Nanomed Res J 4(2):101-110, Spring 2019

RESEARCH ARTICLE

Intellectual structure of knowledge in Nanomedicine field (2009 to 2018): A Co-Word Analysis

Fatemah Makkizadeh*

Department of Information Science and Knowledge Studies Faculty of Social Sciences, Yazd University, Yazd, Iran

ARTICLE INFO

Article History:
Received 05 April 2019
Accepted 03 June 2019
Published 15 June 2019

Keywords:
Co-Word Analysis
Intellectual Structure
Nanomedicine

ABSTRACT

Introduction: The Co-word analysis has the ability to identify the intellectual structure of knowledge in a research domain and reveal its subsurface research aspects.

Objective(s): This study examines the intellectual structure of knowledge in the field of nanomedicine during the period of 2009 to 2018 by using Co-word analysis.

Methods: This paper develops a scientometric approach about nanomedicine over a data set of 2,798 documents published over a period of 10 years (2009–2018) on PubMed databases. The data was analyzed using co-word, clustering methods and strategic diagram assisted by SPSS, Ucinet, and VOSviewer software.

Results: The top journal that published papers on the field was Nanomedicine (London, England). The results showed that the keyword "nanoparticles" and two pairs of frequently-used keywords namely "Drug delivery systems * Nanoparticles" were the most frequent in the field of nanomedicine. Application of hierarchical clustering led to the formation of 9 clusters. "Drug Delivery System (emphasis on cancer)" is the core cluster and plays an effective role. The other clusters like "Nano diagnostic", "Drug design" and "Renovated Medicine" are in marginal.

Conclusions: This study represented that Co-Word analysis can well illustrate the intellectual structure of an area. The frequency of keywords as well as formed clusters demonstrate that the majority of research approaches include Pharmaceutical Nanotechnology. Despite the importance of other aspects as well as Nanosafety/ nanotoxicology and new medical products and equipment such as nanorobots have not been considered.

How to cite this article
Makkizadeh F. Intellectual structure of knowledge in Nanomedicine field (2009 to 2018): A Co-Word Analysis. Nanomed Res J, 2019; 4(2): 101-110. DOI: 10.22034/nmrj.2019.02.007

INTRODUCTION

"Nanotechnology is the study and application of extremely small materials and it can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering. Within the last decade, nanotechnology has changed and influenced considerably every fields of science" [1]. Advancement in the field of nanotechnology and its applications to the field of medicine and pharmaceutical have revolutionized the twentieth century. "The convergence of nanotechnology and medicine has led to the interdisciplinary field of nanomedicine. Advances in genetics, proteomics, molecular and cellular biology, material science, and bioengineering have all contributed to this developing field, which deals with physiological processes on the nanoscale level" [1].

"The use of nanotechnology in the field of medicine could revolutionize the way we detect and treat damage to the human body and diseases in the future, and many techniques only imagined a few years ago are making remarkable progress towards becoming realities. Nanomedicine exploits the improved and often novel physical, chemical, and biological properties of materials at the nanometric scale. Nanomedicine has potential impacts on prevention, early and reliable diagnosis as well as treatment of diseases" [2].

* Corresponding Author Email: *makkizadeh@yazd.ac.ir*

"Nanomedical devices can be applied for analytical, imaging, detection, diagnostic and therapeutic purposes and procedures, such as targeting cancer, drug delivery, improving cell-material interactions, scaffolds for tissue engineering, gene delivery systems, and providing innovative opportunities in the fight against incurable diseases"[3].

Many experts agree that nanomedicine will create a paradigm shift which could revolutionize health care within the next 10 years. Surely, it takes several decades to develop, however, for significant progress to be made toward this goal, much more work needs to be done to establish testing criteria, validate efficacy, and accumulate safety data for various nanotherapeutic agents and materials [1].

Therefore, in order for the researchers to make the studies meaningful and well-informed; a comprehensive overview of research should be done on nanomaterials, while its scientific development should be investigated. It means that, the study of scientific production in the field of Nanomedicine can influence policy `making and scientific development. In this paper, it has been attempted to visualize the scientific profiles of nanomedicine. The article also studies the main topics in researches and reviews thematic relations using co-word analysis method. This type of analysis can help us discover concepts which are dominant in the works [4], unveil trends in a certain sphere [5], find hidden relations in one area of science, promote a concept during a specific period [6].

Concepts scrutinized in this study are in fact keywords which exist on the PubMed database in researches on nanomedicine. Each keyword in the investigated texts will be considered as a variable which is calculated through a co-occurrence matrix of each variable (keyword) with other variables (other keywords). Based on such calculation, the variables are divided into different axes in nanomedicine area through clustering technique. Considering the function of co-word analysis, the current study can scientifically delimit the intellectual structure which governs the nanomedicine area.

A review of literatures on co-word analysis and topic clustering shows that various researches have considered this topic in various aspects and have examined various fields of science through this method, including social media [7], bioenergy [8], scientometrics [9], nanotechnology [10], infertility [11], integrative and complementary medicine [12], anticancer [13], business [14], tourism and sustainability [15], complementary medicine [16], and information behavior [17]. Reviewing background shows the intellectual structure of knowledge and its research front can be identified by the co-word analysis.

This study attempts to reveal the intellectual structure of knowledge in nanomedicine and provides an updated, complete picture of research in this field.. It is derived from PubMed during 2009-2018 via co-word, network analysis, and scientific visualization tools. Furthermore, journals and the countries that published Information Resources in nanomedicine field were introduced.

MATERIALS AND METHODS

This study used co-word analysis and social networking analysis. The items under study were taken from the PubMed database (www.ncbi.nlm.nih.gov/pubmed). PubMed was chosen because it is one of the best-accepted and the most widely used database in medicine. The search for included the articles was done in December 2018. The research was restricted to nanomedicine [MH], journal article [PT] and 2009:2018 [DP]". After retrieving data, bibliometric methods were initially applied to analyze the distribution of the publishing years, keywords, publication outputs of articles from countries. After that, all the articles were extracted (2,798 articles). The keywords yielded from articles were introduced in PubMed were cleared with check tags and stop word lists. For example, male, infant, etc. which were among the check tags were deleted and the keywords which were not of contexts (such as methods, history) were eliminated from descriptors. For avoiding the *influence* of synonymy and different forms, all the keywords were presented to an expert in the field and after obtaining his views, they were edited. In the next step, based on the Bradford's, 52 keywords with a frequency of 64 upwards were considered in the final analysis. Various thresholds for choosing the top keywords have been used in other researches [18, 19]. Following identification of basic keywords (topics), the symmetrical co-occurrence matrix of the topics was created using Ravar-PreMap software. Towards, hierarchical clustering was performed by SPSS 20. Clustering analysis can show clusters of topics as well as the relations among them. The multidimensional scaling map was prepared by using Ucinet 6.0.

Considering the aforementioned points and the importance of mapping a strategic diagram in co-word studies, a square matrix and a subsequent co-relation matrix were made for each cluster by regarding keywords included in it at the final step. The density and centrality of each matrix were measured where a strategic diagram was drawn in order to display the current status and trends of research topics. Furthermore, analyses of network characteristics were yielded from co-occurrence matrix using Ucinet 6.0 and VOSviewer. Excel was used for the descriptive statistical analysis of the data. The network characteristics in the research include:

Centrality

"Centrality is a measure of how many connections one cluster has to other sections of the network**.** In a network, if the node has a large number of interconnections with others, it has a higher centrality and stands in a basic status in the network. Centrality is applied to measure the connection degree between various topics" [20].

Density

Density is defined as the proportion of ties existing in the social network to all probable ties. It displays the assessment of a cluster's growth. A higher density means higher internal correlation degree among nodes. The density of a field shows its ability to hold and expand itself. Density provides a good show of a cluster's capability to maintain itself and develop as time goes [20].

The Strategic diagram is a two-dimensional planar graph. This paper, which is based on cluster analysis, takes the centrality as a lateral axis, while it presumes the density as a longitudinal axis. Such measures have been taken in order to establish a strategic diagram of clusters. The strategic diagram could demonstrate the position of each cluster throughout the entire research domain. In light of the distribution of each cluster in all the four quadrants, the current status of the subject research domain as well as its development and future changes could also be described. In quadrant I, research topics receive comparatively higher attention, standing at the core of the field while they have high centrality and density. In quadrant II, research topics are not central but are well-developed. Research topics in quadrant III are marginal and get little attention. Finally, the research topics in quadrant IV have received much attention, but they are not considered as hot research spots in recent years.

RESULTS

Bibliometric analysis

In general, 2,798 articles were found in the nanomedicine field indexed in PubMed through 2009-2018. Table 1 displays the geographical dispersion of scientific publications in nanomedicine field. 84.7% of articles were published by these countries. Output publication of this study was published in 567 different journals. The nanomedicine papers which were published in the top 5 journals during 2009-2018, are presented in Table 2.

In order to get accurate results, we initially need to standardize keywords of the literature data so as to objectively and accurately visualize the research

Table 1. Distribution of output of top 5 countries in nanomedicine papers

No.	Country	Frequency	Percentage
1	UNITED STATES OF AMERICA	960	34.31
2	ENGLAND	726	25.94
3	NETHERLANDS	375	13.40
4	GERMANY	165	5.89
5	UNITED ARAB EMIRATES	158	5.16

Table 2. The top 5 Source title of nanomedicine papers

No	Journal	Frequency	Percentage
1	NANOMEDICINE (LONDON, ENGLAND)	224	7.28
2	INTERNATIONAL JOURNAL OF NANOMEDICINE	179	5.82
3	NANOMEDICINE : NANOTECHNOLOGY, BIOLOGY, AND MEDICINE	109	3.54
4	WILEY INTERDISCIPLINARY REVIEWS. NANOMEDICINE AND NANOBIOTECHNOLOGY	99	3.22
5	ACS NANO	97	3.15

status, hot spots, and development trend of the research field. After the keywords are standardized with the help of Ravar PreMap software, as many as 52 high-frequency keywords with a frequency of more than 64 were selected as the research sample for co-word analysis. These 52 keywords, with a total frequency of 22,882 (about 30 % of the total), are capable to show the major context of the nanomedicine field. The top 20 keywords were shown in Table 3.

According to Table 3, the most used words include concepts such as Nanoparticles, Drug Delivery Systems, etc.

Fig. 2 represents the co-occurrence network related to nanomedicine during the period 2009-2018. As it can be seen in Fig. 2, keywords belonging to the same research topic are gathered together, forming a big network. The relative size of nodes represents the frequency of keywords while the relative size of lines represents the correlation degree between keywords. After determining the threshold for the coverage of keywords in the co-word analysis, the rate of the co-word was obtained. At this stage, the rate co-word of 52 frequently-used keywords with all the keywords in the articles was obtained. Table 4 shows the top 20 pairs of frequently-used keywords.

According to Table 4, the occurrence between the two keywords, "Drug Delivery Systems" and "Nanoparticles "is the highest frequency in the field of nanomedicine. Two pairs of frequently-used keywords namely "Therapeutic Use"*"Nanoparticles "and "Drug Design"*"Nanoparticles "are ranked second and third respectively.

With the aim of visualizing the entire structure of these keywords in the field of nanomedicine, it was used the hierarchical clustering approaches, multidimensional scale, and strategic diagrams.

Multivariate statistical analysis

Hierarchical clustering is chosen among multivariate statistical methods. First, the correlation matrix was transferred into SPSS, and the clusters and co-word dendrogram were made. Then, the Within Group method was used for mapping clusters in hierarchical clustering.

Table 3. The top 20 frequently-used keywords in Nanomedicine area (2009-2018).

No.	Keyword	Frequency	No.	Keyword	Frequency
1	NANOPARTICLES	1022	11	POLYMERS	211
2	DRUG DELIVERY SYSTEMS	837	12	PARTICLE SIZE	188
3	THERAPEUTIC USE	818	13	MAGNETIC RESONANCE IMAGING	176
4	THERANOSTIC NANOMEDICINE	708	14	METAL NANOPARTICLES	176
5	NEOPLASMS	641	15	LIPOSOMES	158
6	DRUG CARRIERS	531	16	GOLD	151
7	ANTINEOPLASTIC AGENTS	433	17	CELL SURVIVAL	134
8	NANOSTRUCTURES	395	18	DOXORUBICIN	131
9	CELL LINE, TUMOR	388	19	SURFACE PROPERTIES	130
10	DIAGNOSTIC IMAGING	319	20	BIOCOMPATIBLE MATERIALS	123

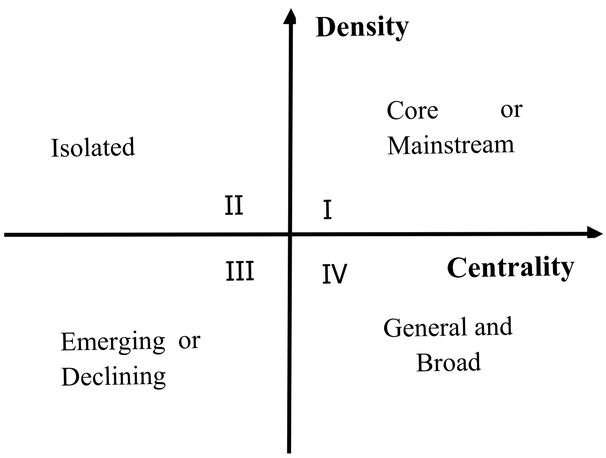

Fig. 1. Strategic diagram characterizations based on density and centrality [21]

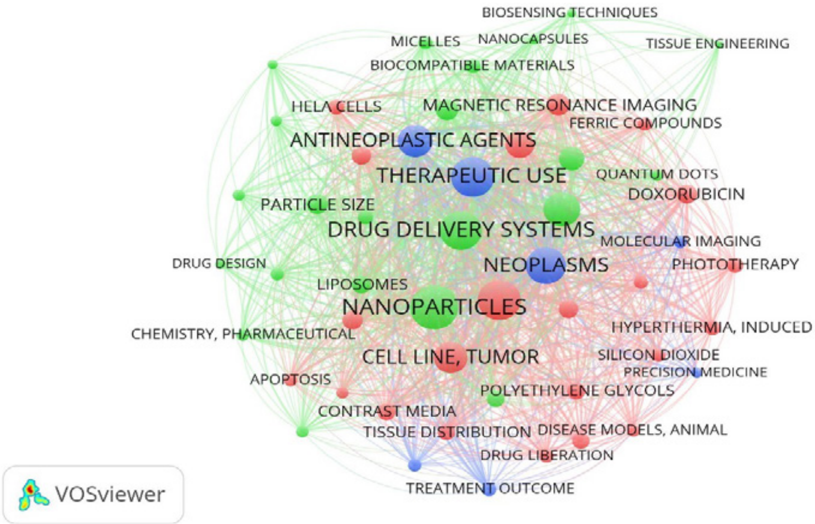

Fig. 2. Keyword network map for nanomedicine research papers over the period 2009-2018

Table 4. The top 20 pairs of frequently-used keywords

Rank	Co-Words	Frequency
1	DRUG DELIVERY SYSTEMS * NANOPARTICLES	403
2	THERAPEUTIC USE * NANOPARTICLES	356
3	DRUG CARRIER* NANOPARTICLES	291
4	NEOPLASMS * NANOPARTICLES	273
5	THERANOSTIC NANOMEDICINE * NANOPARTICLES	232
6	ANTINEOPLASTIC AGENTS* NEOPLASMS	217
7	CELL LINE, TUMOR* THERANOSTIC NANOMEDICINE	183
8	DIAGNOSTIC IMAGING* THERANOSTIC NANOMEDICINE	191
9	NANOSTRUCTURE * THERAPEUTIC USE	142
10	MAGNETIC RESONANCE IMAGING* THERANOSTIC NANOMEDICINE	122
11	POLYMERS* NANOPARTICLES	107
12	PARTICLES SIZE* NANOPARTICLES	95
13	METAL NANOPATOCLES*GOLD	92
14	LIPOSOMES* NANOPARTICLES	78
15	GOLD * METAL NANOPARTICLES	92
16	CELL SURVIVAL* THERANOSTIC NANOMEDICINE	67
17	DOXORUBICIN * THERANOSTIC NANOMEDICINE	70
18	SURFACE PROPERTIES * PARTICLE SIZE	65
19	BIOCOMPATIBLE MATERIALS * NANOPARTICLES	44
20	POLYETHYLENE GLYCOLS * NANOPARTICLES	51

As Fig. 3 shows, the co-word analysis resulted in 9 clusters. In some clusters, the keywords have no direct relationship with other subjects in the cluster. This is the usual case in co-word analyses [22]. These 9 topic clusters could show the current sub-areas of nanomedicine.

Cluster 1: Photothermal therapy: This cluster consists of 8 keywords including “Metal Nanoparticles”, “Gold”, “Photochemotherapy”, “Phototherapy”, “Hyperthermia», “Induced”, “Hela Cell”, “Brest Neoplasms”. These keywords are important in treatment for cancer cells through radiation and heat.

Cluster 2: Nanoparticles in Medical Imaging: Six keywords have contributed to the formation of this cluster. Keywords in the cluster such as “Magnetic Resonance Imaging”, “Contrast Media”, “Magnetite Nanoparticles”, “Ferric Compounds”, “Tissue Distribution”, “Diagnostic Imaging” show that the subject of this cluster can be nanotechnology in medical imaging.

Cluster 3: Nano diagnostic: This cluster consists of five keywords “Molecular Imaging”, “Quantum Dots”, “Treatment Outcome”, “Disease Models Animal”, and “Molecular Targeted Therapy”. The existence of these five keywords indicates that

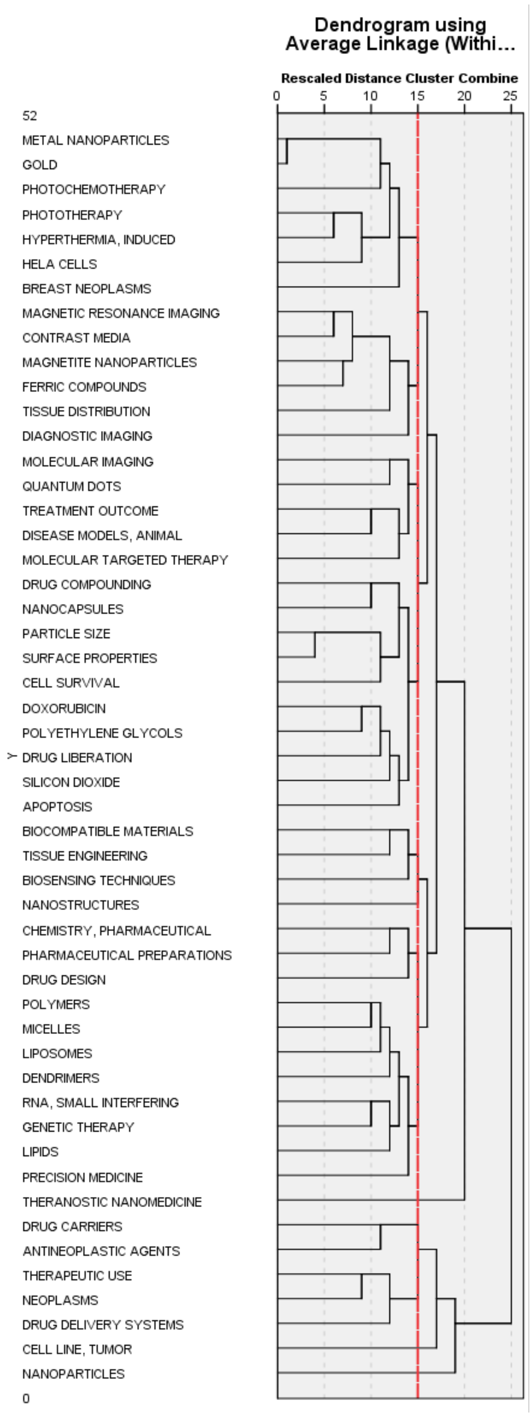

Fig. 3. Hierarchical clustering by co-word (within Group method)

the cluster deals with evolution of devices and it images devices to detect and analyze the diseased condition using engineering.

Cluster 4: Drug design: (referring to as rational drug design): The existence of keywords such as "Drug Compounding", "Nanocapsules", "Particle Size", "Surface Properties", "Cell Survival", Doxorubicin", "Polyethylene Glycols", "Drug Liberation", "Silicon Dioxide" , "Apoptosis" in this cluster represents to design drugs for a specific biological purpose

Cluster 5: Renovated Medicine: Four keywords ("Biocompatible Materials", "Tissue Engineering", "Biosensing Techniques", "Nanostructures") in this cluster reveals the relationship between biocompatible and tissue engineering.

Cluster 6: Drug design: This cluster is closely related to cluster 4. The important keywords in this cluster are "Chemistry Pharmaceutical", "Pharmaceutical Preparations", and "Drug Design"

Cluster 7: nanomedicine's genealogy: eight keywords "Polymers", "Micelles", "Liposomes", "Dendrimers", "RNA Small Interfering", "Genetic Therapy", "Lipids", "Precision Medicine". These keywords in this cluster indicate its connections to molecular medicine and nanotechnology.

Cluster 8: Theranostic Nanomedicine: This cluster, which has a Semantic affinity with cluster 6, consists of three keywords. "Theranostic Nanomedicine" "Drug Carriers", "Antineoplastic Agents" indicate the subject of this cluster is well represented.

Cluster 9: Drug Delivery System (emphasis on cancer): This cluster, which has a Semantic affinity with cluster 6, consists of five keywords. "Therapeutic Use", "Neoplasms", "Drug Delivery Systems", "Cell Line Tumor", "Nanoparticles" are important keywords from this cluster that are related to nanomedicines based drug delivery systems for anti-cancer targeting and treatment

Strategic diagram

In this study, the centrality-density matrix was obtained by Ucinet 6.0. After that, the strategic diagram was drawn to clarify the maturity and cohesion of each cluster.

"A strategic diagram is used to analyze the structure and fluctuating trend of hot spots in a certain research field. It is mostly used to describe the internal relations within a cluster, as well as the interactions among different fields" [22]. In addition, by NetDraw, a relation network which visualizes the keywords structure is generated. On the basis of the centrality and density data of 9 clusters which is in Table 5, a strategic diagram was drawn to elucidate the correlation and maturity of each cluster (Fig 4).

As shown in Table 5, clusters 8 and 9 have higher centralities. It points out that the clusters have joined well with other clusters of nanomedicine and the clusters 6 and 3 have a lower centrality. These are considered as marginal clusters of nanomedicine. Fig. 4 illustrates the strategic diagram of clusters derived from the co-word analysis in the field of nanomedicine. As already mentioned, the horizontal axis represents the centrality and determines the power of interaction for each cluster in the area under study. The vertical axis represents density and shows the internal relation in the subject of research. The higher the density of a cluster is, the more potential the cluster will be for developing [23]. Another finding suggests that no cluster was placed in parts 4 and 2 of the diagram. In general, the clusters positioned in part 4 of the strategic diagram are axial but underdeveloped. There is no such a cluster in nanomedicine. As Fig. 4 illustrates, the one cluster (9) was stood in part 1 of the strategic diagram. This subject cluster is well developed and has a powerful internal correlation and maturation. In other words, the high centrality of this cluster (placement in the center of the research network) indicates that these clusters have a central place in the general nanomedicine network, and stand in an expanded and powerful relation with other clusters. High density shows high internal correlation while high centrality shows that these clusters are broadly joint to other clusters. Conversely, the eight clusters (1, 2, 3, 4, 5, 6, 7, and 8) were placed in part 3 of the strategic diagram. This implies that these clusters are not axial, but developing. They have a relatively discontinuous structure, are underdeveloped and immature, and are in the margins of the nanomedicine network.

Table 5. The centrality and density data of clusters from co-word analysis.

No. Cluster	Name of clusters	Density	Centrality
1	Photo thermal therapy	17.79	16.53
2	Nanoparticles in Medical Imaging	15.66	14.9
3	Nano diagnostic	5.4	3.5
4	Drug design	11.66	12.36
5	Renovated Medicine	7	9
6	Drug design	6.33	4
7	Nanomedicine's genealogy	9.35	9.61
8	Theranostic Nanomedicine	122.33	33.5
9	Drug Delivery System(emphasis on cancer)	229.3	112.83

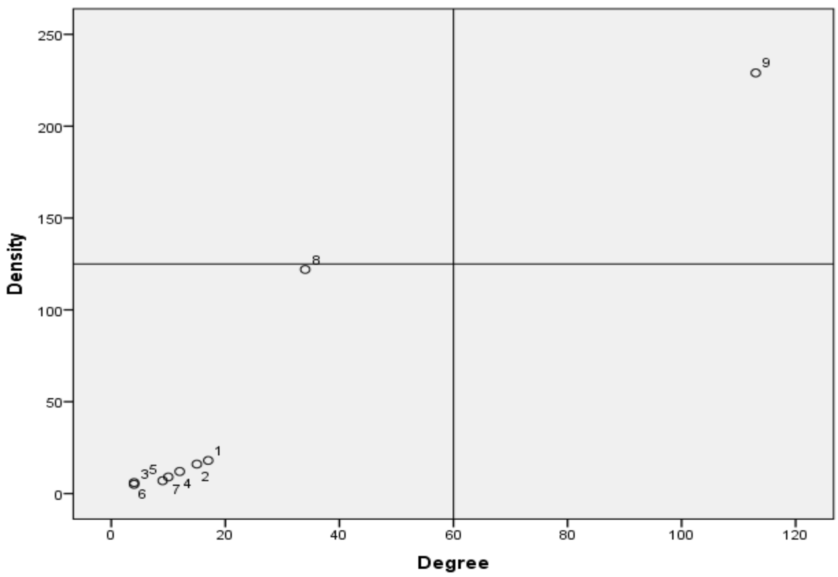

Fig. 4: The strategic diagram of nine clusters.

DISCUSSION

In this research, it was tried to provide an appropriate representation of the intellectual structure of nanomedicine research in a ten-year period by using Co-word analysis, social network analysis as well as visual science software. The growth in nanomedicine field over the mentioned period shows an upward trend with the highest growths seen in countries like the United States (34.31%), the UK (25.94%), and Netherlands (13.40%). The United States was the leading coumtry in nanomedicine field, a fact that has been found in other biomedicine researchs [24, 11].

Findings of the research showed that the keyword "nanoparticles" has been the most frequent throughout the nanomedicine researches. Nanoparticle usually forms the core of nano-biomaterials. "Nanoparticle research is currently an area of intense scientific research due to a wide variety of potential applications in biomedical, optical, and electronic fields" [25]. Also, this subject is one of the components of the nanostructure, therefore, it is no surprise that "nanoparticles" was a hot keyword. "Drug Delivery Systems" and "Therapeutic Use" are ranked second and third, respectively among frequently-used thematics in WoS over the research time span and they have the most occurrences with "nanoparticles".

Nanoparticle technology was recently shown to hold great promise for drug delivery applications in nanomedicine due to its beneficial properties, such as better encapsulation, bioavailability, control release, and lower toxic effect. Today's advanced nanoparticles for drug delivery have been developed to enable the spatially and temporally controlled release of drugs in response to specific stimuli at disease sites. With their unique physical and chemical properties as well as their nanoscale effects, nanoparticle-based drug delivery systems (NDDSs) are currently under extensive development for applications in the treatment of diseases such as cardiovascular diseases, infectious diseases, diabetes, and cancer [26], which was also a hot keyword. Since the last decade, the role of nanotechnology in "therapeutics" has extensively been studied. "Nanotechnology-based delivery systems have shown promising results in targeting only diseased tissue and hence increasing the efficacy and limiting the side effects of therapeutics" [27].

Many studies were considered on the term "Theranostic Nanomedicine", the use of which began at the end of the last century and has steadily increased ever since [28]. "In recent years, theranostics emerged as a novel nano approach which performs diagnostic detection, therapy and follows up simultaneously. Therefore, theranostics can be considered as an appropriate therapeutic approach for personalized medicine, pharmacogenomics and molecular imaging which can open a gate to develop novel therapies" [29].

By analyzing the topics attributed to the documents (keywords), a wide range of scattered data was located in 9 clusters. The greatest cluster was «Drug design,» with 10 high-frequent keywords. "Although hierarchical clustering can demonstrate clusters in a field of study, it has some limitations. For example, it hardly shows within-cluster interactions or internal relations that would determine which cluster has centrality or which one is matured. The interpretation of clusters greatly depends on subjective factors, with the analysis of clusters requiring expertise in the field" [30]. The topics of 9 clusters are» Photothermal therapy «, « Nanoparticles in Medical Imaging «,» Nano diagnostic «, « Drug design «, « Renovated Medicine «, « Drug design «, « nanomedicine's genealogy «, « Theranostic Nanomedicine «, « Drug Delivery System «. The clusters created with common features within each group have structural relationships with each other and clusters represent a research director of the subject. The cluster analysis obtained in this study suggests that researchers emphasize Drug design, Drug delivery, or in general Pharmaceutical Nanotechnology. This finding is consistent with other research [10]. Nanosafety/ nanotoxicology, as well as new medical products and equipment such as nanorobots and artificial tissues have not been considered.

As a result, to complement hierarchical clustering the strategic diagram is employed in the co-word analysis. As Fig. 4 illustrates, the analysis of the strategic diagram shows that quadrant I include cluster 9, « Drug Delivery System «with emphasis on cancer is the most comprehensive subject area in nanomedicine and that it is more developed than other related subjects in the field. This suggests that this cluster occupies the axis and center of the nanomedicine co-word network. Drug Delivery Systems is the Systems for the delivery of drugs to target sites of pharmacological actions. Technologies employed include those concerning drug preparation, route of administration, site targeting, metabolism, and toxicity (Pubmed)

«The use of Drug Delivery Systems as nanocarriers for chemotherapeutic agents can improve the pharmacological properties of drugs by altering drug pharmacokinetics and biodistribution. Among the many drug delivery systems available, both micelles and liposomes have gained the most attention in recent years due to their clinical success. There are several formulations of these nanocarrier systems in various stages of clinical trials» [32]. «Drug delivery refers to approaches, formulations, technologies, and systems for transporting a pharmaceutical compound in the body as needed to safely achieve its desired therapeutic effect» [33]. This finding is consistent with other research [34, 35, 36].

Many clusters are located in part 3 (Fig. 4) including Photothermal therapy, Nanoparticles in Medical Imaging, Nano diagnostic, Drug design, Renovated Medicine, Theranostic Nanomedicine, and nanomedicine's genealogy. Their low centrality and density of these clusters present that they are not highly associated with the topics in the other clusters and they are marginal.

Regarding the stand of these themes in the strategic diagram, it can be said that these themes did not have internal and external relations in the field and have not yet been studied extensively. These topics have almost been related to each other.

That means these clusters of keywords have not yet been studied extensively, and that they are not highly associated with the keywords in other clusters. Thus, they may involve emerging or disappearing topics.

CONCLUSION

This study provided an alternative perspective on the global research trends in nanomedicine studies during the period 2009–2018. In this study, an analysis of hot research topics of nanomedicine was achieved by using co-word analysis, which were based on the data of PubMed. Co-word analysis is a technique that enables us to determine the major topics and semantic structure in a field. It helps to determine both the emerging and the developed subject clusters to suggest the research path in the future. Therefore, using the results yielded from this research can help us to provide some clear and reasonable analyses on the current situation. Bibliometric indicators and network properties reported in this research may help scholars, students and policy-makers to understand the interdisciplinary character of nanomedicine and to have a practical understanding of the direction subjects in nanomedicine field. There is a limitation in the research that studied data are from PubMed database. Using other databases such as WoS and Scopus may lead to different results.

ACKNOWLEDGMENTS

The author appreciates the support of Mr. Ali Taherizadeh, for editing.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

1. Ventola CL. The nanomedicine revolution: part 1: emerging concepts. P T. 2012; 37(9):512-25.
2. Freitas RA. What is nanomedicine? Nanomedicine: Nanotechnology, Biology and Medicine. 2005;1(1):2-9.
3. Abeer S. Future medicine: nanomedicine. JIMSA. 2012; 25:187-92.
4. Wang X, Inaba M. Analyzing Structures and Evolution of Digital Humanities Based on Correspondence Analysis and Co-Word Analysis. Art Research 2009; 9: 123-134.
5. Kumar S, Mohd Jan J. Discovering Knowledge Landscapes: An Epistemic Analysis of Business and Management Field in Malaysia. Procedia - Social and Behavioral Sciences. 2012;65:1027-32.
6. Danell J-AB. Reception of integrative and complementary medicine (ICM) in scientific journals: a citation and co-word analysis. Scientometrics. 2013;98(2):807-21.
7. Leung XY, Sun J, Bai B. Bibliometrics of social media research: A co-citation and co-word analysis. International Journal of Hospitality Management. 2017;66:35-45.
8. Qian G. Scientometrics Analysis on the Intellectual Structure of the Research Field of Bioenergy. Journal of Biobased Materials and Bioenergy. 2013;7(2):305-8.
9. Ravikumar S, Agrahari A, Singh SN. Mapping the intellectual structure of scientometrics: a co-word analysis of the journal Scientometrics (2005–2010). Scientometrics. 2014;102(1):929-55.
10. Makhoba X, Pouris A. Bibliometric analysis of the development of nanoscience research in South Africa. South African Journal of Science. 2017;113(11/12).
11. Makkizadeh F, Sa'adat F. Bibliometric and thematic analysis of articles in the field of infertility (2011-2015). International Journal of Reproductive BioMedicine. 2017;15(11):719-28.
12. Danell J-AB. Reception of integrative and complementary medicine (ICM) in scientific journals: a citation and co-word analysis. Scientometrics. 2013;98(2):807-21.
13. Xie P. Study of international anticancer research trends via co-word and document co-citation visualization analysis. Scientometrics. 2015;105(1):611-22.
14. Hussain T, Edgeman R, Eskildsen JK. Knowledge-based intellectual structure of research in business excellence (1995–2015). Total Quality Management & Business Excellence. 2018:1-24.
15. Garrigos-Simon F, Narangajavana-Kaosiri Y, Lengua-Lengua I. Tourism and Sustainability: A Bibliometric and

Visualization Analysis. Sustainability. 2018;10(6):1976.

16. Danell J-AB. Reception of integrative and complementary medicine (ICM) in scientific journals: a citation and co-word analysis. Scientometrics. 2013;98(2):807-21.
17. Soheili F, Shabani A, Khasseh AA. Intellectual structure of knowledge in Information Behavior: A Co-Word Analysis. Human Information Interaction 2017; 4: 21-36.
18. Liu G-Y, Hu J-M, Wang H-L. A co-word analysis of digital library field in China. Scientometrics. 2011;91(1):203-17.
19. Hu C-P, Hu J-M, Deng S-L, Liu Y. A co-word analysis of library and information science in China. Scientometrics. 2013;97(2):369-82.
20. Ergün E, Usluel YK. An Analysis of Density and Degree-Centrality According to the Social Networking Structure Formed in an Online Learning Environment. Journal of Educational Technology & Society. 2016; 19(4): 34–46.
21. Melcer E, Nguyen T. H.D, Chen, Z, Canossa A, El-Nasr M.S, Isbister K. Game sresearch today: Analyzing the academic landscape 2000-2014. In Proceedings of the 10th. International Conference on the Foundations of Digital Games, At Pacific Grove, CA, USA 2015.
22. Hu J, Zhang Y. Research patterns and trends of Recommendation System in China using co-word analysis. Information Processing & Management. 2015;51(4):329-39.
23. Law J, Bauin S, Courtial JP, Whittaker J. Policy and the mapping of scientific change: A co-word analysis of research into environmental acidification. Scientometrics. 1988;14(3-4):251-64.
24. Salata, OV. "Applications of nanoparticles in biology and medicine" Journal of nanobiotechnology. 2004; 2(1): 3
25. Salata OV. Journal of Nanobiotechnology. 2004;2(1):3.
26. Gaurab, Roy, Shetti Dattatrya, and Yadav Amit. "Nanomedicine: Therapeutic Applications and Limitations." Handbook of Research on Diverse Applications of Nanotechnology in Biomedicine, Chemistry, and Engineering. IGI Global, 2015. 64-89.
27. Gaurab R, Dattatrya S, Amit Y, Gopal C K. Nanomedicine. Handbook of Research on Diverse Applications of Nanotechnology in Biomedicine, Chemistry, and Engineering: IGI Global; 2015. p. 64-89.
28. Torabian P, Erfani-Moghadam V. Theranostics; Application of Nanosystems for Simultaneous Targeted Therapy and Imaging in Diseases. Jorjani Biomed J. 2016; 4 (1) :1-14.
29. Chen X. Integrin Targeted Imaging and Therapy. Theranostics. 2011;1:28-9.
30. Yang Y, Wu M, Cui L. Integration of three visualization methods based on co-word analysis. Scientometrics. 2011;90(2):659-73.
32. Willey EJB. Correspondence. The British Journal of Radiology. 1958;31(361):31-.
33. Cukierman E, Khan DR. The benefits and challenges associated with the use of drug delivery systems in cancer therapy. Biochemical Pharmacology. 2010;80(5):762-70.
34. Raavé, René, et al. "Drug delivery systems for ovarian cancer treatment: A systematic review and meta-analysis of animal studies. Peer J. 2015; 3: e1489.
35. Allen TM, Cullis PR. Drug delivery systems: Entering the mainstream. Science. 2004; 303:1818–22.
36. Allen TM. Drug Delivery Systems: Entering the Mainstream. Science. 2004;303(5665):1818-22.
37. Cukierman E, Khan DR. The benefits and challenges associated with the use of drug delivery systems in cancer therapy. Biochemical Pharmacology. 2010;80(5):762-70.