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Research Article

Mapping the Intellectual Structure of Chronic Heart Failure: A Co-Word Analysis

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ABSTRACT

Co-word analysis is considered as an important method to explore the network concept in different fields. This technique can reveal the knowledge structure in a given research area. This research attempts to map and analyze the thematic structure of knowledge in "Chronic Heart Failure" studies using co-word analysis. This article employed co-word analysis to map and analyze the conceptual and thematic structure of Chronic Heart Failure. The population comprised 11967 documents (articles, reviews, and proceedings) in "Chronic Heart Failure" during the period of 2000 to 2015, which have been indexed in the Web of Science (WoS). According to the results, the keywords "Cardiac Resynchronization" and "Echocardiography" were the most frequent terms. Moreover, the co-occurrences of "Cardiac Resynchronization Therapy" and "Defibrillators Implantable" have the highest frequency among other pairs. Finally, hierarchical clustering analysis has led to the formation of seven subject clusters in "Chronic Heart Failure" studies. It seems that clusters "Cardiac Function and Its Effective Factors" and "Risk Factors for Heart Diseases" have a high centrality and density in the network structure of "Chronic Heart Failure" studies.

Keywords: Chronic Heart Failure, Co-word analysis, Bibliometrics.

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INTRODUCTION

Medical sciences include very extensive fields, the most important of which is cardiovascular. Although, among developed countries, life expectancy has increased significantly, the cardiovascular complications are rising as a disease,[1] and with the growth of cardiovascular diseases, research and innovation has been also grown.[2]

Cardiovascular diseases have become one of the prime causes of death in the developed countries.[3] They are the leading cause of death in the world and a major barrier to sustainable human development.[4] A number of changes over the past 3 decades have made cardiovascular disease (CVD) increasingly important, especially for a developed country like Canada. Firstly, while smoking has prevalenced as one of the leading causes of CVD and it has decreased over the past 3 decades, the obesity rate has increased dramatically. Secondly, the populations in the developed countries are aging rapidly, leading to a growing burden of chronic diseases including CVD. Thirdly, the medical technologies have expanded rapidly, especially in the diagnosis and treatment of CVD. All these changes have implications for the burden as well as the treatment of CVD.[5]

Although life expectancy has increased significantly in many nations, cardiovascular morbidity is growing as the population ages. Therefore, despite decreased acute mortality rates, CVD presents a high burden of disease.[2] Accordingly and in a wide scope, the research and innovation in CVD, and specifically, Chronic Heart Failure, is of great importance for society.

Scientometric studies have attracted the attention of several researchers in different disciplines.[6] Considering the rapid development of Chronic Heart Failure, a comprehensive macro image of research on Chronic Heart Failure should be drawn, and its scientific development needs to be explored. The study on the knowledge structure of technical and scientific fields is possible through various techniques and approaches.[7] One of the techniques employed for analyzing the knowledge structure of diverse fields is "co-word" analysis.[8] By examining and analyzing the keywords co-occurrence noted in the artcles of a specific research field, one can obtain an image of the actual content of the topics in that research field with no intermediate.[9] The co-word analysis is one of the methods used to identify research topics and inter-subject relationships.[10] It allows us to reveal the emerging trends and changes made in paradigms in order to predict the future research path.[11] This technique has been widely developed to draw the concepts' relationships.[12] It enables the researchers

to find research fronts and hot topics, because the keywords used in a research are considered as the subject of that research. In such cases, when drawing a co-word network, each node represents a word, and the larger the size of that node, the greater the co-occurrence of it with other nodes.[13] Three techniques namely hierarchical cluster analysis (HCA), two-dimensional Scaling, and strategic diagram are among frequent methods used in co-word analysis. Briefly, hierarchical cluster analysis (HCA) is a technique to group similar observations into a number of clusters based on the observed values of several variables for each individual.[14] It is an intuitive way to perform data clustering when the number of clusters is unknown as *a priori*. Each leaf corresponds to an observation and the branching reflects the relation between clusters.[15] "Two-dimensional Scaling is a technique to represent dissimilarities among *n* objects in a two-dimensional space so that the inter-point distances can best approximate the observed dissimilarities between pairs of objects".[16] A strategic diagram is mostly used to describe the internal relations within a cluster, as well as the interactions among different fields. Strategic diagram considers both centrality and density, and thus it can also describe the dynamics of research themes.[17]

With regard to the above, this study attempts to explore the thematic structure of knowledge in "Chronic Heart Failure" by co-word analysis. To achieve this goal, this study attempts to answer the following research questions:

RQ1. What are the most frequent keywords in "Chronic Heart Failure" studies?

RQ2. What are the most prominent thematic clusters in "Chronic Heart Failure" studies?

RQ3. What is the status of the multidimensional scaling network in "Chronic Heart Failure" studies?

RQ4. How are thematic clusters of "Chronic Heart Failure" studies represented by the strategic diagram in terms of maturity and development?

The results of co-word analysis in Chronic Heart Failure can help medical librarians and clinicians to gain a comprehensive understanding of the key concepts of this area. In other words, they will become familiar with the topics of interest and prevailing concepts of researchers in this field. Moreover, according to the results of this study, medical librarians and clinicians are well aware of the relationship between the keywords in the Chronic Heart Failure. Armed with such information, medical librarians and clinicians can better consult with cardiovascular researchers and consequently, meet their information needs efficiently.

The extent of bibliometric research in cardiovascular research has been the subject of several studies. For instance, Gal, Thijs, Glänzel and Sipido (2018) indicated that only 50% cardiovascular research were published in core cardiovascular journals, such as the Journal of the American College of Cardiology, whereas one-half of cardiovascular publications were found in broader biomedical/multidisciplinary journals.[18] Nicolau *et al*. (2013) provided insights from Cardiovascular clinical research in South American countries. They believe that "there are many opportunities to improve the conduct of clinical research in South America, but strategies and systems must be developed to overcome barriers in this economically growing region and to establish a robust infrastructure for clinical trials, including high-quality investigator networks".[1]

Bolaños-Pizarro *et al*. (2010) presented a bibliometric analysis of cardiovascular research in Spain and concluded that Spain holds a stable leading position in the world ranking of most productive countries in the field.[3] Colantonio, Baldridge, Huffman, Bloomfield and Prabhakaran (2015) explored trends in cardiovascular publications and their citations from countries in Latin America between 1999 and 2008. They indicated that cardiovascular publications of Latin America increased by 12.9% annually. Brazil had the highest number of publications, followed by Argentina and Mexico.[19] Jia, Guo, Li, An and Zhao (2013) investigated the characteristics and popular topics of research into the effects of air particulate matter on cardiovascular system by bibliometric analysis. Their study led to the identification of six popular topics in the field.[20]

Through a bibliometric study, Bloomfield *et al*. (2015) evaluated the cardiovascular research output and citations of publications from 52 African countries. They found that the number of publications increased over the time for a small number of countries. Most countries' citations were low.[21] Thorough a case study on cardiovascular medicine, McAlister, Lawson, Good and Armstrong (2011) uncovered that judging the worth of research is more complicated than merely counting citations. They concluded that university evaluation and promotion committees, funding bodies, and other stakeholders should consider the multiple indicators of research impact outlined above in assessing merit.[22] Baldridge, Huffman, Bloomfield and Prabhakaran (2014) focused on the time trends in cardiovascular research publications and found increasing trends in collaboration and citation in both general and specialty journals.[23]

Focusing on the abstracts submitted to the European Society of Cardiology Congress, Winnik *et al*. (2013) investigated the factors predicting publication and citation in cardiovascular research. They found that research with high quality was determined by study design and largely identified at Congress level through blinded peer review.[24] Gal *et al*. (2016) explored the world-wide participation and citation impact across the cardiovascular research landscape from 1992 to 2012. They indicated that participation in cardiovascular research is growing but the growth and impact show wide variability

between countries.[2] Ettarh (2016) studied the patterns of international collaboration in cardiovascular research in sub-Saharan Africa and found that pro-active strategies are needed to strengthen collaboration in cardiovascular research across sub-Saharan Africa for the region to derive health and socio-economic benefits from locally conducted research.[25]

Thorough a survey methodology, Mai, Agan, Clopton, Collins and DeMaria (2013) revealed that considerable published cardiovascular research is currently being conducted without direct financial support. This is particularly true for young clinical investigators.[26] Thorough a bibliometric analysis, Winnik *et al*. (2012) showed that cardiovascular researchers in less wealthy countries face challenges to disseminate their research, even after accounting for potential differences in the quality of their work and research infra-structure.[27] Yu, Shao, He, and Duan (2013) investigated the collaboration behaviors across multiple collaboration types in the Coronary heart disease research. They indicated that collaborations have increased at the author, institution and country/region levels in Coronary heart disease research over the past three decades.[28] Huffman *et al*. (2013) performed a time trends analysis of global cardiovascular research output, citations, and collaborations. They indicated that Global cardiovascular publication volume represents a 36% increase.[29]

Considering the literature mentioned above, most of the bibliometric studies in cardiovascular research focused on the publication outputs, citation rates, and collaborations; however, no study was found about conducting co-word analysis on cardiovascular area, generally, and Chronic Heart Failure, specifically. Therefore, the concern about lack of sufficient study on the structure of knowledge in Chronic Heart Failure led the authors to the current study through mapping the keywords used in publications.

MATERIALS AND METHODS

This paper employs both co-word and social networking analysis. In bibliometric studies, the selection of the initial research data is of great importance and these data have a direct effect on the findings and results. For this reason, it is better that the first records have better comprehensiveness and integrity. Referring to this fact, the statistical population of this study is all keywords provided by the authors in documents (articles, reviews, and proceedings) on the subject of "Chronic Heart Failure" during the period 2000 to 2015, which have been indexed in the Web of Science in the category of "Cardiac and Cardiovascular Systems". For this purpose, the following search strategy was used which resulted in the retrieval of 11967 documents (articles, reviews, and proceedings). (WC=Cardiac and Cardiovascular Systems) AND (TS=(chronic AND heart failure AND (cardiac OR heart OR cardiovascular OR heart attack))

It should be noted that this search strategy has already been used by Nguyen *et al*. (2013).[5] After recovering records related to Chronic Heart Failure, for performing the co-word analysis, at the first stage, the keywords related to 11967 records were extracted using BibExcel software. Totally, the preliminary analysis showed that out of 11967 records in this study, 9341 cases had keywords, for this reason, the co-word study was limited to these records.

At this phase of the research, all the keywords contained in these documents were extracted. The results showed that a total of 10,669 unique keywords were repeated 41,786 times, on average, each article has contained almost 4 keywords. At the next stage, these keywords need to be reviewed and edited carefully. Because some words or phrases may be written in different forms or be synonyms. In this part of the work, the keywords were given to the experts of this field and after obtaining their comments, the researchers tried to edit, modify, remove and integrate the keywords. At the next phase, after taking several examinations and tests, 109 keywords with a frequency of more than 50 are chosen as the research sample for co-word analysis. It should be noted, in various studies carried out by using the co-word analysis, various thresholds have been used to include the top keywords in the final analysis. For example, Liu, Hu, and Wang (2012) limited their analysis to 66 repeated keywords. It accounted for about 55% of the total frequency,[30] and Hu, Hu, Deng, and Liu (2013) also limited their final analysis to 181 keywords, which represented 29% of the total frequency.[31]

By setting the threshold on the keywords with a frequency of 50 up, there were 109 keywords in this range, the total frequency of which is 11,405 times and accounted for over 27.3% of the total keywords' frequency which has the potential to provide the main content of research in the field of Chronic Cardiovascular Failure.After detemining the amount of the keywords' co-occurrences, a square matrix comprising 109 frequently repeated keywords was created by BibExcel, one in which the values related to the diagonal cells was 0 and the number in the other cells is the number of co-occurrence of the two keywords in the row and culumn intersect each other. Investigations show that using square correlation matrix in the co-word analysis results in better and more realistic results;[31] for this reason, and in this section of the study, using UCINET software, the square matrix became a correlation matrix.

In order to perform the co-word analysis, hierarchical clustering and multi-dimensional scaling are usually used. Hierarchical clustering has the ability to specify clusters for each of the keywords and show the relationships between them. For this reason, hierarchical clustering was performed using the SPSS and each cluster was visualized by using the VOSviewer software. Also, according to the degree of

correlation, the maps made by using the multi-dimensional scaling can reveal the important clusters and their position among the other clusters.[31] Hence, a multi-dimensional map was prepared by using UCINET.

In addition, it is possible to analyze the characteristics of the co-word matrix network, such as centrality and density, with UCINET to obtain more information about the co-word structure dominating the study area. In a network, if the node has a large amount of links with others, it has a higher centrality and lies in an essential position in the network. Centrality is therefore used to measure the correlation degree among different topics. Similarly, a higher density means higher cohesiveness or equals the higher internal correlation degree among nodes. The density of a research field represents its capability to maintain and develop itself. To sum up, the higher the centrality is, the more central the research topic is in the whole research field; and the higher the density is, the more mature or potential the research topic is.[31]

Therefore, a strategic diagram based on centrality and density of each topics cluster would be drawn in order to indicate the status and evolutionary trends of Chronic Heart Failure. In a strategic diagram, the x-axis represents the centrality of the rating and the y-axis represents the density. The strategic diagram can be represented in the form of four sections, each of which has a different centrality and density, and the clusters in that section are in a different state. More precisely, the clusters that appear in the first section have a high centrality and density, they are both mature (well-developed) and placed at the center of the study area. The clusters that are in the second section are not central, but they are well-developed. The clusters of the third section are marginal and attracted little attention. These clusters are emerging or declining themes.[32,33] And finally, the thematic clusters in the fourth section, although central, are undeveloped or immature. They can be considered as basic and transversal themes.[31]

At the last phase, and regarding the above mentioned cases and the importance of drawing the strategic diagram in the co-word analysis for each cluster, based on the number of keywords, a square matrix and then the correlation were created, then for each of the correlation matrices a centrality and density were calculated, and finally, a strategic diagram was drawn.

RESULTS

The Most Frequent Keywords in "Chronic Heart Failure" Studies

Table 1 shows top twenty keywords in Chronic Heart Failure research. As it is evident, the keyword "Cardiac Resynchronization Therapy" with 514 repetitions has had the highest frequency among all the keywords. "Echocardiography" and "Mortality" are also ranked second and third with a frequency of 401, and 394, respectively. Also, the network structure of the high-frequency keywords is shown in Figure 1.

Table 1: Top 20 keywords in Chronic Heart Failure research based on their frequencies.

Rank	Keyword	Frequency
1	Cardiac Resynchronization Therapy	514
2	Echocardiography	401
3	Mortality	394
4	Myocardial Infarction	389
5	Atrial Fibrillation	344
6	Congestive Heart Failure	290
7	Cardiomyopathies	257
8	Remodeling	203
9	Hypertension	201
10	Natriuretic Peptides	201
11	Pacemaker, Artificial	183
12	Defibrillators, Implantable	173
13	Chronic Kidney Disease	172
14	Hypertension, Pulmonary	171
15	Cardiomyopathy, Dilated	168
16	Hypertrophy	159
17	Coronary Artery Disease	157
18	Arrhythmias, Cardiac	142
19	Cytokines	137
20	Oxidative Stress	133

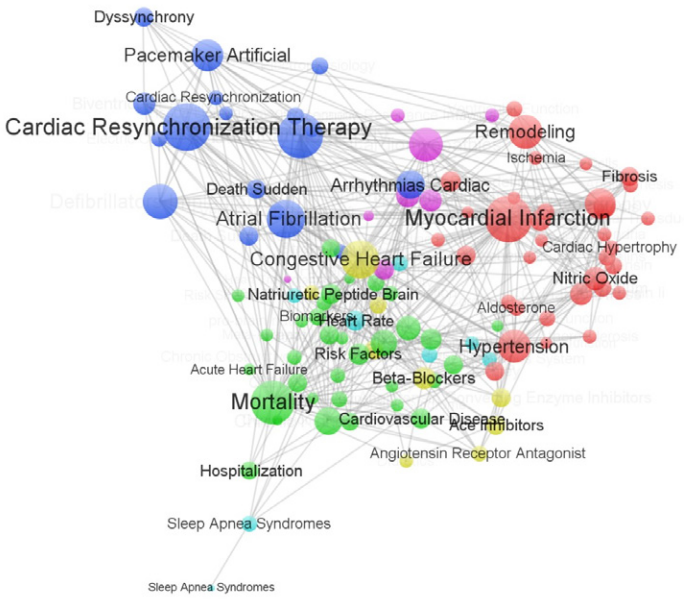

Figure 1: The network structure of high-frequent keywords in Chronic Heart Failure.

After determining the threshold for the inclusion of keywords in the co-word analysis, the amount of the coincidence of the keywords or the co-word was obtained. At this stage, the

Table 2: The frequency distribution of 20 Top co-word pairs.

Rank	Co-word pairs	Frequency
1	Cardiac Resynchronization Therapy***Defibrillators Implantable	60
2	Cardiac Resynchronization Therapy***Echocardiography	44
3	Hospitalization***Mortality	41
4	Biventricular Pacing***Cardiac Resynchronization Therapy	41
5	Myocardial Infarction***Remodeling	35
6	Echocardiography***Pacemaker Artificial	34
7	Cardiac Resynchronization Therapy***Pacemaker Artificial	30
8	Cardiac Resynchronization Therapy***Dyssynchrony	28
9	Cardiac Resynchronization Therapy***Mortality	27
10	Atrial Fibrillation***Mortality	26
11	Cardiomyopathies***Echocardiography	25
12	Cardiac Resynchronization Therapy***Congestive Heart Failure	25
13	Defibrillators Implantable***Mortality	24
14	Myocardial Infarction***Stem Cells	23
15	Hypertrophy***Remodeling	22
16	Atrial Fibrillation***Cardiac Resynchronization Therapy	21
17	Death Sudden Cardiac***Defibrillators Implantable	21
18	Cardiac Rehabilitation***Exercise Training	20
19	Dyssynchrony***Echocardiography	20
20	Echocardiography***Tissue Doppler Imaging	19

repeated keywords were obtained with all the keywords in the papers. Table 2 indicates the frequency distribution of 20 highly frequent co-word pairs.

As it can be seen in Table 2, the coincidence between the two keywords, "Cardiac Resynchronization Therapy***Implantable Defibrillators" has had the most frequency in Chronic Heart Failure studies. And two pairs "Cardiac Resynchronization Therapy *** Echocardiography" and "Hospitalization *** Mortality" ranked second and third.

For a better depiction of the knowledge structure in Chronic Heart Failure, the results of hierarchical clustering, multi-dimensional scaling, and strategic diagram are presented below.

Prominent Thematic Clusters in "Chronic Heart Failure" Studies

Among the multivariate statistical methods, hierarchical clustering phases were first performed. More precisely, the correlation matrix derived on the basis of the matrix of the co-word frequency was transferred to the SPSS. Using the

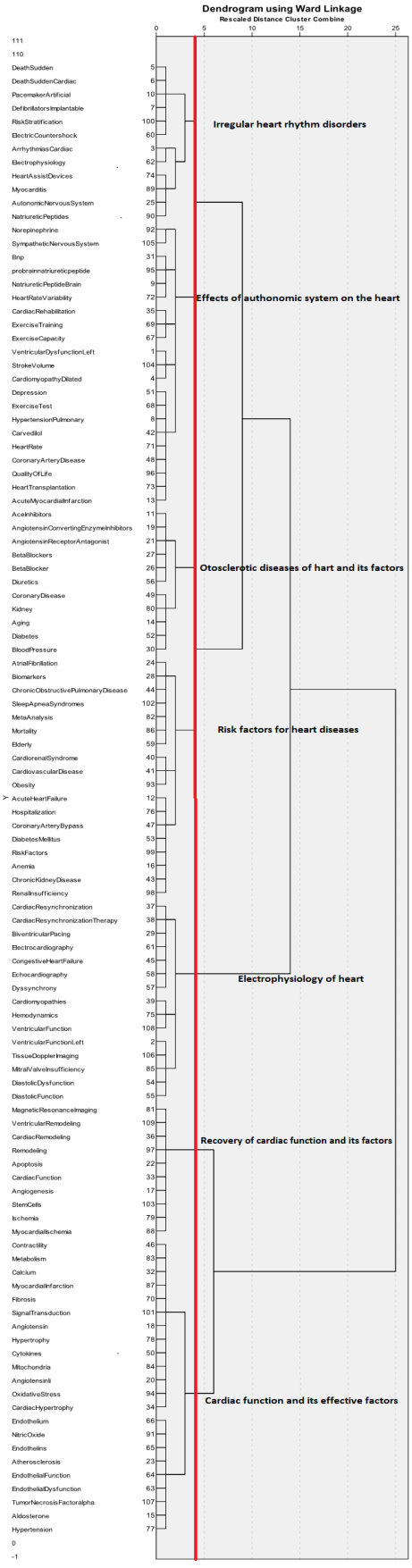

Figure 2: The dendrograms derived from the hierarchical clustering by the co-word method.

hierarchical clustering and employing Ward's method, the dendrogram designed. It should be noted that Ward's method has been used in several co-word studies for hierarchical clustering analysis.[34,35]

The dendrogram obtained from the hierarchical clustering is shown in Figure 2. As it is clear in the dendrogram, the analysis of the results for the co-word analysis has led to the formation of seven thematic clusters. The keywords in each cluster and the topic for that cluster can be seen in the given dredrogram. Of course, it is necessary to note that in some clusters, in addition to the main and important keywords, there are sometimes keywords that seem to have no direct semantic relationship with the topic of that cluster; such a case is common in the co-word analysis because the mentioned keywords have attracted little attention from the researchers, and in terms of the frequency of the co-word as well as the correlation coefficient as compared with other keywords of that cluster, they are less effective.[31]

Cluster 1: Irregular heart rhythm disorders. The results of the co-word analysis showed that 12 keywords played a role in the formation of this cluster. The keywords of the cluster, (such as "Implantable Defibrillator", "Electric Countershock", "Arrhythmias Cardiac", "Death Sudden", and "Risk Stratification") suggest that its theme can be linked to the irregular heart rhythm disorders.

Cluster 2: The effects of the autonomic system on heart. This cluster consists of 21 keywords. The most important keywords in this cluster include "Exercise Training", "Exercise Capacity", "Quality Of Life", "Coronary Artery Disease", "Heart Rate", and "Natriuretic Peptide Brain = BNP".

Cluster 3: Otosclerotic diseases of the heart and its factors. Keywords such as "Angiotensin converting enzyme", "Beta-Blowkers", "Ace inhibitors", and "Diuretics" illustrates that this cluster belongs to the topics discussed in the field of Etosclerotic heart disease.

Cluster 4: Risk Factors for Heart Disease. This cluster consists of 18 keywords. The presence of keywords such as "Mortality", "Chronic Kidney Disease", and "Atrial Fibrillation" shows the subject of this cluster well.

Cluster 5: Cardiac Electrophysiology. This cluster consists of 15 keywords. The most important keywords in this cluster include "Echocardiography", "Cardiac Resynchonization", 'Congestive Heart Failure", and "Cardiomyopathies", which shows that the structure of the keywords' network in this cluster is Figure 3.

Cluster 6: Recovery of cardiac function and its factors: This cluster also consists of 10 keywords. "Angiogenesis", "Remodeling", "Apoptosis", "Stern Cells" and "Ischemia" are among the important keywords of this cluster.

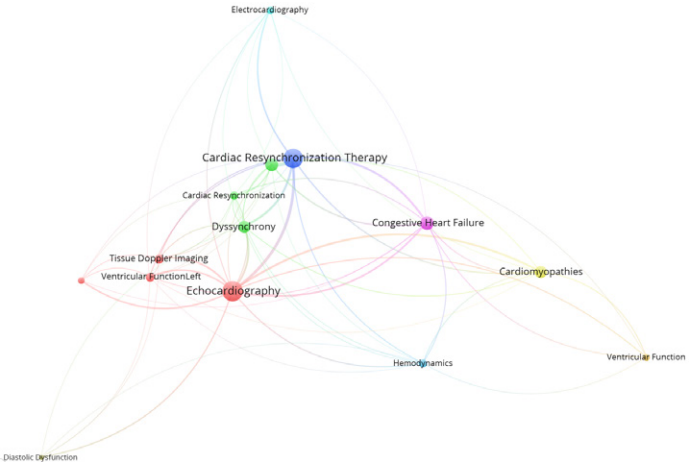

Figure 3: The structure of the keywords' network in the cluster 5 based on the density view.

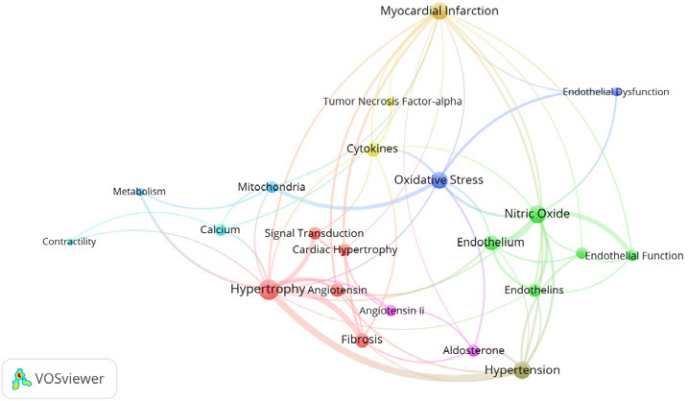

Figure 4: The structure of the keywords› network in the cluster 7 based on the density view.

Cluster 7: Cardiac function and its effective factors. As a biggest cluster in Chronic Heart Failure, this cluster consists of 22 keywords, and "Hypertrophy Angiotensin", "Nitric Oxide", 'Oxidative Stress", "Hypertension", "Endothelium", and "Fibrosis" are among the important keywords in this cluster. The structure of the keywords' network in this cluster is shown in Figure 4.

Multidimensional Scaling Network in "Chronic Heart Failure" Studies

In this section of the study, multidimensional scale method was used to obtain a more comprehensive and better insight into the structure of subjects in Chronic Heart Failure research. For this purpose, from each of the seven clusters, two keywords with the highest frequency of the co-word were selected as the representative of that cluster, and then a quadrant square matrix was created for it. At the next phase , using UCINET, a correlation matrix was created from this matrix. Then the corresponding file was imported into the

software UCINET and the two-dimensional map of the subjects of the Chronic Heart Failure was drawn (Figure 5).

As shown in Figure 5, the use of the multidimensional scaling method has led to the integration of some clusters based on the position and distance of the keywords from each other. So that the seven primary clusters can be reduced to more general clusters.

The horizontal axis (the first dimension) in the two-dimensional map represents the degree of internal correlations of each thematic cluster, and the vertical axis (the second dimension) represents the emphasis of the subject clusters. According to the map, it is found that using this analysis, 3 clusters have been formed, which according to the concepts contained in each of them the following subjects can be assigned:

Cluster 1: Cardiac muscle disease and its effective factors;

Cluster 2: Blood pressure, medications and factors affecting it; and

Cluster 3: Rhythmic diseases of the heart and its effective factors.

Status of Clusters in the Strategic Diagram

In this section, a strategic diagram was drawn based on the network's centrality and density. To be more precise, for each of the 7 clusters, a frequency matrix, and then a correlation matrix were created. The centrality and density of each cluster was then calculated using UCINET. The mean value of each cluster was measured. At the next stage, based on the data on the centrality and density of each of the seven clusters (Table 3), we developed a strategic diagram to determine the maturity and development of each subject. As Table 3, the clusters 5, 4, and 7 have the highest density, respectively, and the clusters 7, 4, and 2 have the highest centrality, respectively.

Figure 6 shows the strategic diagram of the clusters derived from the co-word analysis in the field of Chronic Heart Failure. It should be noted that the origin of the chart was adjusted according to the mean centrality and density of clusters, respectively, on 968.72 and 0.457.

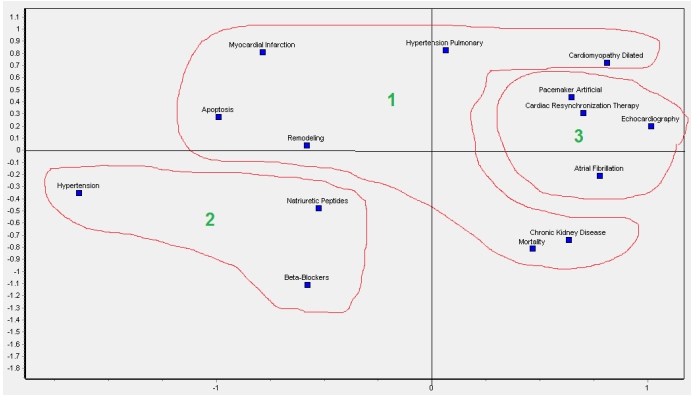

Figure 5: Two-dimensional map derived from co-word analysis of Chronic Heart Failure research.

Table 3: Centrality and density of the clusters resulted from the co-word analysis.

Cluster	Centrality	Density
1: Irregular heart rhythm disorders	305.15	.423
2: The autonomic system effects on the heart	1201.16	.363
3: Otosclerotic diseases of the heart and its factors	153.85	.364
4: Risk Factors for Heart Disease	1534.21	.537
5: Cardiac Electrophysiology	873.59	.538
6: Recovery of cardiac function and its factors	180.53	.468
7: Cardiac function and its effective factors	2532.54	.504

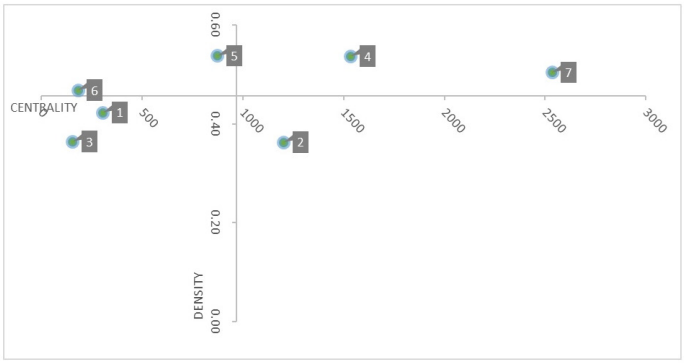

Figure 6: The strategic diagram of the clusters derived from the co-word analysis.

As we know, the horizontal axis in the strategic diagram shows the centrality and determines the power of interaction of each of the clusters in the studied field. The more the centrality of a cluster, the cluster has a more important and central position. On the other hand, the vertical axis is an indicator of the density and indicates the inner relationship in a particular research field. The higher the density of a cluster, the greater the cluster will have the potential to maintain and develop itself.[32]

As shown in Figure 6, two clusters 7 (heart function and its effective factors) and 4 (risk factors for heart disease) are identified in the 1st quarter of the Strategic Chart. These clusters have a high centrality and density, and, in addition to playing a central role, they are well-developed. Also, the clusters 5 (heart electrophysiology) and 6 (recovery of cardiac function and its factors) are in 2nd quarter. The mentioned clusters are not central, but they are well developed. The two clusters 1 (irregular heart rhythm disorders) and 3 (otosclerotic diseases of the heart and its factors) are in the 3rd quarter of the strategic diagram. The mentioned clusters, low in terms of both centrality density compared to other clusters, are marginal and neglected. These two clusters are among emerging or declining themes in Chronic Heart Failure research. And

finally, the cluster 2 (the effects of the autonomic system on the heart) is in the 4th quarter of the diagram; in general, the clusters that are in the 4th quarter of the strategic diagram are central, but remained underdeveloped.

DISCUSSION

The growth in cardiovascular research reflects major activity, in line with the societal burden of cardiovascular disease. Ensuring that the investment in cardiovascular research results in improved cardiovascular health remains a challenge.[18] During the last decades, cardiac diseases have been one of the three major causes of mortality in the world. Preventive methods such as hypertension management, cessation of smoking, and technological advances (e.g. invasive re-vascularization) have decreased sudden death and mortality rate from acute heart diseases such as myocardial infarction. As a result, Chronic Heart Failure has increased significantly due to increased life span and acute phase transition. This study has thus made an attempt to understand the intellectual structure of knowledge in Chronic Heart Failure by performing co-word analysis on Chronic Heart Failure studies.

Results indicated that the keywords "Cardiac Resynchronization", "Echocardiography" and "Mortality", with the highest frequency, are top keywords in this reserch area. Also in terms of the co-word pairs, "Cardiac Resynchronization Therapy *** Defibrillators Implantable", "Cardiac Resynchronization Therapy *** Echocardiography" and "Hospitalization *** Mortality" have been repeated more than other pairs and ranked first to third, respectively.

The pairing of these words are because of their common purposes or function. For instance, "Implantable Defibrillators" are devices used to treat "Cardiac Resynchronization Therapy (CRT)" or the relationship between "Echocardiography" with "Cardiac Resynchronization Therapy" is more because of its role for monitoring the management of dysrhythmia.

The use of hierarchical clustering led to the formation of seven thematic clusters named "irregular heart rhythm disorders", "effects of autonomic system on the heart", "otosclerotic diseases of heart and its factors", "risk factors for heart diseases", "electrophysiology of the heart", "recovery of cardiac function and its factors" and "cardiac function and its effective factors".

A map derived from the use of multidimensional scaling showed that 7 clusters have been integrated and become three broad clusters of "heart muscle diseases and its effective factors", "blood pressure and medications and factors affecting it", and "heart rhythmic diseases and the factors influencing it".

Results of strategic diagram uncovered that the two clusters "cardiac function and its effective factors (Cluster 7)" and "risk factors for heart diseases (Cluster 4)" are two most central subject areas in Chronic Heart Failure studies, and that they are well-developed. This means that these clusters are located in the center of the co-word network of Chronic Heart Failure. In other words, these two clusters are one of the most important issues in the field of cardiovascular diseases, on which most researchers have studied. Regarding to the cardiac physiology and the risk factors for cardiovascular disease, approach to cardiac diseases is very important. Pharmaceutical, relatively invasive procedures (e.g., implantable pacemakers and cardiac resynchronization therapy (CRT)) and new generation treatments such as the use of stem cells in cardiac disease are potential fields for research.

The high centrality of these clusters (at the research network center) suggests that the mentioned clusters in the generic network of studies on Chronic Heart Failure play a central role and have a strong and extensive relationship with other clusters. There is a close relationship between cardiac function, the factors affecting on cardiac function and the risk factors, clusters 4 and 7, with other effective factors found in other clusters.

As mentioned above, at first step, 7 clusters and finally 3 clusters were obtained. Because of the overlapping divisions, it was difficult to isolate and insert each of them under the certain clusters, indicating a strong inter-cluster relationship. Also the density of these clusters confirms the fact that they have strong internal relationships and their development and maturity rate is appropriate. In general, and according to the results from the first section of the strategic chart, it can be stated that the core of the research on Chronic Heart Failure has focused on the clusters 4 and 7.

CONCLUSION

Librarians, clinicians, and policy-makers of science and technology can identify the main thematic clusters with high centrality, at various time intervals (e.g., every two years), and acquaint researchers with these clusters. Moreover, they can uncover the emerging concepts (which are in the fourth quarter of the strategic diagram) and familiarize researchers and library patrons with the emerging concepts of the study area.

It is recommended that emerging areas identified in this study will be addressed by researchers in the field of Chronic Heart Failure and put them among the research priorities of this area. Regarding the capabilities of the scientometric studies, performing other techniques such as citation analysis, document co-citation analysis, author co-citation analysis, journal co-citation analysis, and the like, can provide an illustrative image of Chronic Heart Failure research.

To strengthen the lexical network and the proper analysis of the network, it is suggested to use the MeSH (Medical

Subject Headings) instead of author keywords within articles. This can improve the harmonization of terms, better network analysis conditions, and provide accurate strategies for conducting co-word analysis.

Some items might have limited the findings of this research. Since there are other bibliographic databases in medicine (such as PubMed), using records from Web of Science may limit the study's results. Although many scientometric studies use records indexed in the Web of Science, but the limited coverage of Web of Science in the medical areas may affect the results. However, according to the search strategy used to obtain preliminary records, it was tried to include the most appropriate records in the analysis process as much as possible. In addition, although the journals indexed in Web of Science are international in nature, less non-English articles are indexed in this database, and this can limit results as well. That is why it is suggested that in a follow-up study, the structure of Chronic Heart Failure research to be conducted in the non-English-speaking world. Furthermore, it is suggested to use the words of the entire text in order to use co-word analysis and to compare the results with the results of the current research.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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