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Paradigm shift in medicine and in clinical reasoning method: time has come for a new chest semiotics.

Three pillars are enough

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ABSTRACT

Introduction: Clinical reasoning in medicine is a complex cognitive process that integrates sensory perception, interpretation, and abductive inference to develop diagnostic hypotheses. Despite the rise of artificial intelligence, the patient-clinician encounter remains rooted in semiotics and a probabilistic approach driven by Bayesian updating. In this context, medical knowledge is viewed as context-dependent and subject to continuous revision based on new clinical signs.

Main body: This paper identifies bedside ultrasonography as a transformative "epistemic mediator" that enhances traditional semiotics by uncovering subtle clinical signs often missed by conventional inspection, palpation, percussion, and auscultation. In managing respiratory diseases, ultrasound provides direct, contextualized data that refines the interpretation of findings such as dullness, altered fremitus, and crackles by linking them to specific anatomical correlates. Based on these principles, the AdET-CHEPHEUS initiative proposes a new paradigm for chest physical examination centered on three pillars: 1) Visual inspection; 2) Auscultation integrated with ultrasound; 3) Palpatory ultrasound evaluation

Conclusion: By replacing traditional percussion with more informative and reproducible ultrasound-based methods, this model aligns modern technology with classical clinical epistemology. The integration of ultrasound into bedside reasoning represents a vital evolution in chest semiotics, preserving the human element of the diagnostic process while increasing accuracy.

Key words: Semiotics, Clinical reasoning method, Chest ultrasonography, Lung ultrasound

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Meaning of clinical reasoning

In the modern era, clinical medicine has occupied an intermediate area of knowledge between science and art [1].

More recently, it has been increasingly interpreted as a science by virtue of advances in fields such as physiology, biochemistry, physics, and, not least, technology and artificial intelligence. However, the initial contact with the patient remains fundamentally a cognitive act free from intermediation, and the clinical examination is accomplished through a process that integrates physical perceptions and reasoning [2].

Human mediation is always required in every process of integration between the patient's experience and its translation into symptoms and diagnostic hypotheses.

Clinical reasoning is the mental process that allows the physician to gather, interpret, and integrate information (signs) from a patient to accomplish an assessment, and to get to a diagnosis, an appropriate intervention or treatment plan. It is an inferential process based on semiosis. We believe that this initial stage of access to the patient and the disease cannot be replaced by any artificial system other than a tool specifically designed to amplify semiosis for the interpreter.

Since its inception, AdET (Academy of Thoracic Ultrasound) has prioritized reflection on the current meaning of clinical reasoning, respecting its history, current needs, and future relationship with artificial intelligence (AI).

The first aim of this manuscript is to analyze the clinical reasoning as a dynamic process of inquiry and knowledge based on interpretation of signs.

Beyond a generic description of the phases of clinical reasoning, that can be found in any medical semiotics textbook, this discussion will rather involve a "philosophical" and methodological reflection on how, in our opinion, medical and clinical knowledge is formed, justified, and validated. This topic can be translated as "clinical philosophy or epistemology"[3]. Consequently, in this context of clinical knowledge, it will be examined the role of ultrasonography as potential epistemic mediator.

Starting from these considerations, the second aim of the manuscript is to investigate and deepen the entire physician-patient relationships in a philosophical reflection.

Essentially, the discussion will be focused on how knowledge is produced and validated in the medical context, where the object of study is not a universal law, but the uniqueness of each patient.

Finally, the third objective of this manuscript is to examine how ultrasound, particularly thoracic ultrasound which is the focus of our interest, is closely integrated with the classical pillars of medical semiotics, either reinforcing or substituting them in a modern approach to certain historical semiotic signs. Classical medical semiotics could thus be reconsidered in a different framework, in which chest ultrasonography pervades, strengthens, integrates, or replaces the other pillars, working as epistemic mediator for clinical knowledge and reasoning.

Clinical knowledge and reasoning based on interpretation of signs

The logic of uncertainty that concerns the interpretation of signs (semiotics) cannot make use of axioms and therefore, from an inferential perspective, it cannot be considered deductive logic. Rather, clinical reasoning can be fairly described as the search for the best explanatory hypothesis: the evidence that a trained mind seeks the most plausible hypothesis to explain even surprising facts (signs) that may occur. This method is known as "retroduction": inference of cause from effect.

This kind of inference arises in its final form from Charles Sanders Peirce's considerations and is called abduction (Table 1) [4].

Peirce developed a general theory of signs, known as pragmatic semiotics ("Pragmatism") that refers to a practical behavior when creating knowledge collecting signs [5]. His pragmatism is based on:

- Promoting concrete actions and results over idealistic considerations
- Approaching problems seeking effective and functional solutions within the specific context
- Evaluate ideas and actions based on their usefulness and consequences

Table 1. Synthetic scheme of abductive inference: in the central column the example cited by Peirce, in the right column the example of the application of abductive reasoning in clinical practice.

	Abductive inference	**Abductive reasoning in clinical practice**
Rule	All the beans from this sack are white	Whoever has the disease M, has the sign S
Result	These beans are white	The patient has the sign S
Case	(It is possible that) these beans come from this sack	The patient may have the disease M

Every act of knowledge based on interpretation of signs (semiosis) implies the relationship between a triad of factors:

1) the sign, what is observed; 2) the object, to what the sign stands for; 3) the interpreter, the meaning given by the subject [6].

Pragmatism focusing on practical utility of ideas and on scientific method as a dynamic process of inquiry, as in the specific case of the clinical reasoning, finds in abduction and Bayesian approach, the engines for innovation.

In the Bayesian approach, probability expresses a degree of confidence in an event. This confidence can be based on prior knowledge of the event, such as knowledge of the results of previous similar experiments, or on personal beliefs about the event.

For instance, Bayes' theorem [7] in its simplest form, states that the probability of a hypothesis H, given evidence of event E, is directly proportional to the product of the probability of E (when hypothesis H is given) and the probability of H (probability of the hypothesis itself, before knowing E), and indirectly proportional to the probability of E (probability of the event E itself),

$$P(H \mid E) = P(E \mid H) * P(H) / P(E)$$

In abductive inference, these probability values statistically "correct" all stages of the cyclic inference when new evidence (E) is considered in the subject under study (with its probability H).

In clinical practice, its role is essential: while frequentist statistics considers probability as an intrinsic and fixed property of the event, the Bayesian approach allows for an adaptable evaluation based on available information, which is more effective in open and dynamic processes like the one described. Moreover, a Bayesian "intuition," combined with a "satisfactory" abductive/iterative process, will put an end to the inferential loops described.

Peirce conceives knowledge as an open, probabilistic, and fallibilistic process: there are no absolute truths, but hypotheses that are always subject to revision in light of new evidence [8]. Clinical knowledge is therefore, like and perhaps more so than science, probabilistic (Bayesian) and self-corrective. This leads us to believe that semiosis and abduction are strongly correlated: operationally, semiosis provides information to be integrated into an abductive construct, which must necessarily be iterative to allow the self-corrective process. Actually, the process of abduction starts with an emotional reaction (puzzlement or surprise) which can emerge from the collection of signs (sometimes unexpected and incidental) performed by classic semiotics and anamnesis together with epistemic amplificators [9-12].

According to Magnani, epistemic mediators are the tools, artifacts, and practices that facilitate scientific knowledge and discovery. They are not simply passive instruments, but actual cognitive actors that mediate between the mind, the environment, and reasoning processes [13-15].

Physicians need to search for explanation of the signs detected, generating hypotheses that can be accepted, if more likely, or refused (Ockham's razor) [16].

Whether the correct diagnostic pathway is undertaken, the abduction process ends with another emotional reaction (pleasure or satisfaction of having been able to get the diagnosis) [10,17].

In this pathway, the diagnosis is always a provisional hypothesis, undergoing a probabilistic investigation and subjected to continuous reviews (uncertainty reasoning). By this point of view, clinical knowledge is progressively self-correcting and drastically influenced in a Bayesian ground and by serendipitous findings [18-21]. Doctors' search for signs, especially when

crucial, even if unexpected and incidental, is the basis of the reasoning method explained. This search is actually conducted through physical examination and medical semiotics.

Insonation as semiotic maneuver

Generally speaking, the term "semiotics" refers to the study of sign and symbols and how they create knowledge. It investigates how meaning is created, communicated and interpreted [22].

The study of signs for medical matters, their interpretation and meaning in order to approach patients' symptoms, to get the more correct diagnosis, is known as "medical semiotics". It includes the study of signs collected from patient's medical history and chest physical examination [23].

Chest physical examination is conventionally based on four pillars: Inspection, Palpation, Percussion, and Auscultation [24]. In the last years bed-side ultrasonography has gained an important role as a potential new semiotic technique to be added to already existing ones. Indeed, "Insonation" can be considered as the fifth pillar of medical examination [25].

"Insonation" is able to improve accuracy of diagnosis, to enhance physician-patient interaction, to optimize, limit or justify other diagnostic techniques and to guide interventional procedures or therapeutic choice. Moreover, insonation sounds like percussion.

For instance, during percussion, physicians use acoustic energy to assess structures. They interpret the interactions between acoustic waves and body tissues to get signs leading to diagnostic hypothesis. Percussion, like every semiotic maneuver, costs nothing and can be performed bedside [26].

Similarities between medical percussion and ultrasonography are evident. Ultrasound machines in medicine use acoustic energy to assess means. Physicians interpret interactions between acoustic (ultra) waves and body tissues to get signs leading to a diagnostic hypothesis. Ultrasonography is also cheap and can be performed bedside [9].

Therefore, could ultrasonography be considered a semiotic maneuver? Semiotics is the study of sign processes and meaningful communication. A sign is what creates a relation between the signifier and the meaning. In medicine the signifier is the physician, the meaning is the disease, the sign is detected by semiotics techniques [9].

As a matter of fact, ultrasonography (US) is an amplifier of signs that cannot be revealed or easily detected with classic semiotics [9]. From a cognitive point of view, we therefore consider it an "epistemic mediator" [13-15].

Although ultrasonography can have many advantages, it has to be acknowledged that ultrasound findings themselves are subject to interpretative bias, overuse, overconfidence, particularly because of variety of training programs and personal education [27-31]. In our work chest ultrasonography is intended to be as a semiotic maneuver. Thus, as all semiotic maneuvers, ultrasonography should be carefully taught and trained in order to reduce interpretative biases that need to be considered central in a probabilistic and self-corrective model of diagnostic reasoning.

Iteration in clinical reasoning

If semiosis, even though with the epistemic mediation of ultrasounds, and abduction initiate the cognitive cycle, a single cycle rarely leads to a plausible diagnosis. In that case, however, we would be in the context of a semiosis classically defined as "pathognomonic."

The cycle of abductive afferents, interpretations, and temporary validations is instead usually repeated in light of other signs that can be acquired from the clinical history, from physical examination, or from epistemic mediators. In this sense, we can also consider laboratory data, radiological investigations, and other medical assessments to be "signs" in a broad sense (i.e., information). However, information acquired in this way are indirect, mediated by other professionals who originally generated and often interpreted them. Laboratory, pathological, and especially radiological findings can act as mediators in a circular process of abduction. However, they are exposed to a potential bias related to preliminary interpretation (pre-judice in the Gadamerian sense) by individuals generally unconnected to the patient and to its inferential process [32].

Currently, the stethoscope, ultrasound, and little else used by the clinician that directly examines the patient, are truly direct epistemic mediators.

The interpretation of an illness

Semiosis and abduction are at the basis of the inferential process described. However, to achieve plausible knowledge, it requires a theoretical foundation consisting of the specific knowledge possessed by the physician seeking a diagnosis. From a hermeneutic perspective, understanding is never linear but circular: every interpretation of the parts depends on the whole, and the whole is clarified only through the parts. The abductive circularity described thus configures a hermeneutic circle that, according to Gadamer [33-34], must also include the interpreter's history and preconceptions: understanding always means establishing a dialogue between our own horizon and that of the object to be known. If we transfer these concepts to the clinical field, we understand how the process leading to knowledge involves not only the interpretation of texts or history, but also the physician's practical activity. In this context, the theoretical basis (the interpreter's prejudices, obviously understood in a non-negative sense), or rather, preconceptions, are located in the physician's knowledge (but also in the knowledge of the patient's history, the empathy for him, and, fundamentally, in the ability to merge the clinician's horizon with that of the patient).

On the other hand, there are the patients, that bring their personal history, their feelings and emotions, their fears, needs, values and expectations (patients' pre-judices, again obviously understood in a non-negative sense).

These initial pre-conceptions represent the "horizons" of both patients and physicians, essential to begin the process of the diagnosis.

Starting the "hermeneutic circle" of the clinical knowledge, the initial pre-conceptions of physicians and patients are continuously questioned, controlled and corrected in a dialogic pathway. An authentic interpretation occurs when the initial anticipation is confirmed through a process of verification. Hermeneutic circle reaches its culmination in the fusion of the two horizons. Horizons integrate and merge into a new common broader horizon which is represented by the diagnosis and its consequences [33,34].

From the physicians' point of view, not surprisingly, the abductive circle we have configured as a hermeneutic circle, shows similarities with what Ginzburg defined as the "evidentiary paradigm" or "the method of clues" [35].

Although their origins and roots are different, it is now clear that the hermeneutic circle and the evidential paradigm share a common cognitive logic: essentially, the hermeneutic circle is primarily rooted in philosophy, while the latter is characterized by a strong empirical imprint (Table 2). In our opinion, however, both fit rationally—the former with a theoretical foundation, the latter with a practical approach—into the dynamics of diagnostic reasoning.

From a pragmatic perspective, it is the evidentiary paradigm as described by Ginzburg that guides diagnostic reasoning step by step. Moreover, the evidentiary paradigm is characteristic of every activity in which signs intended as traces or clues are sought.

Table 2. Correlations between hermeneutic circle and evidentiary paradigm. Shared common cognitive logic.

	Hermeneutic circle	**Evidentiary paradigm**
Origin	Gadamer's epistemology	History and epistemology (Ginzburg)
Roots	Understanding of ancient and sacred texts, laws, historical documents	Medicine, hunting, philology, art criticism
Object	Understanding and interpretation	Search for signs, traces, clues
Method	Circular abduction	Detail-based abduction
Process	Open, dialogical, never definitive interpretation	Open, dialogical, never definitive interpretation
Role of the interpreter	Uses preconceptions and fusion of horizons	Uses intuition, experience and comparison
Described applications	History, literature, jurisprudence	History, criminology, psychoanalysis, art

It operates transversally in all fields of knowledge: in everyday activity, in art criticism, in detective work, in clinical practice as well as in scientific research [36-38].

Finally, an interpretative approach that uses apparently insignificant details to obtain broader and more significant information is essential to understanding the complexity of the biological world and disease.

An incidental small detail and an unexpected finding can sometimes be able to dramatically change the diagnosis. For example, chest ultrasonography can allow physician to incidentally detect pleural thickenings, suspected for malignancies, in a contest of pleural effusion. In a compatible clinical/anamnestic context, this finding can orient physician towards the most likely diagnosis [9].

This process is known as "Serendipity": allowing for chance finds, accepting that what is found is not necessarily what was being looked for and takes place in the absence of any obvious project, logic and predictability [39,40]. These incidental findings, however, become crucial in the search for truth, modifying the diagnostic pathway [39].

Insonation as epistemic mediator in respiratory diseases

Although direct comparisons between ultrasound and traditional semiotics are few, clinical experience has shown that the informative content of chest ultrasound can be very broad when compared to the detection of classic thoracic signs evoked with accurate semiotics. In our opinion, ultrasound is a powerful epistemic mediator, not only for the chest, but for all body regions. In fact, its use should be encouraged in virtually all specialties.

US insonation can help physicians better interpret some classic semiotic signs in respiratory diseases. Multiple examples can be given for medical signs, especially for percussion and palpation [41,42].

One example is the Damoiseau-Ellis line, that represents the upper limit of dullness to percussion caused by the presence of pleural effusion. The latter is usually associated with Garland's triangle, which is a triangular area of relative percussion resonance between the paravertebral line of the chest and the upper limit of the pleural effusion. Insonation can easily detect the limit of pleural effusion, can add crucial information regarding features of pleural effusion and can reveal extension and characteristics of collapsed consolidated and pre-consolidated lung parenchyma because of the presence of pleural effusion, therefore better explaining the relative percussion resonance of Garland's triangle and Damoiseau-Ellis line (Figure 1). Moreover, insonation can also reveal the real origin of Grocco's triangle, the triangular area of dullness often present at the basis of the hemithorax opposite to pleural effusion. When present, it corresponds more frequently to a small amount of reactive pleural fluid on the opposite side in case of exudative pleural effusions or empyema, and less frequently to mediastinal displacements caused by massive effusions or large empyema, with increased intrapleural pressure (Figure 1).

Pneumothorax occurs when air leaks and accumulates between parietal and visceral pleura. Tympanic sounds to percussion with hyper-resonance on one side of the chest ("sonus altior" in Latin), may indicate the presence of pneumothorax. In chest ultrasonography, the presence of lung point(s) and the absence of sliding sign has been reported as the highest specific sign for detecting pneumothorax (Figure 2).

Accordingly, ultrasound can also easily detect the presence of hydro-pneumothorax. Hippocratic succussion sound from the chest, which is a splashing noise produced by shacking the body in case of presence of both air and fluid in the thorax, can be substituted by a simple ultrasound evaluation (Figure 2).

Percussion dullness in the chest also increases the probability of pulmonary consolidation (pneumonia, atelectasis, pulmonary infarction, peripheral lung or pleural cancer).

In all cases, chest ultrasonography plays a crucial role, allowing the accurate detection and assessment of peripheral pulmonary consolidations, adding important and helpful information on the features of the consolidation itself, such as bronchogram characteristics, consolidation shape and relationships with adjacent structures, or, by means of Contrast-Enhanced Ultrasound (CEUS), the presence of necrosis, abscesses, distribution of vascularization (Figure 3).

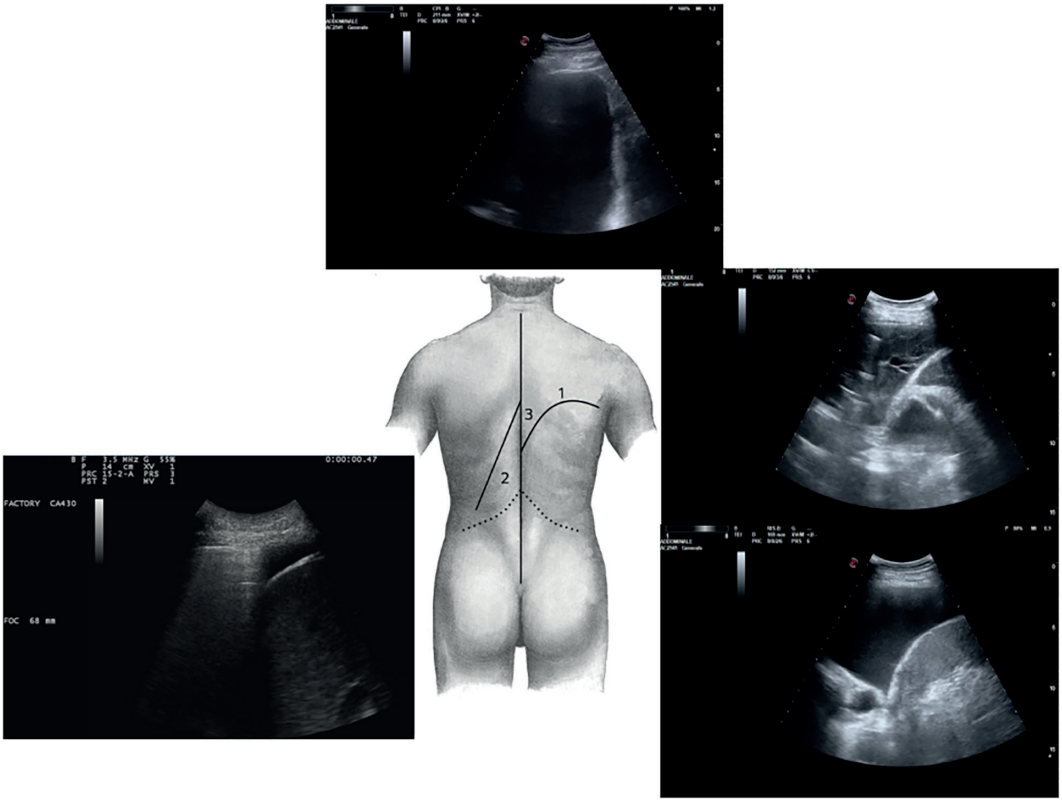

Figure 1. Damoiseau-Ellis line (1), contralateral Grocco's triangle (2) and relative percussion resonance of Garland's triangle (3). Ultrasound evaluation can reveal anechoic free flowing pleural effusion (bottom right side), complex pleural effusion (upper right side) or hypertensive pleural effusion in one hemithorax (top center). Small amount of reactive pleural fluid or mediastinal displacement for increased intrapleural pressure explaining contralateral Grocco's triangle (left side).

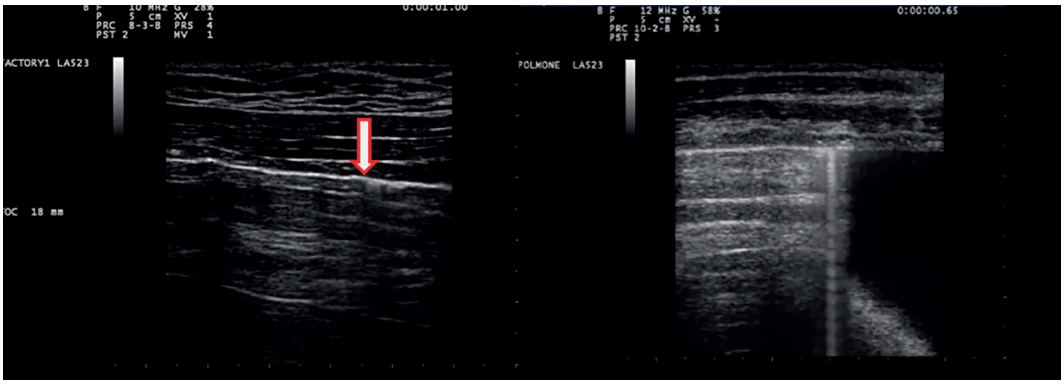

Figure 2. On the left: Lung point (arrow) revealing pneumothorax. On the right: hydropneumothorax. Vertical artifacts emerge from bubbles on the surface of the pleural effusion, moving simultaneously with body shacking (Hippocratic succussion).

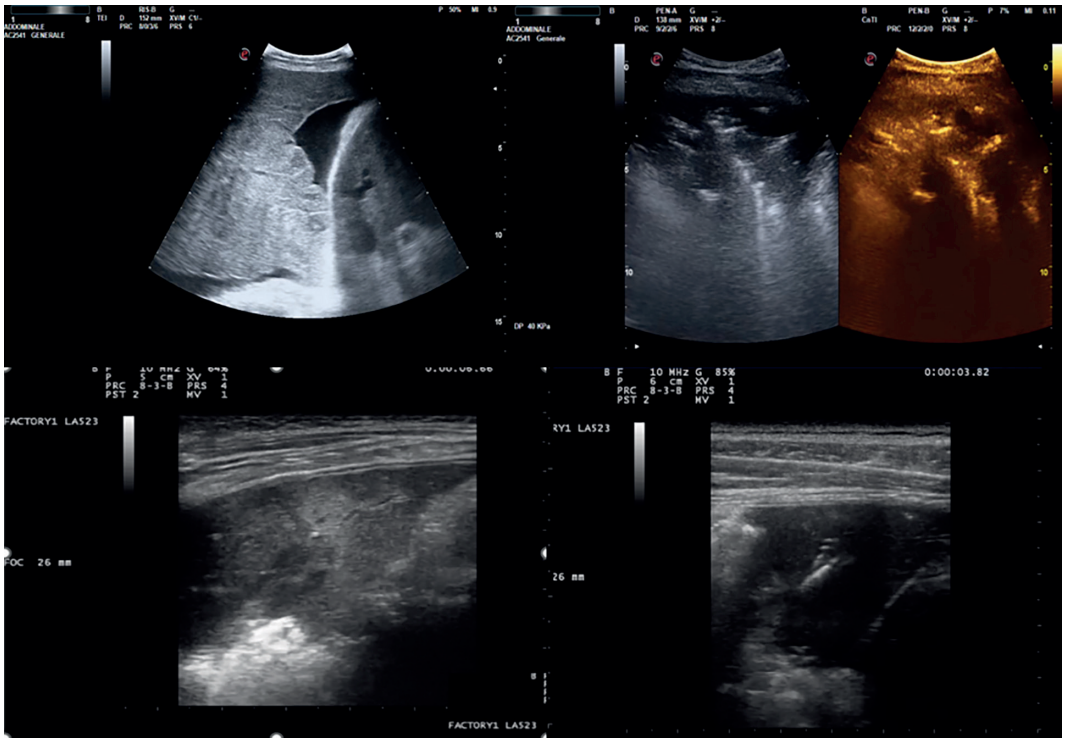

Figure 3. Examples of ultrasound evaluations of percussion dullness and altered tactile fremitus. Upper left: lung cancer with pleural effusion; upper right: pneumonia with abscesses revealed by CEUS evaluation; bottom left: pulmonary consolidation with fluid bronchograms; bottom right: pulmonary consolidation with air bronchograms.

Moving to palpation, in cases of either pleural effusion or pneumothorax or pulmonary consolidation, tactile fremitus is altered. As already reported, insonation can yield a better interpretation of the value of this altered semiotic sign (Figure 3).

In any case, whenever something is palpable during the physical examination of the chest, it will certainly be better evaluated, understood, and analyzed through ultrasound.

Finally, chest ultrasonography can integrate some auscultatory findings (Figure 4). This is the case, for example, of crackles and rales: detecting sonographic interstitial syndrome with features compatible with specific alterations of pleural line and peripheral airspace geometry (cardiogenic vs pneumogenic/fibrotic), together with novel emerging techniques of quantitative lung ultrasound spectroscopy, would allow physicians to speed up the diagnostic process [43-49].

Also, bronchial blow and silence are auscultatory items that can benefit from chest ultrasound evaluation (bronchogram, atelectasis, pleural effusion, consolidation, diaphragmatic disfunction, etc.) (Figure 3).

Starting from these considerations, a panel of AdET's experts (Academy of Thoracic Ultrasound) has drawn the project CHEPHEUS, aimed at investigating the role of chest ultrasound as the pillar of a new way of seeing and interpreting chest semiotics. First results from CHEPHEUS 1 have already been published [50], and a second project (CHEPHEUS 2) [51] is currently ongoing, designed to demonstrate that pillars of classic chest physical examination might be more effectively replaced by three pillars aided by ultrasonographic assessment: visual inspection, auscultation, and palpatory ultrasound evaluation (Table 3).

Conclusions

This document outlines ADET's proposal regarding the valorization of the objective examination of the respiratory patient, respecting traditional clinical

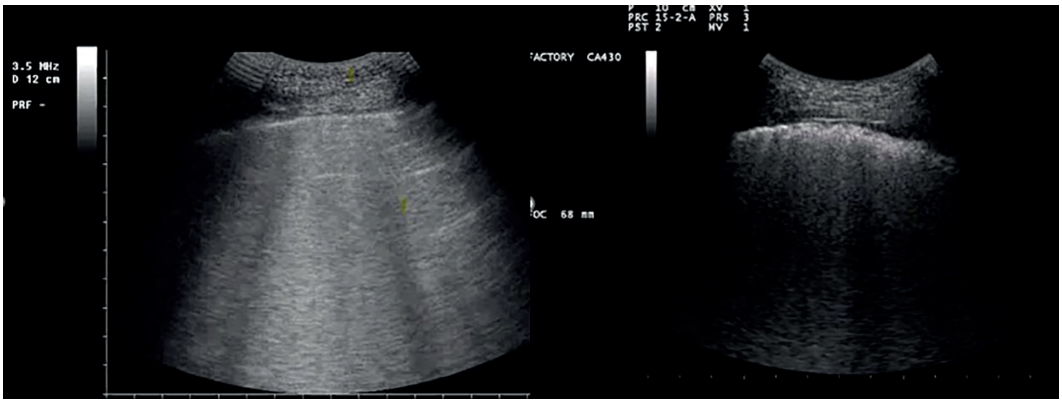

Figure 4. Examples of ultrasound evaluations of some auscultatory findings as crackles and rales: On the left: Sonographic interstitial syndrome in cardiogenic pulmonary edema. On the right: Sonographic interstitial syndrome in fibrotic interstitial lung disease.

Table 3. Proposal of new chest physical examination based on three pillars.

Chest physical examination	New chest physical examination
Visual inspection	Visual inspection
Auscultation	Auscultation integrated by information from chest ultrasound
Palpation	Palpatory ultrasound evaluation
Percussion	Replaced by ultrasound evaluation

principles. Furthermore, the principles outlined can be applied to any field of clinical medicine. This does not mean that attention is diverted from the necessary modern technologies, the use of diagnostic algorithms, evidence-based medicine, and even artificial intelligence.

The discussion is essentially focused on the physician's first contact with the pathology, which must necessarily be "humanized" in light of the principles of clinical epistemology, which are generalizable. In this context, we introduced the use of ultrasound as an information tool, seen therefore as an epistemic mediator. This means that ultrasound is a tool for the clinician performing the patient's examination, not a diagnostic tool to be delegated (and relegated to specific environments). The classification of the pillars of semiotics must therefore be revised, and insonation should not necessarily represent only the fifth pillar.

We believe that, nowadays, diagnostic reasoning must be valued and can regain a prominent role in patient management. In our opinion, the integration of traditional and technology-mediated semiosis, which places in the clinician's hands a highly informative tool such as ultrasound, is an easily accessible path, one we have already explored in numerous courses.

Aware that diagnosis is always burdened by uncertainty and subject to revision in light of new evidence, the iteration proposed in the inferential loop, which in practical terms is a circumstantial paradigm, avoids many errors of underestimation or "tunnel vision."

The iteration of the inferential loop must have a limit. This limit coincides with a satisfactory probability of a correct diagnosis, which in practical terms is achieved by the "clinical sense", statistically supported, as already mentioned, by the Bayesian hypothesis.

Finally, diagnostic conclusions can only be fusions of horizons (of the interpreter-the doctor-with his knowledge-pre-judices-and the object of study, which is none other than the patient with his present, past, and future). We believe that medicine, symbiosis of science and "stochastic art", can enter into this synthesis.

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