Original Article

Analysis of the multimorbidities network in the elderly in a reference center: a cross-section study

Análise da rede de multibormidades em idosos atendidos em um centro de referência: estudo transversal

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ABSTRACT | INTRODUCTION: Elderly people have multiple diagnoses with similar patterns that can be analyzed by the theory of complex networks. Chronic disorders with repercussions on functional capacity tend to increase in number and severity in these individuals, requiring an integrated analysis to understand the relationship between aging and multimorbidities. **OBJECTIVE:** To analyze patterns of interaction between diseases that affect elderly people in a reference center. **MATERIALS AND METHODS:** Clinical data and diagnosed diseases were collected from 2973 medical records of elderly people registered at a reference center for elderly health care. Diseases were considered nodes in the network and the elderly were considered to be rough edges. The weight of the edges corresponded to the number of elderly people with two diseases simultaneously. Through the Gephi software (version 0.9.2), the degree of connectivity between diseases (degree of entry), the interaction of diseases in subgroups (Community), most influential diseases (Hubs), and diseases that act as bridges between two or more communities were analyzed. **RESULTS:** 30 nodes (diseases) and 433 edges with different weights were identified according to the number of elderly people, and 3 communities where the degree of connectivity is greater among themselves. Systemic Arterial Hypertension (SAH) was the most influential hub in the network. **CONCLUSION:** The construction of the complex network mapped diseases and the influence on care for the elderly. Relevant information for local managers, in search of effective interventions in the service that aims to contribute to the prevention of the main comorbidities and assist in the functional independence of patients.

KEYWORDS: Health Services. Comorbidity. Aged.

RESUMO | INTRODUÇÃO: Idosos possuem múltiplos diagnósticos com padrões de similaridade que podem ser analisados pela teoria das redes complexas. Distúrbios crônicos com repercussões na capacidade funcional tendem aumentar em número e gravidade nesses indivíduos, sendo necessária análise integrada para compreender a relação entre envelhecimento e multimorbidades. **OBJETIVO:** Analisar os padrões de interação entre as doenças que acometem idosos de um centro de referência. **MATERIAIS E MÉTODOS:** Foram coletados dados clínicos e doenças diagnosticadas em 2973 prontuários de idosos cadastrados de um centro de referência de atenção à saúde do idoso. As doenças foram consideradas nós da rede e os idosos as arestas de modo não direcionada. O peso das arestas correspondiam à quantidade de idosos com duas doenças simultaneamente. Através do software Gephi (versão 0.9.2) foram analisados grau de conectividade entre as doenças (grau de entrada), interação das doenças em sugbrupos (*Comunity*), doenças mais influentes (*Hubs*) e doenças que atuam como pontes entre duas ou mais comunidades. **RESULTADOS:** Foram identificados 30 nós (doenças) e 433 arestas com pesos distintos de acordo com a quantidade de idosos, e 3 comunidades onde o grau de conectividade é maior entre si. A Hipertensão Arterial Sistêmica (HAS) apresentou-se como o *Hub* de maior influência na rede. **CONCLUSÃO:** A construção da rede complexa mapeou as doenças e a influência na assistência ao idoso. Informações relevantes para os gestores locais, na busca de intervenções efetivas no serviço que visem contribuir para prevenção das principais comorbidades e auxiliar na independência funcional dos pacientes.

PALAVRAS-CHAVE: Serviços de Saúde. Comorbidade. Idoso.

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Introduction

Diseases that affect a population have similar patterns that can be analyzed by the theory of complex networks. The new method of analysis in the scientific context that assesses the interactions between diseases in a given group of individuals[1]. In the elderly, chronic diseases tend to increase in number and severity, and it is necessary to extrapolate the isolated analysis and understand them in a network context.

Although research is incipient in this area, the study of the relationships between diseases already has its own terminology called network medicine[1]. The focus of network medicine is to identify the indirect connections between apparently unconnected diseases[1]. Initially developed to analyze genomic interactions between diseases, its use has been extended to epidemiological studies in communities[2]. It is a new field of research that has emerged in the last decade to address biological complexity in an integrated manner, enhancing the ability to decipher the relationship between aging and multimorbidities[3].

The aging process is associated with a higher prevalence of diseases and chronic disorders[4] with a direct impact on functional capacity, length of hospital stay, and mortality in the elderly[5]. Health services for vulnerable elderly people who focus on the treatment of isolated diseases will have difficulty understanding complex health problems and finding effective solutions to this cases[6]. Since most non-communicable diseases are associated with the aging process and often coexist in the same individual[7]. The presence of two or more diseases in an individual with a major disease is defined as "comorbidity" and the presence of two or more diseases in the same individual without reference to any major disease is defined as "multimorbidity"[8].

The starting point in the analysis of disease networks will depend on the perspective of those who observe it[9]. There are three perspectives: 1) Genetic perspective - genetic similarities between diseases[10], 2) Metabolic perspective - shared metabolic paths between diseases[8] and 3) Perspective of multimorbidity - the coexistence of different diseases in the same individual beyond what is expected by chance[11]. The three can be used together or separately, but the understanding of disease interactions among the elderly in a health service can already be obtained from the perspective of multimorbidity. With this, through the use of complex networks, this study aims to analyze the characteristics of the multimorbidity network of the elderly and secondly to characterize the profile of these individuals with active registration in a state reference center for elderly health care.

Methodology

Scope of the study

An observational cross-sectional study was carried out with secondary data from medical records of the elderly registered at the State Reference Center for Elderly Health Care (SRCEHC).

Sample and source of data

All medical records of elderly people with active registration at the State Reference Center for Elderly Health Care (SRCEHC) from February to October 2019 were used. The information was obtained through the Multidimensional Assessment of the Elderly Person (MAEP), which is mandatorily completed when the patient is admitted to the unit. MAEP contained a checklist of the most common diseases in the elderly defined by Assessing Care of Vulnerable Elders-3 (ACOVE 3)[12]. The survey collection form captured the information in this checklist and also socio-demographic data to characterize the sample.

This work was submitted to and approved by the Research Ethics Committee (REC) in human beings of the Secretary of Health of the State of Bahia under the number 2.581.226 (CAAE 84753617.4.0000.0052). The recommendations proposed by resolution 466/12 of the National Health Council were considered by the researchers during their execution.

Disease Checklist

MAEP has a list of the most common morbidities in vulnerable elderly people. This list was validated and standardized by the advising committee of Assessing Care of Vulnerable Elders-3 in 2006[12]

which contemplated 32 diseases in the vulnerable elderly population[13]. The checklist was completed by a geriatrician during the application of MAEP. The diseases present in the checklist were: dementia, Parkinson's disease, depression, diabetes mellitus, systemic arterial hypertension, coronary artery disease, heart failure (HF), stroke, atrial fibrillation, malnutrition, osteoarthritis, osteoporosis, pneumonia/influenza, ulcer pressure, falls and postural instability, immobility, urinary and fecal incontinence, visual impairment, hearing impairment, chronic pain, hypothyroidism, continuity of care, medication management (polypharmacy), hospital care and palliative care.

Data collect

The data collection at MAEP was performed by 13 assistant researchers supervised by the main researchers to minimize duplicate collections and rework through weekly reviews of the database. All researchers received prior training and performed the collection using an electronic form. The application of this form was carried out in a restricted room of the Center for Teaching and Research (CTR) of SRCEHC. The site has been properly equipped for this purpose with up to four computers available for this purpose. In case of doubts, the researchers were able to turn to CTR professionals who know the MAEP items in depth. Therefore, the bank was treated continuously to ensure the reliability of the information recorded. After a final review, in a copy, the identification data were replaced by alphanumeric codes of the subjects, being released for the elaboration of the data mask of the multimorbidity network.

Analysis of the multimorbidity network

The sociodemographic data of the elderly were used to characterize the study population. A descriptive analysis was performed with measures of central tendency for quantitative variables. Frequency measures were used in the ordinary and/or dichotomous variables to verify the proportions. This analysis was performed with the aid of the statistical package StatisticalPackage for Social Sciences - Statistics for Windows (SPSS), version 20.0.

The individuals were categorized, based on the frailty classification by Moraes et al., into three levels, according to their clinical-functional stratum: 1) Robust Elderly (1 to 3), 2) At Risk of Fragility (4 and 5) and 3) Frail Elderly (6 to 10)[14].

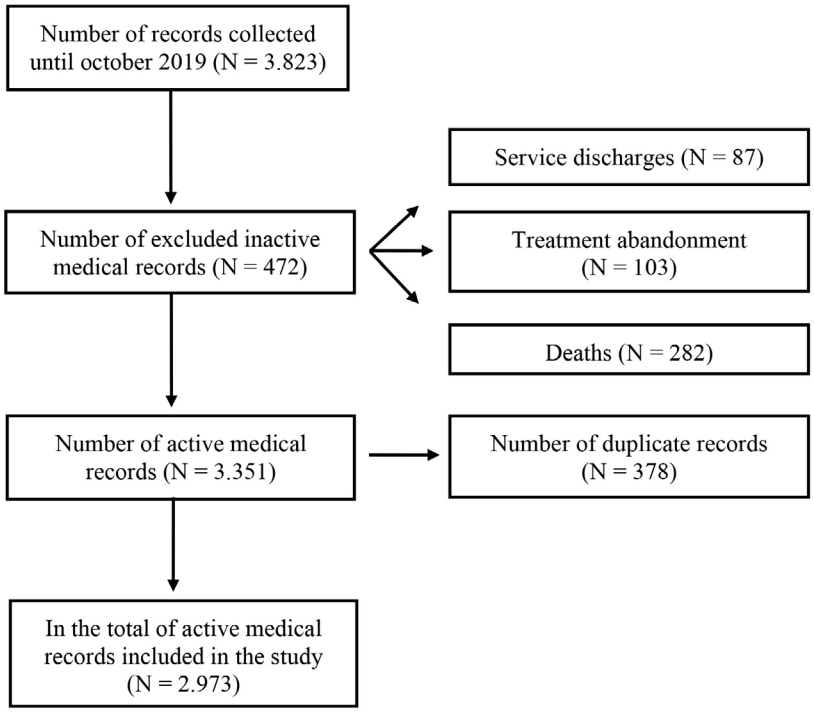
The network analysis was performed with the aid of the Gephi software (version 0.9.2) and the layout adopted was based on the ForceAtlas 2[15] algorithm. All elderly people with active registration in SRCEHC were included in this network, totaling 2,973 elderly people. First, the nodes that are the comorbidities were defined. Then the sets of connections to the same node were established, which establishes the appearance of central vertices, called hubs. Those vertices that concentrate more connections with others are more likely to create new connections[16].

The degree of the entry (the number of edges reaching the node) together with the measure of centrality (total number of non-redundant shortest paths that pass through a given node) were used to assess the relevance of the location of the nodes in a network9. Three well-known measures of centrality were used, namely, centrality between proximity, the centrality of proximity, and centrality of its own vector (available as part of the Gephi package). In summary, the centrality of the eigenvector is a measure of the importance of the node in a network based on the connections of a node, and the centrality of proximity is the average distance from a given initial node to all other nodes in the network. We define a cluster as a part of a network where the nodes are accessible only from nodes on the same network. Community or modularity was obtained in the network with a resolution of 0.6[17], this measure represents greater connections between the nodes of a specific group in comparison with other nodes in the entire network. The community detection algorithm used in Gephi is able to identify modules in bipartite networks like the one in this study[1]. PageRank was also used, which measures the importance of a vertex in the network considering each edge, the more edges received by each adjacent vertex, the greater the importance or authority of that vertex, which indicates the importance of that comorbidity in a given group of patients.

Results

The results of the collection process are described in Figure 1. 3,823 medical records were collected from the elderly assisted at SRCEHC. 472 medical records were excluded because they were inactive patients at the service (87 discharges, 103 abandonments and 282 deaths). In addition, 378 duplicate records were excluded, thus leaving 2,973 records of patients with active registration, included for the description of this study.

Figure 1. Flow chart of the selection of medical records



The highest percentage of the elderly were aged between 70 to 79 years old (38.9%), were mostly female (71.9%), with a level of education between 1 to 7 years of study (48.9%), color / race declared (36.9%), married (20.8%), resident in the city of Salvador (90.4%). The socio-demographic characteristics of these individuals are shown in Table 1.

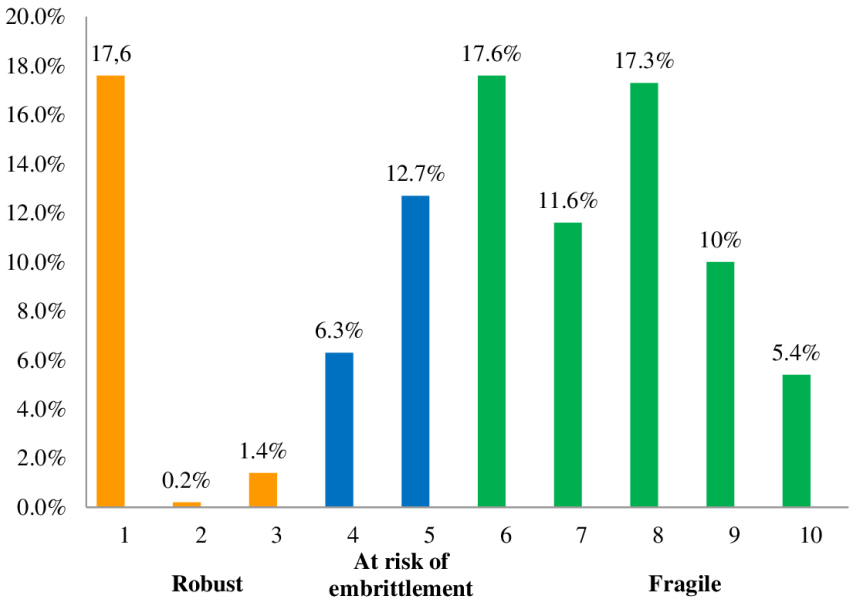
Table 1. Socio-demographic data of the elderly attended at the State Reference Center for Elderly Health Care in Salvador, Bahia

	N	%
Age (n = 2,973)		
60 a 69	649	21,9
70 a 79	1153	38.9
80 a 89	944	31,6
90 a 99	215	7,1
100 or more	12	0,3
Sex (n = 2.973)		
Female	2166	72,9
Male	807	27,1
Education (n = 2.973)		
Illiterate	628	21,1
1 to 7 years	1453	48,9
8 years or more	575	19,3
Unfilled data	317	10,7
Color/Race (n = 2.973)		
Yellow	78	2,6
White	278	9,4
Indigenous	7	0,2
Parda	1098	36,9
Black	332	11,2
Ignored	1180	39,7
Marital Status (n = 2.973)		
Not married	292	9,8
Married	617	20,8
Divorced	63	2,1
Widower	362	12,2
Unfilled data	1639	55,1
City (n = 2.973)		
Salvador	2688	90,4
Interior cities of Bahia	285	9,6

Source: State Reference Center for Elderly Health.

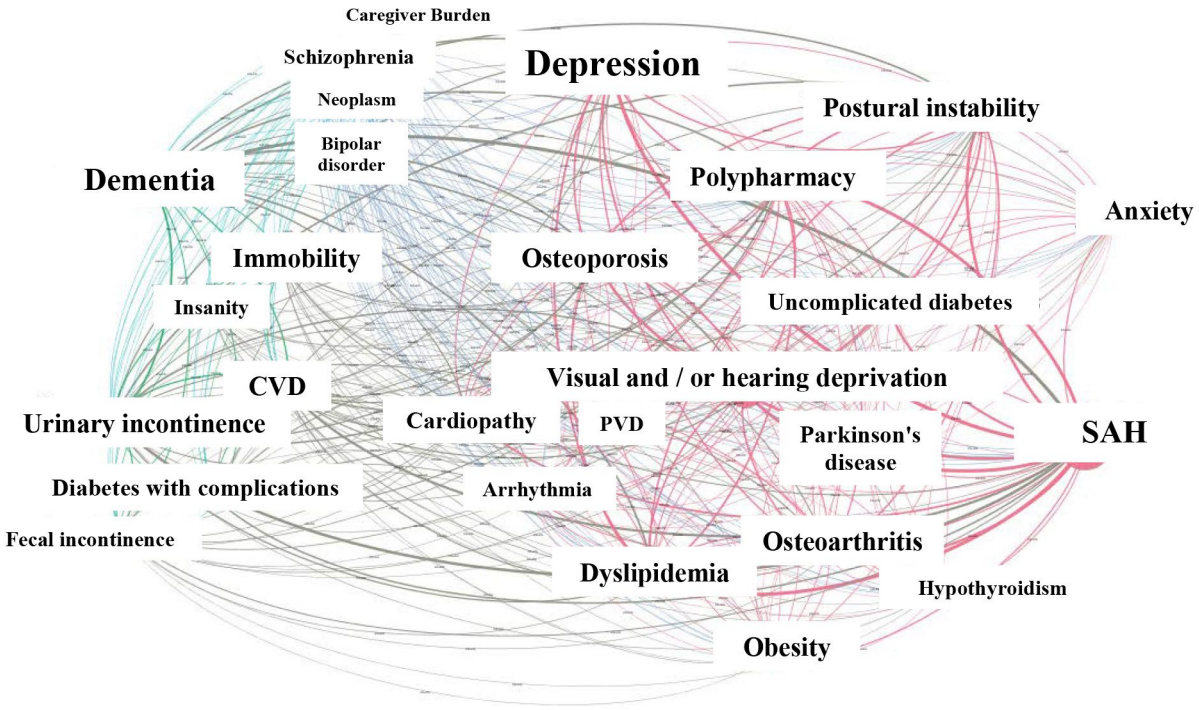
The most prevalent clinical-functional strata were 1 with 17.6%, 6 with the same percentage of 17.6% and 8 with 17.3%. Most of the elderly (61.9%) seen at the service were identified as fragile, at risk of frailty they represented 19% and robust 19.2% of patients (Figure 2).

Figure 2. Clinical-functional stratification of the elderly assisted at the State Reference Center for Elderly Care in Salvador, Bahia



Altogether, the bipartite network comprised 30 nodes with 443 edges that are the links between diseases. The morbidities were grouped into 3 interconnected communities (nodes that are accessible only from nodes in the same network), varying in size and colors (Figure 3). The larger the size of the node in the network, the greater its importance, that is, the more connections there are with that morbidity. And the colors were selected according to the morbidities that are in the same community.

Figure 3. Representation of the disease network according to interconnected communities



Source: State Reference Center for Elderly Health.

The construction of the network also made it possible to detect the most relevant diseases, those with more connections with a higher degree of entry, such as SAH, which is the disease with the greatest relevance with 2,084 connections, followed by depression with 1,063, dementia with 1,043, dyslipidemia with 932 and osteoporosis with 889, as shown in Table 2. Still, the identification of the elderly with a greater predisposition to the emergence of new morbidities, was possible to be analyzed through the measure of connectivity strength, according to the analysis of the PageRrank and Degree of Entry variables (Table 2).

PageRrank also allows the evaluation of the presence of influencers, that is, nodes that have extreme relevance or authority. The five diseases with the highest authority index were ranked from highest to lowest among them SAH, dementia, depression, dyslipidemia and osteoporosis respectively (Table 2).

Table 2. Presentation of PageRrank and Degree of Entry variables

PageRank	Degree of Entry
SAH 0,080077	SAH 2084
Insanity 0,0405	Depression 1063
Depression 0,040417	Insanity 1043
Dyslipidemia 0,030313	Dyslipidemia 932
Osteoporosis 0,029795	Osteoporosis 889

Source: State Reference Center for Elderly Health.

Discussion

Aging makes the individual more susceptible and vulnerable to multiple chronic diseases, functional disabilities, which requires multidisciplinary care, hospital admissions, higher expenses, and challenges health system[18]. By building a complex network, it is possible to understand the behavior and interaction of these diseases in a given population.

The use of networks to model systems is little-used information in the health area, however, it allows representing and understanding problems such as the identification of the most common disease in a specific group, as well as mapping the diseases that are most associated with those individuals.

A network corresponds to a graph, which is represented by a set of vertices (nodes) connected by edges (lines), which establish a relationship with each other, that is, each line has a direction that connects a node to another node[19]. In this network, patients and comorbidities represent nodes and the feeling of connections or edges always leave the patient for the disease, there are never inter-group connections.

The data describe that the elderly assisted at SRCEHC are characterized as women, between 70 and 79 years old, married, brown, with an education level from 1 to 7 years old, and living in the capital of Bahia, Salvador. Despite being a state reference center, the secondary care service serves only 9.6% of elderly people from inner cities and is the only reference for the health of the elderly population in the state.

Aging is associated with the multidimensional fragility process in which there is a reduction in the ability to adapt to biopsychosocial aggressions and, consequently, increases the vulnerability to functional decline and its repercussions. Through the application of the Multidimensional Assessment of the Elderly (MAEP) it is possible to classify the elderly into ten clinical-functional categories[20], which is based on functionality (dependence or independence for activities), in the presence of risk factors, diseases, and comorbidities[20]. In the data analysis, the presence of the majority of elderly people classified as fragile (61.9%) was identified, that is, they presented a functional decline and need more help to carry out activities of daily living[14]. The most prevalent strata in the elderly were 6 and 8, which indicate that the elderly have a partial functional decline in instrumental activities of daily living,

but that they remain independent in basic activities of daily living (BADL); and elderly people who have a total functional decline in instrumental activities of daily living (IADL), as well as semi-dependence on BADL, respectively[14]. Based on this stratification, it is possible to identify and monitor the groups and direct appropriate planning and treatment for each one, especially to the frail elderly who have a high degree of dependence and need greater attention[20].

Systemic arterial hypertension was the health condition that had more connections and greater relevance in the network, being one of the five diseases most present in these individuals (2,084). In Brazil alone, 60.9% of people over 65 years of age have this disease, which is one of the main risk factors for the occurrence of cardiovascular and brain diseases[21]. In 2017, the country recorded 141,878 deaths due to hypertension or causes attributable to it. Despite the high risk of mortality, it is a disease that can often be avoided with healthier lifestyle habits and regular physical exercise[22], making it possible to treat it at the level of primary health care.

The presence of chronic health conditions increases the complexity of clinical management, implying an increased risk of iatrogenesis. Functional decline and frailty are closely related[14]. In addition, the occurrence of one morbidity generally leads to the existence of other successively. As it is a very common underlying disease in the Brazilian population, hypertension usually influences the existence of others, for example, hypertensive individuals use potassium-sparing diuretics, which increase the risk of hydro-electrolyte disorders, which is one of the causes of arrhythmia[23].

This analysis is of fundamental importance for the managers of the place, who can obtain information about the current situation of the patients and, with this, seek effective interventions through services and actions that aim to contribute to the prevention of the main comorbidities presented by these individuals, seeking active aging and healthy, in view of the functional independence and autonomy of the elderly.

This study has some limitations. Initially, because it is an observational study of a transversal type based on the analysis of medical records, which increases the risk of bias in the final result since it is not the same evaluator who fills out all medical records. In addition, as several researchers collected and filled out the database manually, some errors may have gone unnoticed, even with the review of the main researchers.

Conclusion

The mapping of the disease network demonstrated the influence of comorbidities in the care network for the frail elderly at SRCEHC, with SAH, depression, dementia, dyslipidemia, osteoporosis, and visual and/or hearing deprivation as the main influences. In addition, the analysis made it possible to assess the profile of the elderly assisted, characterized by fragile, female individuals who have SAH as their main disease, in addition to two or more comorbidities.

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Author contributions

Silva MFC, Santos CL participated in the conception, design, data collection, search and statistical analysis of the research data, interpretation of results and writing of the scientific article. Santos DOL participated in the conception, design, data collection, search and statistical analysis of the research data. Rattes TSR, Silva AR, Miranda BS, Barbosa JO participated in the design, data collection, search and statistical analysis, interpretation of data and relevant contributions to the writing of the scientific article. Bernardes KO participated in the conception, design, interpretation of results, writing and review of the scientific article.

Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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