abductive argument:

C: ALCN
A ← C: SxALCN ← ALCN
A: SxALCN

Thus, the syndromic diagnosis arrives at the following conclusion: Pancerebellar Syndrome (SxPC) with Syndrome of Affectation of the Lower Cranial Nerves (SxALCN).

Topographic diagnosis: The physicians had greater difficulty in ascertaining a precise topographic diagnosis because there appeared to be several lesions, and they were not all associated with one single site. In the discussion, they posited the existence of a lesion at the level of the rachidian bulb due to the affectation of the cranial nerves, though they also evaluated other probable sites, such as an extension into the medulla, and insisted that the proprioceptive problem indicated an association between the central and peripheral nervous systems.

In what follows, we present the formalized data that the doctors considered during their discussion, and which referred to possible sites of the affectations of the lower cranial nerves:

Lesion at the level of the rachidian bulb (LRB) ← Affectation of the cranial nerves (ALCN)

Lesion at the level of the rachidian bulb/medulla (LRBM) ← Affectation of the cranial nerves (ALCN)

Bilateral cortical affectation (BcA) ← Affectation of the cranial nerves (ALCN)

As stated above, a topographic diagnosis focuses on the anatomical localization of diseases and the physiological alterations they cause. The diagnosis is especially complicated in this case because, on the one hand, there are several possible locations, none of which would explain *both* of the affectations (Pancerebellar Syndrome, Syndrome of Affectation of the Cranial Nerves). The functioning of the cerebellum does not involve the cranial nerves because their nuclei and initial trajectories are localized in the brain stem. So, in order to explain the Syndrome of Affectation of the Cranial Nerves as well, it was suggested that the effects of a lesion in the cerebellum could extend out as far as the brain stem (because the cerebellum is located on one side of the brain stem, lesions there often spread and compress neighboring structures; in this case, the brain stem). This hypothesis is important because it would explain both syndromes simultaneously. We symbolize the hypothesis of a cerebellar lesion extending to the brain stem as SxPCe, and the rule that corresponds to a causal relationship with the two syndromes as follows:

SxPCe ← SxPC, SxALCN

Thus, the abductive argument can be represented as follows:

C: SxPC, SxALCN
A ← C: SxPCe ← SxPC, SxALCN
A: SxPCe

This completes the topographic diagnosis: Pancerebellar Syndrome to the brain stem (SxPCe).

Etiological diagnosis: A Paraneoplastic Syndrome is suggested, due to the remote effect of a cancerous lesion. How?

Several possibilities were considered to explain a lesion at this location, beginning with those most frequently associated with the age and gender of the patient and with the temporal profile and evolution of her illness. Initially, tumorous cerebral lesions were postulated, but it was pointed out that if a brain tumor were present, symptoms would include progressive growth and the compression of neighboring structures. But the patient did not present any data indicating an increase of intracranial pressure, which would be expected in this type of lesion due to the compression of the fourth ventricle and secondary hydrocephaly. It was also pointed out that the patient did not complain of headaches, a common clinical datum in such cases. The following is a symbolization of this information:

Tumorous Cerebral Lesion (TCL) + Progressive tumor (pT) +
Compression of Neighboring Structures (Cns)
↑
Increased intracranial pressure (IiP), cephaly (C)

However, the patient DOES NOT present cephaly (C) or an increase in intracranial pressure (IiP), thus the hypothesis of a tumorous cerebral lesion (TCL) was discarded. What type of argumentation was involved in arriving at this conclusion?

¬C: NO (IiP), NO (C)
A ← C: TCL + pT + Cns ← IiP, C
¬A: NO (TCL + pT + Cns)

This argument uses the *Modus Tollens* form of deductive reasoning to reach a conclusion that can be inferred with certainty; therefore, there is no tumorous cerebral lesion.

Moreover, the following information was also available: due to the patient's age, and despite the absence of other factors that might suggest a greater risk at the vascular level, the physicians discussed the possibility of cerebral infarctions or hemorrhages. However, they immediately noted the slow, progressive nature of the manifestation of the disease, which made vascular disorders unlikely, as their principle characteristic is the sudden or abrupt nature of their presentation. The possibility of vascular disorders was rejected by refutation, through a deductive argument using *Modus Tollens* that can be expressed as follows:

Vascular Disorders (VD) ← Symptoms appear abruptly (SA)
Progressive Diseases (PD) ← Symptoms appear gradually (SG)

¬C: NO (SA)
A ← C: VD ← SA

¬A: NO (VD)

Thus it was inferred deductively that vascular disorders were not involved.

Other etiological options mentioned included degenerative afflictions of the cerebellum, though the most frequent causes of that condition are the chronic ingestion of alcohol or certain medications; neither one of which was involved in this case. Therefore, this alternative hypothesis was also rejected by a rapid refutation, as follows:

DDc: Degenerative Disorder of the Cerebellum
cIA: Chronic Ingestion of Alcohol
om: Other Medications

DDc ← cIA
DDc ← om

¬C:	NO (cIA)	NO (om)
A ← C:	DDc ← cIA	DDc ← om
¬A:	NO (DDc)	NO (DDc)

Thus, it was concluded deductively through *Modus Tollens* that a degenerative disorder of the cerebellum could be discarded. After that, other factors were introduced into the discussion: sub-acute degeneration of the cerebellum and paraneoplastic degeneration of the cerebellum; the latter a progressive syndrome that the data on the affectation of the cerebellum would complement and aggravate. This syndrome is considered paraneoplastic, meaning that it is caused by the remote (long-distance) effects of a tumorous lesion that is usually found to be malignant. We represent this as follows:

Paraneoplastic Syndrome (SxPN)

↑

Tumorous lesion with remote effects (TLre)

Similarly, because it thus became necessary to rule out any other kind of brain lesion, cerebral imaging studies were ordered for the patient. Those tests reported a decrease in the volume of the cerebellum (DVc) but no other lesion. This finding confirmed that there was no tumorous cerebral lesion (TCL) or vascular disorder (VD), thereby strengthening the hypothesis of paraneoplastic degeneration.

It is important to note that there is a causal rule relating a possible tumorous lesion with the Paraneoplastic Syndrome, but that none of the data available in this particular case suggested the existence of such a lesion. Given that this obstacle made it impossible to construct a complete argument, the next step was to confirm the existence of a cancerous tumorous lesion; otherwise, this option would have to be discarded definitively. But here, the doctors brought up the patient's antecedents of hypothyroidism, which opened up the possibility that there could be a thyroidal tumor. Thus, they proposed the following diagnosis:

Diagnosis: Thyroidal tumor and paraneoplastic degeneration of the cerebellum

The broad range of possible afflictions made it difficult to decide just what studies to order but, at the same time, led to the above inference. The tomographic sections corroborated the finding of atrophy of the cerebellum and brain stem, but also revealed a lesion on the thyroid. In fact, a thyroidal tumor was soon discovered, and a biopsy confirmed that it was malignant. We formalize this information as follows:

CTT: Cancerous Thyroidal Tumor

C: CTT
A ← C: TLre ← CTT
A: TLre

C: TLre
A ← C: SxPN ← TLre
A: SxPN

Once the existence of the cancerous thyroidal tumor was confirmed, abductive reasoning led to the conclusion that, in effect, a tumorous lesion was exercising remote effects (TLre). This in turn suggested that the disorder was a paraneoplastic syndrome (SxPN), thus confirming the etiological diagnosis.

One of the doctors emphasized the *importance of data for interpreting reality*. In this case, the imaging studies supported the clinical supposition and helped form the diagnosis. Clearly, the thyroidal function tests were of primary importance at this stage. This case was a particularly difficult one because it involved so many variables and theoretical-conceptual problems of bio-medicine. Because the physicians had to distinguish among metabolic, neoplastic and psychological elements they turned to abductive reasoning, mainly because of the following two factors: the remote effects and direct infiltration or metastasis caused by the primary thyroidal lesion.

Returning to the session, it turned out that the R2 was unable to find any literature for a theoretical analysis, so the case was classified as a "report" because of its unique nature. To some degree, such unique case reports may lead one to think of common situations. Though the physicians did not say as much in the case of this patient, their comments on another strange case: *things happen that we just don't understand*, is certainly applicable here as well.

Conclusions and Final Reflections

> To obtain an initial idea of things, one must first see them, one must observe them.
> — Claude Bernard

This study reflects on the theoretical bases of the medical act that involves the cognitive processes used to reach diagnoses. Our starting point was the analysis of real life situations – though only one specific case was presented in detail– as they were discussed by resident physicians during their struggle to reach a mutually acceptable diagnosis. The analysis presents a logical reconstruction of the cognitive process involved in this medical act.

On the one hand, our examination supports the idea that clinical judgment based on the anatomical-clinical method, whose antecedents date back to the 19th century, rests upon a system of rational medicine based on diagnostics that is still current. In the words of the neurologists at the INNN: "[Clinical medicine] calls the shots; a diagnosis is reached when all the signs and symptoms are brought together correctly." On the other hand, though our analysis of the cognitive process of the medical act is theoretical and based on forms of logical argumentation, it places the physician at the very center of the act and, indeed, of medicine. Thus, we can affirm that the biological approach to patients is not only scientific in nature but also entails aesthetic and artistic elements. Therefore, it is hard to imagine that doctors could ever be fully replaced by computer programs in the area of medical diagnostics.

Such diagnoses are rarely conclusive or absolutely certain (perhaps only pathological diagnoses can achieve that). They are only posited as being probable or possible. Clinical medicine does not follow a unique procedure, as no one single, established strategy exists in this activity. Because it is a creative process, clinical judgment can at times be brilliant, but it can also be quite frustrating and may even appear illogical, a situation that appears frequently in neurology; which is a particularly complex field whose practitioners state that "there are things we don't understand; that we don't know how to interpret." But this does not preclude systematization, especially when forms of reasoning are employed that go beyond deduction to recognize that we must deal with incomplete information and uncertain conclusions. There are indeed other forms of approaching reasoning, such as Bayesianism, which may prove useful for modeling other type of medical cases. The theoretical thesis of the present study is that the medical act known as diagnostics has a rational component that can be reconstructed logically, and that it is possible to show how several distinct forms of reasoning may be interwoven in this process. As suggested, abduction, deduction and induction are the most paradigmatic forms of argumentation and the ones that provide a solid theoretical foundation for physicians' thinking when they attempt to arrive at diagnoses. When a conclusion is reached by applying a general concept of medicine (*i.e.*, when a diagnosis is made in a specific case) the method used is deductive; the only case where it can be assumed that the result is certain (as long as the underlying precept is true, that is). Enumerative induction characterizes those diagnoses made using a form of reasoning that goes from the individual to the general; *i.e.*, when a general conclusion is inferred on the basis of particular instances. But diagnoses of this type can only achieve a level of probability. Abduction, meanwhile, though the least conclusive of these three forms of argumentation, is the type of reasoning that is most widely used in medical diagnostics. As in deduction, abductive inferences also move from the general to the particular, but the conclusions they generate only attain the status of a possibility. Despite this fact, abduction is more suited to the reality of medicine because it is a type of reasoning that begins with effects (symptoms, signs) and proceeds from there to possible causes (syndromes, disorders). Furthermore, it is part of abduction's very nature to deal with changes in the information over time. Illnesses evolve and a diagnosis that seems accurate in one moment may well have to be modified as the variables change; variables that include symptoms, signs and the data from tests and studies. This is in part what makes the complete formalization of the diagnostics enterprise very hard, for any kind of formal system modeling in full the diagnostic process as done by doctors, should be done in a piecemeal fashion: first creating a hypothesis using abduction, then testing it out against evidence, and then continue to create more hypotheses and testing them until a successful one is achieved. And in the way it should be possible to add or delete information[10]. We have only highlighted a direction towards this goal.

We propose, and demonstrate through the specific case presented, that the mechanics used in the field of neurology to reach syndromic, topographic and etiological diagnoses and, as a result, clinical-medical conclusions, is best represented by the pattern of abductive reasoning –combined with deduction, which is used to reject diagnostic hypotheses– which thus provides a formal theoretical foundation for the approach that generated the anatomical-clinical method; one that, though based on logic and reason, had not been formalized.

Returning to the neurological case presented, we should underline certain moments of the diagnostic process in which abductive reasoning was revealed in its full extension. Once they discarded the suggestion that the patient was suffering from a brain lesion (especially of a tumorous kind), vascular disorder, or degenerative malady of the cerebellum, the doctors began to evaluate the hypothesis of a paraneoplastic syndrome caused by a tumorous lesion that was exercising remote (long-distance) effects. This was an abductive hypothesis that postulated the existence of a tumor in some other area of the body. At this point, the physician's fund of knowledge becomes crucial, especially the datum that this particular patient had antecedents of hyperthyroidism. As was shown in the description of the case, tests of the thyroid function were ordered, together with imagenological studies, and it was found that the patient did have a cancerous tumor on her thyroid gland. Here, the key to finding the tumor was the suggestion of its existence and the formulation of a strategy to determine where to look for it. Abduction played a dual role in this process: first, it postulated the existence of a tumor; and, second, it used that information and other specific data on the patient to find it.[11]

Another point to stress is the importance of identifying the best abductive hypothesis from among those proposed. In the present case, the result of the syndromic diagnosis, achieved through abduction, mentioned two medical problems: pancerebellar syndrome and the syndrome of the affectation of the cranial nerves. Though these two syndromes together account for the signs that the patient manifested, the doctors decided to seek a unified explanation as suggested by the topographic diagnosis: pancerebellar syndrome with extension to the brain stem. The search for one single syndrome that would explain all the symptoms is a reflection of medicine's goal of achieving "clinical unity"; *i.e.*, a single diagnosis is preferable to a series of diagnoses that together make up an explanation. That is, the ideal of unification in Science, in this case, medical science.

Also significant is the interaction between abduction and deduction, especially the *Modus Tollens* form. In a first moment, diagnostic hypotheses are generated by abduction; then those hypotheses are conformed, or refuted, using deduction, especially *Modus Tollens*. It is interesting to note that not even isolating certain aspects of the case for systemization through abduction justifies the exclusive use of this form of reasoning: both logical forms interact in this cognitive process and, as this case clearly shows, abduction and deduction collaborate in reaching the diagnosis.

Every new patient represents a challenge to clinical physicians, who must exercise their cognitive capacities and personality, sharpen their senses to make more acute perceptions and apply their experience and sensibility. Then they must place all these elements in the framework of the theoretical references they learned at medical school. Errors in medicine are unavoidable, but never willful. They may result from faulty reasoning, theoretical ignorance or the limits of scientific knowledge, but may also involve erroneous calculations of the probability of error and confidence limits, when clinical physicians pay the consequences of studies they consider accurate that may not be so (Bailar 1985:1081).

With respect to the support that technology provides, we reproduce here some opinions heard in the sessions: *one must not place excessive faith in laboratory and cabinet results*, but recognize *the importance of the data they provide to interpret reality* without giving them undue credit, as they only constitute *an extension of our senses*. Similarly, experience, different perceptions of the same situation and medical knowledge all play important roles.

Medical science has developed a specific style of thinking to confront its problems. In contrast to laboratory scientists, who seek to understand typical, normal phenomena, the hospital scientist must explain that which is atypical, surprising or morbid, a path plagued with a broad range of individual cases that have no predefined limits. And this is precisely the goal of abductive reasoning, making possible to explain and diagnose a surprising phenomenon. Many decades ago, Claude Bernard argued that health and illness are two variables of one single scale and that the distance separating them is imperceptible (Rodríguez de Romo 2003). The cognitive and emotional activity involved in clinical medicine must be able to overcome the confusion that arises from the enormous range of variance that patients present. Its fundamental problem consists in finding a law for irregular phenomena and discerning how best to approach and then relate those phenomena as they strive to reach a rational understanding (Cohen and Schnelle 1986:39).

Singularity is another aspect that must be considered. Statistical observation alone cannot aspire to be the fundamental notion of knowledge because imponderable situations may arise to complicate prognoses. In such cases, intuition plays an important role, which means that the human presence of the physician is indispensable and can never be replaced by a computer. There are computer systems that assist clinicians, but do not replace them (Peng and Reggia 1990).

Intuition is very important in medical reasoning because doctors rarely have all of the pathognomonic signs they need to clearly define a clinical condition. Echoing the words of neurologists at the INNN, we would say that *patients have* [the disease] *that* ***they*** *want to have,* ***not*** *the one that* ***we would like them to have***. It is no easy task to reduce unanalyzable facts to common elements; for example, situations in which there is a physiological alteration but no apparent anatomical basis: in other words, a divergence between theory and practice. Whatever the case may be, however, the problem must be resolved and it is there that the interdependence of medical arts and medical science becomes evident and reveals, once again, that this is beyond the capabilities of any machine. It is clear that apparently aberrant biological processes frequently cause confusion among neurologists and make it difficult to exercise medical logic. In this regard, one author has pointed out that medical knowledge is generated in groups but is applied to individuals, and that this is the reason why a patient's life, history and feelings cannot be translated easily into biomedical variable statistics (Malterud 2001:398).

Causal relationships are fundamental to medical reasoning, though it is accepted that the result is generally not proportional to the cause, a situation that is perceived clearly when doctors say that [some] *important findings are silent while lesser lesions are scandalous*. In addition, as we have seen, they admit that *there are things we do not understand*. The broad range of morbid phenomena is fascinating and, because doctors are immersed in a maelstrom of facts from their early days as students, their clinical decisions must be made by taking into account various possibilities, each one of which must be evaluated on scales of experience and evidence (Horton 1995:3).

Medicine is based on scientific knowledge, and clinical practice can be expressed formally, as we suggest in this study; but, this issue is more complex because clinical decisions and patient care transcend the scientific method. The problem with medicine as a discipline is that it lacks strategies for systematizing its interpretations, phenomena beyond the norm, and medical reasoning itself (Malterud 2001:397). In 1905, a physician summed this up as follows:

> … not all affectations of the nervous system cause anatomical changes. All afflictions for which it has not yet been possible to identify the presence of anatomical lesions are called functional nervous illnesses or neuroses. Neuroses of the brain, of the spinal medulla, of the sympathetic [nervous system] and of the peripheral nerves have all been described. Those disorders that manifest affectations of the nervous system may be related to the motor apparatus and the sensorial [system] or to the trophic nervous and vasomotor apparatus, so it could be said that in practice these disorders are often associated with [those systems] (Eichhorst 1905:801).

One may well ask whether all areas of medical specialization require the same qualities of cognition or personality; whether logical thinking has levels and, if so, if the same level is required for different fields of medicine, such as neurology, dermatology, forensic medicine or psychiatry. Is it possible to learn to organize and structure knowledge so as to favor medical logic? (Nonaka *et al*. 2000:34). These are certainly interesting questions, though there is no immediate answer to them. They indicate the need to develop a methodology to support medical diagnostics.

Medical reasoning compiles symptoms and signs, searches intentionally for data that it will then interpret in the framework of reasoning, knowledge and experience in order to develop a diagnostic hypothesis. This is a scientific act. Here, the method consists in postulating one or more hypotheses that will later be corroborated or refuted. Medical reasoning and the art of diagnostics are interdependent, mutually reinforcing and require the figure of the physician, who is a rational, intuitive human being.

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[1] Dysarthria: Difficulty in articulating language.
[2] Dysphagia: Difficulty in swallowing solids and liquids.
[3] Dysmetria: Difficulty in coordination; especially incorrect calculations of distance while moving.
[4] Dysdiadochokinesia: An alteration of the coordination required to make alternative movements.
[5] Ataxia of the torso: Irregularity in coordinating movements of the torso.
[6] In an earlier version of this work (---), we presented a detailed account of three main types of reasoning: deduction, induction and abduction, but we believe it is not necessary to do so here, for an audience of philosophers of science.
[7] We should clarify that in logical circles the arrow (material implication) proceeds as in the formalized interpretation: A → C. This is because abduction is usually presented in its deductive format, though this is counter-intuitive, especially when applied to medical diagnostics, the focus of our research. However, note that a reversed arrow is used in logic programming, representing Horn clauses, and there exists indeed the area of *abductive logic programming*.
[8] The abductive formulation given by Peirce has been the point of departure of many classic studies on abductive reasoning in artificial intelligence, such as in logic programming, knowledge acquisition and natural language processing, but its formalization into this rather simple argument form has been challenged, as it does not capture neither the surprising nature of fact C, nor other elements of Peircean philosophy, in particular those found in his epistemology. As argued in (------), Peirce´s abductive formulation goes beyond this argument form and it is better captured as a process of belief revision. But for the purposes of this paper, it suffices to view it in its argument form.
[9] In fact, as well-known, the abductive logical form is better known as the "*fallacy of affirming the consequent*". It is a fallacy precisely because it is possible to find a case in which the premises are true while the conclusion false. But in abduction, there is no pretension of affirming the conclusion with absolute certainty, but only as a hypothesis, a possibility.
[10] In fact, **adaptive logics** is a framework to characterize defeasible reasoning. Originally created for handling inconsistent information, the framework has been extended and generalized to deal with some kinds of ampliative reasoning such as induction and abduction. The standard format that characterizes an adaptive logic as a triple: a lower limit logic (which is a Tarskian logic), a set of abnormalities (defined by a possibly restricted logical form), and an adaptive strategy (to handle abnormalities). Adaptive logics for abduction produce explanatory hypotheses for a set of observational statements. The general idea is that an inference rule (in this case the abductive one: C, A ← C /A) is applied in a conditional way: on the condition that one of more formulae is not derived (in this case ¬A). It supports a dynamic proof theory, one that makes it possible to check every time an step of the proof is added, whether the "abnormalities" do not hold, and marks those lines in the proof which are no longer to be taken into account. However, existing adaptive logics for abduction do not really model the process of diagnostics in a piecemeal fashion as we suggest, but rather: "*infer the maximally successful hypotheses from the set of background assumptions and the set of observational statements*" (Meheus 2005:194). Thus some modification to this framework should be done to be able to infer an hypothesis, wait for the results, perhaps add or delete some information from the background theory, and then come back to the proof

with the results and continue checking and inferring, until an acceptable hypothesis is obtained. (For more on adaptive logics for abduction, cf. Meheus and Batens 2006).

[11] Postulating the existence of an object by abduction (in this case, a tumor) reminds us of other cases in the history of science where similar arguments were used. One interesting example from astronomy is the discovery of Neptune. In the mid-19th century, data on planetary movements did not coincide exactly with the theory of Newtonian physics. To explain this anomaly, scientists argued abductively as follows: they supposed that if there were another planet in the solar system, then the data on planetary movement would align with Newtonian physics. Therefore, they postulated the existence of a new planet, assigned it a location and specific mass and then set out to find it, which they eventually did. That is the story of the discovery of Neptune.

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