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Network of nanomedicine researches: impact of Iranian scientists

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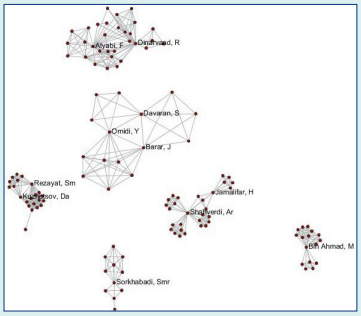
Abstract



Introduction: We may define the nanomedicine as the use of nanotechnology in the health care, disease diagnoses and treatment in order to maintain and increase the health status of a population through improve pharmacotherapy. The main objective of the current study is to analyze and visualize the co-authorship network of all papers in the field of nanomedicine published throughout 2002-2014 in journals and indexed in the Web of Science database.

Methods: The Web of Science database was used to extract all papers indexed as a topic of nanomedicine through 2002-2014. The Science of Science Tool was used to map the co-authorship network of papers.

Results: Total number of papers extracted from the Web of Science in the field of nanomedicine was 3092 through 2002-2014. Analysis of data showed that the research activities in the field of nanomedicine increased steadily through the period of study. USA, China, and India were the most prolific countries in the field. The dominant language of publications was English. The co-authorship connection revealed a network with a density of 0.0006.

Conclusion: Nanomedicine researches have markedly been increased in Iran. Ninety-five percent of Iranian papers were cooperated with multi-authors. The collaboration coefficient degree was 0.731.

Introduction

The "nanomedicine" term may be defined as the nanoscaled medicines that are formulated/engineered by means of nanotechnology techniques. These advanced therapies have great potentials in medical diagnosis, treatment and/or prevention of a wide spectra of diseases. These multifunctional pharmaceuticals exploit the improved and often novel physical, chemical, and biological properties of materials at a nanometer scale. The nanometer scale ranges from the atomic level at around 0.2 nm up to around 100 nm.[1] As echoed in the definition given by the National Institutes of Health (NIH), "nanomedicine refers to highly specific medical intervention at a molecular scale for curing diseases or repairing damaged tissues such as bones, muscles or nerves."[2]

Contemporary years were the eyewitness of extraordinary growing of research and applications in the area of nanoscience and nanotechnology.[3] It is confirmed that applying nanotechnology to medicine would bring significant advances in the diagnosis and treatment of disease. Applying nanomedicne in drug delivery is the major goal of researchers - a novel field of sciences and technology so-called pharmaceutical nanobiotechnology.[4] In 2005, the NIH officially launched its roadmap on nanomedicine initiative by establishing a national network of eight nanomedicine development centers. The research areas that prompted by NIH nanomedicine roadmap included: (I) a study of the molecular events inside cells as real-time, (II) the design of artificial systems for engineering with living cells, (III) the ensurement of nanodevice biocompatibility, and (IV) the development of nanodevices that may reduce the cost of health care.[5]

In addition, nanomedicine covers several different areas of application such as drug delivery, drugs and therapies, in vivo imaging, in vitro diagnostics, biomaterials and active implants. In these fields, nanomedicines have imposed a surge in the research activity over the past decade with publication numbers rising from ten per year in the late 1980s to more than 1200 in 2004. Nowadays, health innovations are increasingly being assessed also with respect to the costs at which the improvements come. Nanomedicine products will have to show cost-

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effectiveness in comparison to conventional alternatives, as health care systems increasingly face cost pressure.[6]
Scientific collaboration is among the most important subjects in scientometrics and many studies have considered this concept so far.[7-12] In this concept, all papers that were indexed as a topic of "Nanomedicine" in Web of Science (WoS) database (through 2002-2014 was extracted and went under analysis. The major aim of our study was to visualize the impact of leading countries in the field of nanomedicine and to map the co-authorship network through 2002-2014. The Iranian scientific profiles were highlighted to show the impact of Iranian authors in the field.

Materials and methods

The Web of Science database was used to extract all papers indexed as a major topic of nanomedicine by entering the term of nanotechnology in the search box and limiting the search into topics by selecting the tag of topic from the list of field-tags. The time span was limited to 2002-2014. This kind of search strategy resulted in 23411 documents. These numbers of documents were categorized in several sub-categories. We took only into consideration the categories related to medical fields based on the WoS classifications, which counted 6412 documents including all type of publications. We got 3092 papers after refining the documents into the publication type of paper.
The Science of Science Tool was used to map the co-authorship networks of papers in the field of nanomedicine both for entire the world and the papers originated by Iranian authors. Only papers cited more than two times in the WoS were considered for mapping the co-authorship network.
Based on the size of the population for the countries, data were extracted from the website of World Databank (http://databank.worldbank.org/).

Results

The extraction of data in the field of nanomedicine resulted in 3092 papers. Analysis of data showed that the number of papers increased 20 times; from 24 papers in 2002 to 494 papers in 2014. The average number of publications was 257 papers annually. This reveals an increasing trend in the number of papers that appeared during the period of study, in spite of slightly decline in 2012. The last three years of study (2012-2014) was the most proliferation years of under study; so that 43% of total papers were published during these years. The trend of publication in this field is shown in Fig. 1.
The most prolific individual country in terms of number of publications was the USA, with 38% of global scientific output in the field. Other productive countries were: China sharing 10% of the global scientific publications followed by India sharing 6%, England sharing 5% and Italy sharing 5% of global production in the field. The last column in Table 1 provides data on the number of published papers by each country divided by the number of inhabitants (in millions) of the same country (optimized rank). When the productivity of countries based on the number of inhabitants was calculated, we found that the five top productive countries (after reassessing the respective population size) were Singapore, Switzerland, USA, Australia, and Belgium respectively. Most interesting finding is that, considering the optimized rank, Iran stands before the countries such as Brazil, China, and India. Table 1 shows the number of publications by origin countries. Table 1 is restricted to the 20 top productive countries.
The most prolific authors were Thomas J. Webster from Northeastern University in USA contributing a total number of 66 papers, followed by Si-Shen Feng from the National University of Singapore sharing 45 papers; Peixuan Guo from Kentucky University in USA sharing 19 papers; Alexander Michailovich Dygai from Siberian State Medical University in Russia sharing 16 papers. The list of ten top prolific authors is shown in Fig. 2.
As shown in Table 2, the top 20 productive organizations were the National University of Singapore distributing 67 papers followed by Brown University in USA with 50 papers and Chinese Academy of Science with 49 papers. It is remarkable that fifteen organizations among 20 top productive organizations are located in the USA. Considering the origin country of prolific organizations, the USA stands on the top of ranking. This is remarkable that Tehran University of Medical Sciences positioned among 20 top productive institutes.
English was the most dominant language of publications. Ninety-eight percent of publications were in English; whereas only 2% of publications were in other languages. This should not come as a surprise while the database of WoS has been focused on papers in English since many years ago (Table 3).[13]
Table 4 shows the sub-categories of papers in the field of nanomedicine. Twenty-one percent of papers were classified in pharmacology & pharmacy. The following sub-categories are: nanoscience, biochemistry, molecular biology, biotechnology, applied-microbiology, engineering-biomedical, materials science biomaterials, and toxicology respectively. Table 4 is restricted to 20 top sub-categories. Fig. 3 Shows the co-authorship network of nanomedicine papers indexed in the WoS during the study time. There were 12456 nodes, 46377 links, and 1303 clusters. It was a connected network and its density

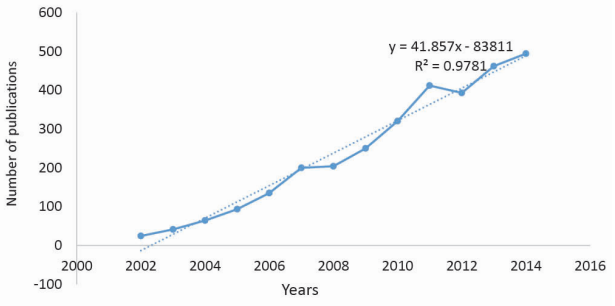

Fig. 1. Number of publications in the field of nanomedicine in Web of Science in years 2002-2014.

Table 1. Origin country of papers in nanomedicine indexed in WoS in years 2002-2014

Rank	Countries	Number of papers	Percentage	Population (in millions)	Number of papers/million population	Optimized Rank
1	USA	1187	38.389	322,583,006	3.6	3
2	China	309	9.994	1,393,783,836	0.2	19
3	India	185	5.983	1,267,401,849	0.1	20
4	England	164	5.304	63,489,234	2.6	9
5	Italy	162	5.239	61,070,224	2.6	8
6	Germany	151	4.884	82,652,256	1.8	12
7	Japan	142	4.592	126,999,808	1.1	16
8	France	111	3.590	64,641,279	1.7	14
9	Brazil	102	3.299	202,033,670	0.5	18
10	Canada	98	3.169	35,524,732	2.8	7
11	South Korea	88	2.846	49,512,026	1.7	13
12	Spain	87	2.814	47,066,402	1.8	11
13	Singapore	82	2.652	5,517,102	16.4	1
14	Australia	80	2.587	23,630,169	3.4	4
15	Iran	70	2.263	78,470,222	0.8	17
16	Switzerland	60	1.940	8,157,896	7.5	2
17	Netherlands	49	1.585	16,802,463	3	6
18	Saudi Arabia	48	1.552	29,369,428	1.6	15
19	Taiwan	43	1.391	23,410,280	1.8	10
20	Belgium	38	1.229	11,144,420	3.4	5

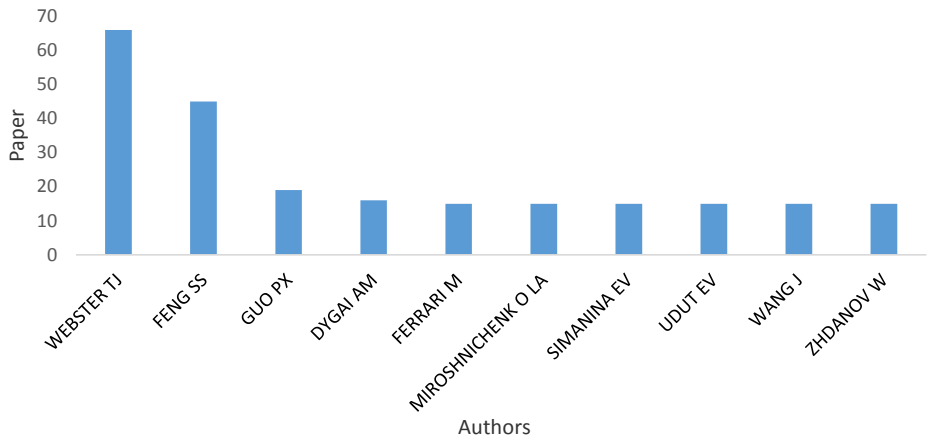

Fig. 2. Ten top productive authors in the field of nanomedicine in the WoS in years 2002-2014.

was 0.0006. The giant component in the center of co-authorship network with 4951 nodes was the biggest cluster.

We restricted the map to the giant component of the co-authorship network (all small sub-networks have been removed) and those authors who had at least two times co-authorship remained in the network for better consideration and analysis (Fig. 4). Each node representing one author and every line connecting two authors shows the presence of co-authorship. The network illustrates the strategic positions of some authors. Without the works of these authors, the co-authorship network would be divided into some sub-networks. The strategic authors in the co-authorship network are called cut-points and the links between them is called bridges.[14,15]

Fig. 5 shows the co-authorship network of Iranian papers throughout 2002-2014. The network consists of 7 relatively large clusters and some small clusters. This network had 275 nodes and 659 ties; therefore it was a dense network because the number of ties was more than the nodes, and its density was 0.0175.

Fig. 6 shows the important clusters of network for Iranian authors in nanomedicine. All small clusters have been removed. The map is made up six separated clusters. The cluster located in the center belongs to Tabriz University of Medical science. In this sub-network the polar position of Omidi Y. is noteworthy and can be considered as a consequence of his leading position in collaboration with Davaran S. and Barar J. which constructed one of the clearest sub-networks among Iranian co-authorship network in nanomedicine. These researchers have mostly worked on development of anticancer nanomedicines and theranostics.[16-34]

Considering the productivity of Middle East countries,

Table 2. Productive organizations in the field of nanomedicine in WoS in years 2002-2014

Rank	Organizations	Records	Percent
1.	National University of Singapore	67	2.16
2.	Brown University, USA	50	1.61
3.	Chinese Academy of Science, China	49	1.58
4.	Harvard University, USA	45	1.45
5.	Purdue University, USA	37	1.19
6.	National Cancer Institute, USA	34	1.09
7.	University of California, Los Angeles, USA	30	0.97
8.	Northeastern University, USA	27	0.87
9.	Ohio State University, USA	27	0.87
10.	University of Michigan, USA	27	0.87
11.	University College London, UK	26	0.84
12.	King Saud University, Saudi Arabia	24	0.77
13.	National Institute For Occupational Safety And Health, USA	23	0.74
14.	Rice University, USA	23	0.74
15.	University of California, San Diego, USA	23	0.74
16.	University of Illinois At Urbana–Champaign, USA	23	0.74
17.	University of Washington, USA	23	0.74
18.	Northwestern University, USA	22	0.71
19.	University of Minnesota, USA	22	0.71
20.	Tehran University of Medical Science, Iran	22	0.71

Table 3. The language of papers in nanomedicine indexed in the WoS in years 2002-2014

Languages	Records	Percent
English	3030	97.995
French	24	0.776
German	18	0.582
Japanese	5	0.162
Spanish	5	0.162
Chinese	4	0.129
Portuguese	2	0.065
Italian	1	0.032
Polish	1	0.032
Romanian	1	0.032
Turkish	1	0.032

Iran is the most dynamic country in the field of nanomedicine through the period of study. Significant growth in the research literature on nanomedicine has been reported from Middle East countries. The number of publications contributed by authors from Middle East countries in 2014 was 59 times greater than those in 2002 (Fig. 7).

The study indicated that multiple-authorship was dominant in the field by Iranian authors. The proportion of papers authored by co-authors accounted for almost 95% of the total publications coming from Iran. The collaboration more than five authors was the most common tendency in the pattern of co-authorship. Iranian collaboration coefficient (CC) value was calculated 0.731 in the field (Table 5).

Table 4. The twenty top sub-categories of nanomedicine in the WoS in years 2002-2014

Web of science categories	Records	Percent
Pharmacology pharmacy	668	21.604
Nanoscience nanotechnology	490	15.847
Biochemistry molecular biology	480	15.523
Biotechnology applied microbiology	426	13.777
Engineering biomedical	315	10.187
Materials science biomaterials	281	9.087
Toxicology	262	8.473
Medicine research experimental	242	7.826
Chemistry multidisciplinary	228	7.373
Chemistry medicinal	193	6.241
Food science technology	157	5.077
Cell biology	115	3.719
Oncology	110	3.557
Biophysics	107	3.460
Public environmental occupational health	99	3.201
Biochemical research methods	96	3.104
Radiology nuclear medicine medical imaging	72	2.328
Materials science multidisciplinary	68	2.199
Surgery	65	2.102
Environmental science	64	2.069

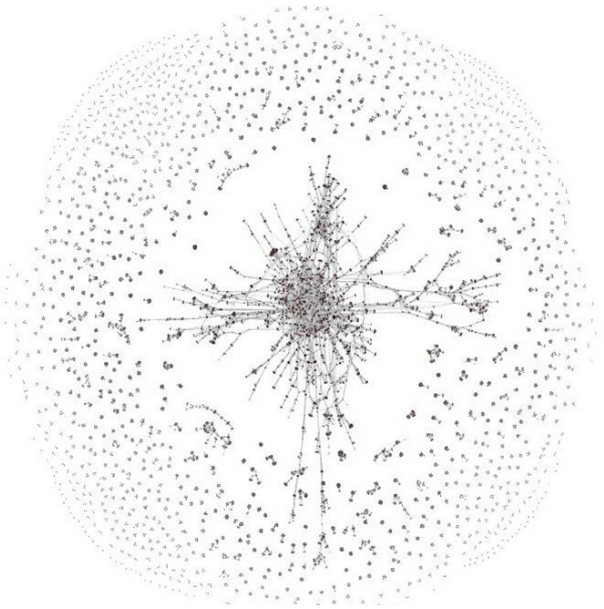

Fig. 3. The co-authorship network of papers in the field of nanomedicine in WoS in years 2002-2014.

Discussion

The main aim of current study was to analyze and map the co-authorship of scientific output of nanomedicine indexed in the WoS through 2002-2014. The study found that during the study period, a total number of 3092 papers in the field of nanomedicine were published in the journals that indexed in the WoS. The study indicated a remarkable increase regarding to the number of publications during the study period in spite of little fluctuation in 2012. The USA, China, India, England, and Italy were the most productive countries. Nevertheless

Table 5. Pattern of Iranian co-authorship in the field of nanomedicine in WoS in years 2002-2014

Year	Single author	Two authors	Three authors	Four authors	Five authors	More than five authors	Cc
2007	-	-	-	-	1	1	0.837
2008	-	-	-	1	1	1	0.809
2009	1	-	-	1	1	2	0.671
2010	-	-	3	-	1	4	0.785
2011	-	-	3	5	2	1	0.744
2012	2	1	4	2		2	0.583
2013	1	3	3	2	4	2	0.661
2014	-	1	3	3	3	5	0.765
Total	4	5	16	14	13	18	0.731

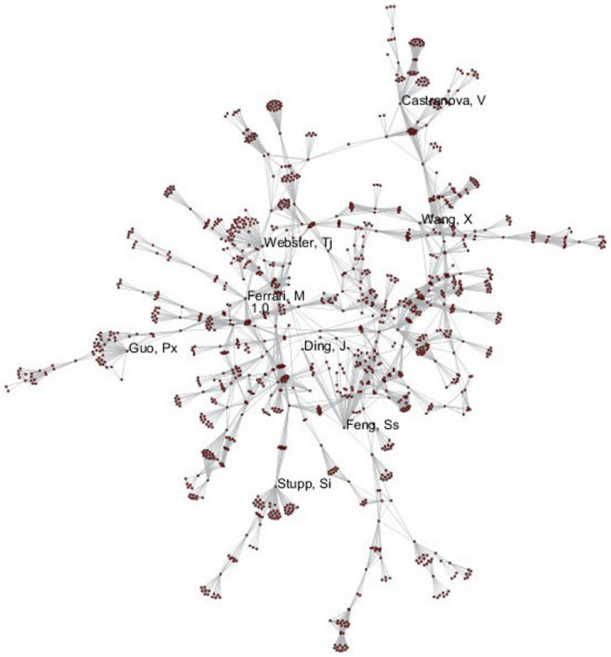

Fig. 4. The giant component of co-authorship network of papers indexed in the field of nanomedicine in WOS in years 2002-2014.

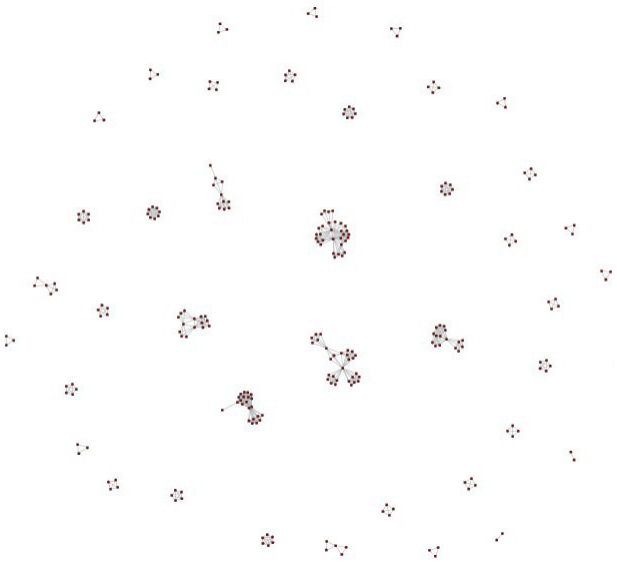

Fig. 5. Co-authorship network of Iranian papers in nanomedicine in years 2002 -2014.

this study is not the first to show the dominance of these countries in producing and publishing scientific profiles, other studies have also confirmed the productivity of these countries.[35] Although the majority of publications in the subject area (nanomedicine) in the WoS database was from the USA, but when the productivity of countries considered based on the number of inhabitants, it was showed that Singapore was the foremost country, which is not surprising since the national university of Singapore was the most productive organization among productive institutes in the field. The majority of prolific authors and organizations were from the USA, which is a clear indicative for the research focus of the American scientists on the nanomedicine field. English was the leading language of papers which is not unusual; since the editorial policy of this database focuses on selecting papers written in English since many years.[36] When the focus was on the most cited authors, it was found that T. J Webster and Si-shen Feng were the most prolific and most cited authors in this field (Table 6). This clearly indicates that the authors who had the most papers in the field of nanomedicine had more citation than others too. Map of the co-authorship network of nanomedicine indicated the strategic position of authors from different countries. The most strategically positioned authors in the global network (cut points) were T.J Webster from the University of Northeastern in USA who had authored 66 papers with a total number of 2140 citations in the WoS during the period of study; Si-shen Feng from National University of Singapore had authored 42 papers with a total number of 2126 citations; M Ferrari from CNRIFN in Italy); Si Stupp from the University of Northwestern; Guo Px (Kentucky) and V Castranova (West Virginia University). Without the work of these authors, the global network would be divided in some smaller components.

Considering the Iranian network of co-authorship revealed that Omidi, Dinarvand, Atyabi, Sorkhabadi, and Shahverdi were the cut points and had strategic positions to connect authors together in the network. Tehran University of Medical Sciences, Azad Islamic University, and Tarbiat Modarres University were the most prolific organizations in this field in Iran. Ninety-five percent of Iranian papers had 2 authors or more. Tendency towards co-authorship by Iranian authors was greater than single authorship in the field of nanomedicine. The study indicated that Iranian authors endeavored to involve doing researches in the field of nanomedicine through the

Table 6. Highly cited authors of papers in the field of nanomedicine in WoS in years 2002-2014

Authors	Citations	Institutions	Number of papers
Thomas J Webster	2140	University of Northeastern	66
Shishen Feng	2126	National University of Singapore	46
NJ Halas	1903	Rice University	5
JL West	1414	Duke University	5
Jv Frangioni	1201	Beth Israel Deaconess Medical Center	2
E Tanaka	1198	Ishikawa Prefectural University	1
JP Zimmer	1198	University of Ulm , Germany	1
BI Ipe	1198	Dortmund University , Germany	1
P Misra	1198	Beth Israel Deaconess Medical Center	1
HS Choi	1198	Hallym University , Korea	1
MG Bawendi	1198	Massachusetts Institute of Technology	1
W Liu	1198	Chinese Academy of Science	1
Lr Hirsch	1193	Rice University	2
VL Colvin	1166	Rice University	3
SM Nie	1125	Emory University and Georgia Institute of Technology	3

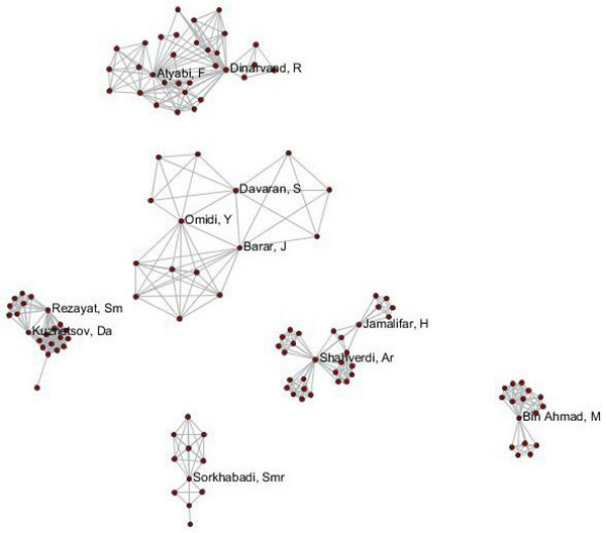

Fig. 6. Iranian co-authorship network in the field of nanomedicine in WoS in years 2002-2014.

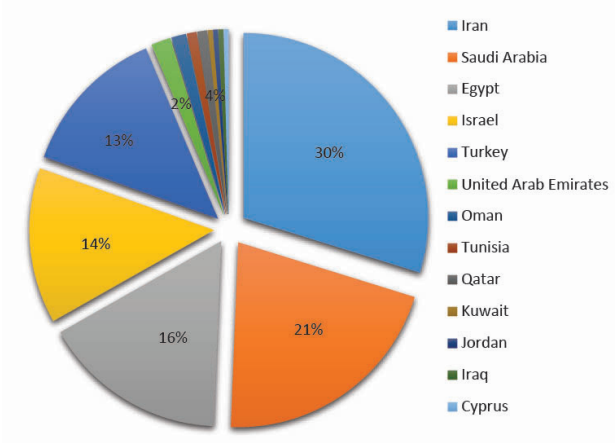

Fig.7. Scientific profiles of Middle East countries in the field of nanomedicine in WOS in years 2002-2014.

Scientific Analysis Highlights

What is current knowledge?

√ Nanomedicine is considered as a rapidly growing field of research and development of advanced medicines against various diseases worldwide.

What is new here?

√ The USA and China are the leading countries in the filed of nanomedicine researches.

√ Iranian scientists have markedly contributed in the nanomedicine researches.

√ Much more integration and contribution of Iranian scientists is expected in the field of nanomedicine research and development in the future.

period of study; therefore they stood in higher position in the ranks in Middle East countries.

Conclusion

The current work aimed at studying the impacts of the most influential scientists in the filed of nanomedicine research and development using co-authorship mapping approach. It was found that there has been a significant global attention in nanomedicine throughout the period of study (2002-2014). Iranian scientists showed outstanding cooperation in advancing researches in the field of nanomedicine, in which 95% of the scientific papers were collaboratively written by multi-authors from different institutions.

Ethical issues

None to be disclosed.

Competing interest

The authors declare no conflict of interests.

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