Opinion Paper

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The challenge of clinical reasoning in chronic multimorbidity: time and interactions in the Health Issues Network model

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Abstract: The increasing prevalence of multimorbidity requires new theoretical models and educational approaches to develop physicians' ability to manage multimorbidity patients. The Health Issues Network (HIN) is an educational approach based on a graphical depiction of the evolutions over time of the concurrent health issues of a patient and of their interactions. From a theoretical point of view, the HIN approach is rooted in Prigogine's vision of the "becoming" of the events and in the concept of knowledge organization, intended as the process of storing and structuring of information in a learner's mind. The HIN approach allows to design clinical exercises to foster learners' ability to detect evolutionary paths and interactions among health issues. Recent findings of neuroscience support the expectation that interpreting, completing, and creating diagrams depicting complex clinical cases improves the "sense of time", as a fundamental competence in the management of multimorbidity. The application of the HIN approach is expected to decrease the risk of errors in the management of multimorbidity patients. The approach is still under validation, both for undergraduate students and for the continuous professional development of physicians.

Keywords: clinical reasoning; knowledge organization; medical education; multimorbidity.

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Introduction

Clinical reasoning is a fundamental competence for any practicing physician [1]. Clinical reasoning is a process ripe with complexity and prone to diagnostic or therapeutic errors [2]. Multimorbidity, the term applied to patients with multiple chronic conditions, is increasing in prevalence, clearly compounds the complexity of clinical reasoning, and likely increases the chances for diagnostic errors [3, 4]. Establishing a diagnosis or managing a patient's treatment will be substantially different tasks if the patient suffers only from one disease or if they have other concurrent diseases [5].

Attention to the diagnosis and management of chronic conditions is gaining momentum [6], however research on educational approaches to promote learning of clinical reasoning in the setting of multimorbidity over time is limited [7]. Hence, there is a need for theoretical and practical educational models to represent the non-linear interactions of multimorbidity and to develop physicians' abilities to care for complex multimorbidity patients over time.

The Health Issues Network (HIN) is a novel approach to support the development of clinical reasoning in the setting of multimorbidity over time, based on a graphical depiction of a clinical case. The core concept is the evolution of the patient's clinical problems. The Health Issues Network approach allows one to better appreciate the interrelatedness of multiple conditions while also tracking how a patient's overall state of health changes over time. Being able to anticipate a patient's clinical trajectory over time [8] while considering the influence of concurrent health issues is a critical skill for health professionals. Learners must recognize the symptoms and signs that come with the progression of the patient's condition, be able to appreciate the interactions among chronic coexisting conditions, and frame the patient's present condition as just one moment in a longer, evolving story.

In the following paragraphs we describe the theoretical framework of the Health Issues Network approach, summarize

its main features and illustrate how it supports clinical reasoning in multimorbid patients over time.

Theoretical framework of health issues network

Experts have argued that improving healthcare will require appreciating its complexity [9, 10], and we propose that a comparable, systems-oriented mindset is critical to appropriately diagnose and manage patients with multimorbidity. The Health Issues Network, grounded in the theoretical tenets of complexity theory and cognitive models of knowledge organization, is a useful approach to illustrate and understand this complexity.

In his studies of complex systems, Ilya Prigogine developed a vision of time in which the core concept is the "becoming", and multimorbidity can be considered the result of the fluctuating probability of a change in events occurring over time [11]. The event can be a new, intervening disease, or a chronic condition that worsens due to age, life habits or social determinants, or to interactions with other co-existing conditions or their treatment (Figures 1 and 2).

Knowledge organization is the mental process of storing, structuring, and re-structuring information to make meaning, and it plays a critical role in the clinical reasoning process [12]. Research shows that novices have less elaborated and interconnected knowledge networks, while experts have more structured and semantically rich networks [13]. The number of concepts, and more importantly, the meaning of relationships between concepts are important components of knowledge organization. Through the different types of possible clinical exercises, the Health Issues Network approach can promote knowledge organization by creating time-oriented links among nodes and time-oriented connections among different domains of knowledge across the levels of clinical, semiotic, and pathophysiological representation.

Another relevant contribution to the design of the educational aspects of the HIN approach and pedagogy comes from the neurosciences applied to learning, namely knowledge representation techniques called "visual thinking networking". By building network diagrams with semantic and figurative aspects to depict knowledge linkages, students can leverage visual thinking networking as a metacognitive learning technique to enhance knowledge organization. According to Arnheim [14], "the perception of shape marks the beginning of concept formation" (p. 27). By chunking and connecting conceptual labels with colorful symbolic visualizations of scientific concepts, processes, and experiences into a unified whole, visual thinking networking provides a tool for learners to organize, depict, and change their meaning-making of science knowledge. Colors are often used to add further information about the dynamics of the overall diagram, enhancing effectiveness of a diagram [15]. The Health Issues Network approach adopts this kind of graphical representation, in which health issues are linked with arches of evolution or causal relationship, on a time-oriented plane (Figure 1).

The health issues network (HIN)

The HIN approach uses two basic conceptual elements: a health issue or problem and its evolution [16, 17]:

1. The Health Issue (HI) or problem can be a diagnosis, a hypothesis, a sign/symptom, a risk factor, a pathophysiological condition, or any other element of a patient's clinical state, including the results of lab tests or imaging. This broad definition of a health issue allows the teacher designing an exercise for students to consider a wide range of topics and issues.
2. The evolution is any change of a health issue, through which the patient transits from one state to another. As examples, a health issue can change its state in an irreversible way, such as the worsening of a chronic condition or the recovery of an acute condition, or generate a new issue, such as a new complication of an existing problem. The evolution may also be impacted by a range of social determinants of health, or environmental factors, or any number of different influential factors.

HIN diagrams can include a clinical section with description of the signs and symptoms of a disease and a corresponding, interconnected basic science section with concepts that relate to the clinical concepts depicted in the diagram. A HIN diagram can have both a mathematical and a graphic dimension. The underlying mathematical representation allows computer-assisted scoring to compare scores for a student's diagram to that drawn by an expert [18].

Practical implications for teaching and learning

Asking students to depict a patient's clinical course using a HIN diagram will foster their ability to appreciate the evolutionary paths of the different health issues of a patient with multimorbidity and the interactions among these

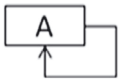
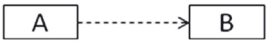
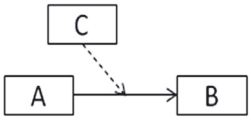
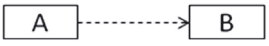
	Evolution types	Graphic representation	Example
1	Recurrence		A = acute diverticulitis Evolution = recurrence Meaning = the patient had recurrent episodes of acute diverticulitis
2	Worsening; Examining in-depth; Improvement		A = Mild renal insufficiency B = Advanced renal insufficiency Evolution = worsening Meaning = mild renal insufficiency progressed A = abdominal pain B = acute appendicitis Evolution = examining in-depth Meaning = an abdominal pain was interpreted as acute appendicitis
3	Complication		A = diabetes B = diabetic neuropathy Evolution = complication Meaning = diabetes now complicated by neuropathy
4	Worsening with co-morbidity		A = mild dementia B = severe dementia C = pneumonia Evolution = worsening with comorbidity Meaning = dementia of a patient worsened after the onset of a pneumonia
5	Cause		A = bacterial infection B = fever Evolution = cause Meaning = a bacterial infection causes fever

Figure 1: The types of evolution in the HIN model. A full thickness line represents an evolution in which the HI of origin disappears, becoming the HI of destination. A dotted line represents an evolution in which the HI of origin remains active and is responsible for the development of a new HI. A co-morbidity represents the influence on another evolution, intended as the increase of the likelihood of that worsening or developing a complication. The evolution "cause" is only used from a pathophysiological process to a symptom/sign/test result or disease, to express a linear cause-effect relationship.

health issues. Here are practical suggestions on how the health issue network approach can be used:

- Ask the learner to draw a diagram of a real patient the student is following in the hospital or in the outpatient setting.
- Instruct the learner to read a case report, a book chapter or a narrative of illness and draw the corresponding diagram.
- Provide a preliminary diagram and ask the learner to hypothesize the future evolution of current diseases, or to anticipate an interaction with other diseases that may arise at some future point in time.
- Provide the student with a HIN diagram that includes a previously completed clinical section and ask the student to add the corresponding basic sciences section. For example, if the diagram depicted the key clinical features of a patient with congestive heart failure, atrial fibrillation, and mitral regurgitation, the student should be able to describe the corresponding pathophysiology concepts related to those diseases. These exercises promote the integration of basic and clinical sciences.

Discussion

The Health Issue Network approach provides students with an opportunity to learn clinical reasoning within the context of multimorbidity and chronic diseases. We argue that a wider theoretical understanding of how we conceive the evolution of health and disease over time would be beneficial for clinical reasoning. Cairo Notari et al. interestingly noted that "The lack of guidelines adapted to multimorbidity, and the necessity to navigate these different issues make general practitioners feel uncertain, ill-equipped, and sometimes guilty" [7]. A patient's long story of multimorbidity can be unfolded and represented in a HIN diagram, making more evident the connections between different diseases, complications, age, social determinants of

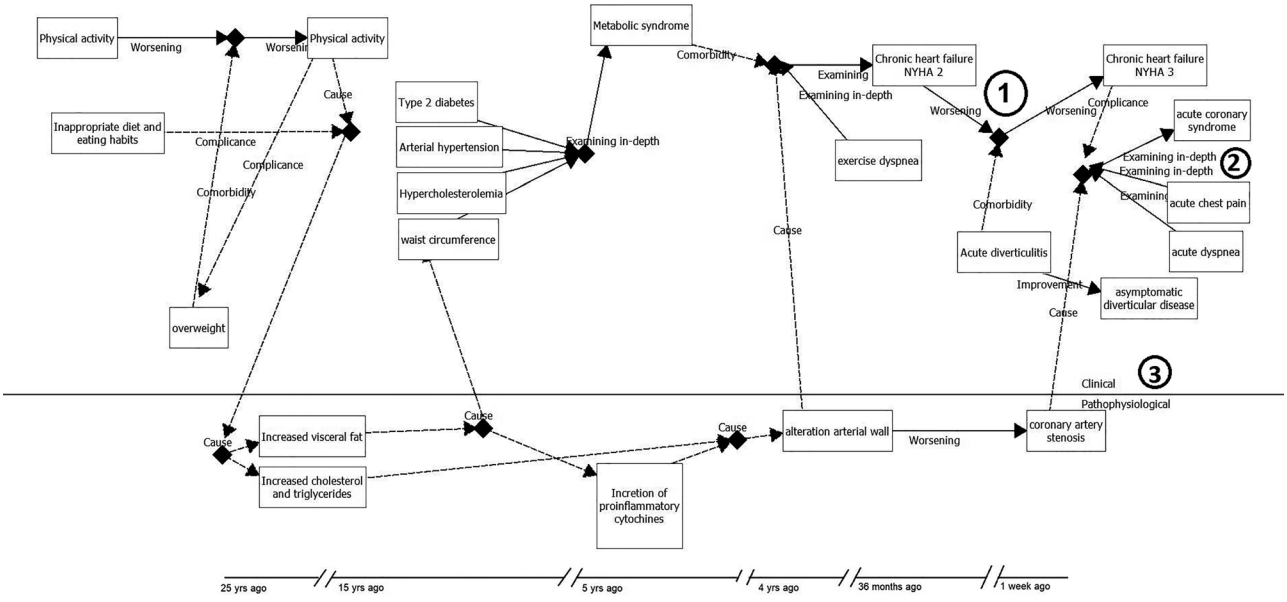


Figure 2: This is an example of a health issue network representing a clinical history of a patient. A 76 years old man with metabolic syndrome, and chronic heart failure. An episode of acute diverticulitis triggers a worsening of the chronic heart failure. Coronary artery disease (and its key presenting symptoms) develops as complication of heart failure. The underlying pathophysiological processes (under the line) and time axis of the patient's illnesses are depicted in the section below. The black diamonds are connectors among two or more evolutions. The plane is time oriented, and the time axis is interrupted to mark leaps in the time scale. #1: The episode of acute diverticulitis causes a worsening of a chronic heart failure. This worsening is a typical example of bifurcation, according to Prigogine's conception, and evolution. #2: This is a representation of some of key clinical features of acute coronary syndrome. #3: A line splits the plane in the two levels of pathophysiology and clinical symptoms, signs, and diseases.

health, risk factors, and so on. The Health Issues Network adds the concepts of evolution and interaction over time for both diagnosis and management of a disease. Finally, diagraming the process of care for a patient with an unexpected outcome could provide the clinician or a team with new insight into the timing, nature, and possible reasons for diagnostic or therapeutic errors.

An interesting concept in the field of cognitive psychology is the construct of temporal focus, defined as the degree to which individuals think about the past, present, and future. Studies of temporal focus have explored the relationship of temporal focus to memory and motivation [19]. Other studies have explored polichronicity (doing more than one action at the same time) [20] or how mood can alter one's orientation toward the past or the future [21]. There is evidence that the cognitive representation of space and time is inter-connected, and that the 'place cells' and 'grid cells' of the hippocampus are involved [22]; the anatomic relationship of these cells may correspond to mental travels forward or backward in time [23]. The importance of these studies for education remains to be determined, but the concept that perceptions of space and time are inter-connected could provide a foundation for using graphical representations of time and disease for educational purposes.

The Health Issues Network approach is still under development. It has been introduced and evaluated in teaching with medical students, residents, practicing doctors, and in veterinary medicine [24]. Learners' feedback has been positive and has contributed to fine tuning the HIN layout and syntax. Ongoing development is aimed at defining a metric to quantify the complexity of a diagram and exploring the use of HIN diagrams in different contexts. These efforts will make it possible to diagram cases of increasing clinical complexity (number of comorbidities, rare diseases, or unusual complications), and cases of increasing syntactic complexity (number of health issues and evolutions of different type). Future research will hopefully validate this approach as a helpful way to assess progressive development of knowledge organization, as the learner moves from semantically poor to semantically rich conceptualizations [13].

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