Original Article
http://mjiri.iums.ac.ir
Medical Journal of the Islamic Republic of Iran (MJIRI)

Med J Islam Repub Iran. 2023 (5 Apr);37.33. https://doi.org/10.47176/mjiri.37.33

Citation Analysis and Mapping of Iranian's Stem Cell Research Output

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Received: 14 May 2022 Published: 5 Apr 2023

Abstract

Background: This study aims to map the research trends in the field of stem cell research in Iran by presenting a systematic and analytical bibliometrics approach based on data from the Web of Science database.

Methods: In this study, we provide a visualization overview of the distribution of stem cell publications in Iran. The HistCite software was used to draw and analyze the historiographical maps, based on Global Citation Score (GSC) and Local Citation Score (LCS) in order to indicate the most frequent thematic trends. The accuracy of clustering and classification of scientific fields is enhanced by the incorporation of algorithms and main bibliometric analysis.

Results: A total of 5123 records were collected from the Web of Science database in 2020. The most prolific author had a GCS of 5890 and the most productive university earned GCS of 13677. "Cell Journal," with 186 records contributed the highest number of publications. The highest cited document based on GSC had a score of 646 and the highest cited article based on LCS had a score of 71. We documented regular growth in outputs. In addition, the scientific maps based on LCS and GCS have been drawn. The prominent, distinguished areas of study revolve around differentiation, generation, proliferation, and the therapeutic use of stem cells as well as "genotoxicity in stem cells", "mesenchymal stem cells" and "embryonic stem cells". Journal articles were the predominant document type.

Conclusion: Research on stem cells is a biomedical venture with great scientific impact, and its development in Iran is undeniable. This study provides an overview and a framework for the weaknesses and strengths of Iranian research outputs on stem cells, representing the main clusters in scientific maps. We hope that our results help researchers to plan future studies and promote their research productions.

Keywords: Scientometrics, Scientific map, Stem cells, Research, Web of Science, Iran

Conflicts of Interest: None declared
Funding: This study was funded and supported by Iran University of medical sciences (IUMS).

Cite this article as: Sedghi Sh, Ghaffari Heshajin S, Mousakhani Gh. Citation Analysis and Mapping of Iranian's Stem Cell Research Output. *Med J Islam Repub Iran.* 2023 (5 Apr);37:33. https://doi.org/10.47176/mjiri.37.33

Introduction

Scientometrics is a quantitative approach evaluating and analyzing scientific productions and their distribution (1-4). The most important techniques that are used in scientometric studies are science mapping and visualization techniques (5).

Special kinds of maps that help us understand the scientific environments and learn about the various research fields are scientific maps (6, 7). A definition provided by the Encyclopedia of Information Science and Technology, IGI Global, says: "Science mapping is the development and application of computational techniques to the visualization, analysis, and modeling of a broad range of scien-

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↑What is "already known" in this topic:
Stem cells are undifferentiated cells in the human body with the ability to divide in order to replenish dying cells. In recent years, research with stem cells has been a biomedical venture with great scientific impact, and its development in Iran is undeniable.

→What this article adds:
This study provides an overview of Iranian research outputs on stem cells, representing the main clusters in scientific maps. Our analysis reveals the publication patterns in the cases of document types, authors, institutions, etc., and provides an alternative demonstration of research advancements, which may serve as a potential guide for future research.

[DOI: 10.47176/mjiri.37.33]

tific and technological activities as a whole". If we want to have a visible overview of the scientific fields and understand them more clearly, verify the scientific concepts, have a general outlook of them, and have an updated awareness of the developments of the fields of science, we should use scientific maps (5, 6). In totally, "mapping of science is nothing but to represent complex, abstract or raw data in a visually understandable format" (5).

Among the techniques used for science mapping, visualization techniques are especially useful since they make the maps more informative and easier to understand (8). Visualization tools that create the maps through citation analysis provide the historical data covering the literature year by year (9). HistCite software is a tool for mapping the data obtained from the Science Citation Index (SCI) of the Web of Science (WOS) (5, 10). HistCite allows researchers to identify core papers in a particular subject; calculate the impact of specific authors, articles, and journals; and have regular literature of old and new scientific works (8, 11). In addition, HistCite produces several statistical indicators, including Global Citation Score (GCS); (the global number of citation scores to an article in WOS), Local Citation Score (LCS); (the frequency of local citations inside the collection), Total Global Citation Score (TGCS); (the total number of citation score to all the publications of an author or source in WOS in a special year), Total Local Citation Score (TLCS); (the total frequency of the local citation inside the collection in a special year) (5, 12-14).

On the other hand, a huge body of research has been dedicated to an emerging field of biomedical research: "stem cells". The stem cell topic is one of the most important biomedical research fields that an increasing number of researchers and practitioners are studying it as useful tools for regenerative medicine (15-17) or for the treatment of far incurable diseases (18) such as hematological, cardiovascular, neurodegenerative, and genetic disorders (15).

Due to the importance of stem cells in medical treatments, researchers and practitioners need to have a comprehensive and current reference for a huge body of scientific works in this field, and as stated beforehand, visualization tools and scientific maps can be useful tools for these objectives. In 2009, Li et al. predicted that the orientation of all stem cell research in the 21st century would be on "embryonic stem cell", "mesenchymal stem cell" and stem cell transplantation technology to human disease therapy (17). Cantos-Mateos in 2011 had similar results regarding the stem cell research output in Spain (18). Also, according to a recent study conducted by Gupta et al. in 2022, Iran is one of the most productive countries in publishing research results on the "application of stem cell therapy to covid-19" (19). Although some studies have been conducted on visualization of the research outputs in the field of stem cells in Iran, but we have not done a comprehensive study by identifying prominent areas and in-depth analysis of the study process. Therefore, we decided to conduct a scientometric study and draw a scientific map of the published literature relating to stem cells in Iran. We hope to identify and present the most important clusters in this field and identify its growth rate, the highly cited literature, main lines of research, authors, as well as institutions and journals. We hope that our study will be a baseline for researchers who are interested in studying stem cells to determine the panorama of stem cell research in Iran and plan further research directions.

The specific objectives of the present study address the following aspects:

1. To identify the most prolific Iranian authors, institutions, and journals on the topics of stem cells in WOS.
2. To identify the highly cited Iranian papers and literary works on the topics of stem cells in WOS.
3. To identify and analyze the rate of growth of Iranian author's productions on the topics of stem cells in WOS.
4. To identify the most important clusters in the scientific map of stem cells in Iran.
5. To identify the distribution of Iranian published literature on the topics of stem cells indexed in WOS.

This is a general assessment of research performance of a study field enriched by elements of structural analysis of Iranian's research output in stem cell research. Our goal was to elicit and introduce the main lines of research, authors, institutions, and journals, as well as the main clusters of the publications. To this end, we used bibliometric techniques and visualization tools to respond to the aims and objectives of the current study.

Methods

The current bibliometric study targeted a schematic view of the scientific map in stem cell research in Iran. The research involved the following steps for the scientific mapping of stem cell literature:

In the first step, we identified major terms and keywords representing the domain clearly. Also, we extracted equivalent headings from the Medical Subject Heading (MESH) of the National Library of Medicine. These were: Stem cell, Mother cell, Progenitor cell, and Colony-forming unit. In the next step, the keywords and search filters were used to search in the WOS database and locate the papers published by the author with the country affiliation of Iran by the end of 2020. The final dataset consists of a total of 5123 documents. We used HistCite as a capable tool in drawing the structure of science and providing detailed information about authors, journals, institutions, yearly output, distribution of documents, and so on. Because the maps were unclear or complex to analyze, so we preprocessed and enriched them by adding more attributes like colors, shapes, and changes in size and thickness. The last step was analyzing the results by exploring the maps and answering the research questions.

Literature review

There have been numerous studies conducted on drawing scientific maps by using visualization tools in order to analyze scientific works in various fields. Braam et al. (1991) developed a combination of co-citation and word analysis methods to evaluate scientific publications and improve the co-citation mapping procedure (20). Li et al. (2008) assessed the status of nanotechnology research output by using the bibliographic method, scientific map,

[DOI: 10.47176/mjiri.37.33]

and citation network analysis of the articles published in SCI from 1976 to 2004 (21).

Li et al. (2009) evaluated the global scientific production of stem cell research between 1991 and 2009. They assessed many aspects of the articles, including the exponential fitting of the trend of publication outputs, distribution of source titles, author keyword, and keyword plus analysis (17). Cantos-Mateos et al. (2012) used bibliometric indicators and techniques for analysis and visualization of Spain's scientific output in the field of stem cells from 1997 to 2007 based on a study of KeyWord Plus(18). Hariri et al. (2013) used co-citation analysis to discover and draw the scientific map of medical domains in Iran during 2003-2007 (6).

Ahmadi et al. (2014) examined the quality and quantity of stem cell research productions in Iran. They extracted 709 articles and proceedings indexed in WOS in order to extract information production patterns (16). Lin et al. (2015) assessed the pluripotent stem cell literature during the period from 1991 to 2012. Additionally, they identified highly cited articles in total citations and citations of the past two years (22). Ramin et al. (2016) conducted a study to analyze the scientific production in the field of glaucoma using the bibliometric method and scientific map during 1993-2013 (23). Rostami dovom et al. (2016) mapped the scientific publications on polycystic ovary syndrome in Iran and compared them with other countries' publications (7).

Muthukrishnan et al. (2017) used HistCite and CiteSpace software for mapping the scientific publication research productivity in the British journal of cancer during 2005-2015 (24). Ye et al. (2017) used HistCite software for bibliometric analysis of tuberculosis pleurisy based on the Web Of Science (25). Koo (2017) investigated the profile of original and reviewed articles on aromatherapy using bibliometric analysis. The article's visualization analysis showed three clusters of research topics, including essential oil, intervention, and complementary medicine (2). Ghaffari et al. (2017) conducted a study to analyze the scientific production in the field of intellectual property rights using HistCite software for scientific mapping during 2006- 2016 (26).

Scientific literature represents the knowledge produced in different fields by academia (21). Most of the reviewed research have used visualization techniques and scientific maps to evaluate the progress of scientific works. Science mapping and visualization techniques are used to explore scientific knowledge and intellectual concepts and display the structural relationships of scholarly articles (5). Totally they include both qualitative descriptions of scientific outputs and quantitative analysis (16).

Despite the high growth rate of stem cell research in Iran during the last decade (16), there have been few attempts to gather organized data on Iranian scientific production in this field. Therefore, the status of stem cell research development in Iran is investigated here using the literature documented in the Web of Science (WOS) database. In the present study, we used citation analysis and scientific map analysis in order to have a clear understanding of the trends of scientific production on the topic of stem cells in Iran and discover the network of relationships among authors and institutions.

Results

The original information source of this study was the Science Citation Index (SCI) of the Web of Science (WOS), where we extracted information about scientific outputs that Iranian researchers had published their findings on the topic of stem cell science. Our search resulted in 5123 documents on stem cells subject published by 12630 Iranian authors. In addition, 2611 Iranian universities and institutions, as well as 1248 journals, had contributed to producing stem cell research publications up to 2020.

According to Ho et al. (2003) stem cell research emerged in the world in 1981 (15), while our study shows that stem cell research in Iran started 11 years later in 1992 with 2 articles. However, the year 2018 has the higher rank in stem cell research output in Iran. We have selected the top 50 papers based on LCS and the top 70 documents based on GCS in order to make their chronological charts. Based on our findings, both LCS and GCS charts have two main clusters. In addition, based on LCS we have one smaller cluster and based on GCS two smaller clusters. In the following, we present our results according to the specific objectives of the study.

1. The most prolific authors

The findings revealed that 12630 Iranian authors had publications on stem cells in WOS up to 2020. Table 1 ranked 10 Iranian authors based on the number of publications on the study's subject.

According to Table 1, the most productive authors, Soleimani, Baharvand, and Ghavamzadeh, have outputs that surpass 245 documents. On the other hand, Soleimani has the first rank in TGCS and TLCS indicators.

The high difference between the rate of TLCS and TGCS in Table 1 is noteworthy. We can result that while stem cell research is passing its childhood time in Iran, this is a stable and more interesting subject in the world.

Our data show that the average number of documents per author is 0.4. In comparison with developed countries, this number is so low, while in Contos-Moteos et al. (2012) study the mean of documents per author in Spanish stem cell research was five and this number was stable over time (18). In addition, our author productivity analy-

Table 1. Most productive authors based on the number of publications

Author	No. of documents	Percent of documents	TLCS	TGCS
Soleimani M.	396	7.7%	1411	5890
Baharvand H.	325	6.3%	1144	5664
Ghavamzadeh A.	245	4.8%	148	1838
Alimoghaddam K.	144	2.8%	113	1315
Hamidieh AA.	119	2.3%	37	187
Aghdami N	102	2.0%	225	1379
Eslaminejad MB	92	1.8%	289	1245
Nasr-Esfahani MH	89	1.7%	173	2010
Ai J	88	1.7%	260	856
Mowla SJ	82	1.6%	284	1412

[DOI: 10.47176/mjiri.37.33]

sis revealed that a small group of authors had contributed a large number of publications on stem cell research in Iran. Among 12630 authors who authored or co-authored at least one document on the stem cells field, 8432 or 66.8% published only one document, 1763 or 13.9% contributed two documents, and 12161 or 96.3% contributed less than 10 publications each. Moreover, the top 469 or 3.7% of authors published more than ten documents each. These 469 authors have contributed a total of 10222 documents. This number is near twice our total documents and indicates that co-authorship is so high between authors. According to our investigations, among 5123 studied documents, only 79 have one author and the last 5044 documents have been written by at least two authors.

2. The most productive universities and institutions

Our search in the WOS database found that 2611 Iranian universities and institutions had scientific documents in the stem cell field up to 2020. Table 2 shows the top 15 most productive universities and institutions in the study's subject in Iran with more than 158 publications.

Table 2 shows that 24% of Iranian researchers' output in stem cells belonged to the Tehran University of Medical Sciences, followed by Tarbiat Modares University and Shahid Beheshti University of Medical Sciences with 15.2% and 11.4% of publications, respectively. In addition, Tehran University of Medical Sciences and ACECR has earned the highest rank in TLCS and TGCS between universities and institutions respectively.

Amongst the total of 2611 universities and institutions that participated in stem cell research output in Iran, 164 (6.3%) had published 10 or more documents. Whereas 1674 or 64.1% of these organizations, published only one document.

3. Journals that have the most publications on Iranian's stem cell research output

Iranian stem cell scientists published their works in 1248 journals listed in WOS. The top 15 journals with the most publications are presented in Table 3, and Iranians published 1209 or 23.6% of 5123 retrieved items in these journals.

According to Table 3, "Cell Journal" is in the first rank of journals with 3.6% of publications, followed by "Bone Marrow Transplantation" and "Journal of Cellular Physiology" with 2.8% and 2.4%, respectively. In addition, "Cell Journal" has scored the highest TLCS and TGCS. "Materials Science & Engineering C-Materials for Biological Applications" and "Plos One" have earned the next ranks in TGCS respectively. Also, "Cell Biology International" and "In Vitro Cellular & Developmental Biology-Animal" have scored second and third ranks in TLCS.

Further investigation of the journals indicated that 107 or 8.6% of journals had published 10 or more documents (2822 out of 5123 documents). Moreover, 664 or 53% of journals have published only one document on stem cell research (664 documents in 664 journals). These findings show that a small group of journals (15 titles presented in

Table 2. Most productive universities and institutions

Name	No. of documents	Percent of documents	TLCS	TGCS
Tehran University of Medical Sciences	1220	23.8%	2210	13677
Tarbiat Modares University	777	15.2%	1958	9159
Shahid Beheshti University of Medical Sciences	582	11.4%	1064	5290
ACECR	511	10.0%	995	6511
Islamic Azad University	479	9.3%	699	4760
University Tehran	468	9.1%	1037	5909
Iran University of Medical Sciences	347	6.8%	623	3075
Shiraz University of Medical Sciences	324	6.3%	332	2756
Tabriz University of Medical Sciences	322	6.3%	432	2567
Mashhad University of Medical Sciences	288	5.6%	384	2682
University Science & Culture	257	5.0%	715	3276
Stem Cell Technology Research Centre	214	4.2%	770	2812
Isfahan University of Medical Sciences	200	3.9%	354	2184
Pasteur Institute of Iran	198	3.9%	354	2533
Amirkabir University Technology	158	3.1%	398	2291

Table 3. Journals that have the most publications on Iranian's stem cell research output

Name	No. of documents	Percent of documents	TLCS	TGCS
Cell Journal	186	3.6%	208	1090
Bone Marrow Transplantation	144	2.8%	35	285
Journal Of Cellular Physiology	121	2.4%	134	542
Journal Of Cellular Biochemistry	114	2.2%	156	479
Iranian Journal Of Basic Medical Sciences	102	2.0%	181	507
Artificial Cells Nanomedicine And Biotechnology	72	1.4%	47	398
Materials Science & Engineering C-Materials For Biological Applications	70	1.4%	99	1055
Journal Of Biomedical Materials Research Part A	60	1.2%	131	736
Cell Biology International	58	1.1%	197	870
In Vitro Cellular & Developmental Biology-Animal	50	1.0%	193	590
Cytotherapy	49	1.0%	104	511
Plos One	47	0.9%	0	915
Archives Of Iranian Medicine	46	0.9%	83	724
Biology Of Blood And Marrow Transplantation	46	0.9%	15	131
Yakhteh	44	0.9%	63	137

[DOI: 10.47176/mjiri.37.33]

Table 3) has contributed a large number of publications on stem cell research in Iran.

4. The highly-cited documents

As stated earlier, we collected 5123 documents authored by Iranian researchers in the stem cell area in the WOS database. Tables 4 and 5 illustrate the top 10 highly cited items based on GCS and LCS, respectively.

As presented in Table 4, a paper authored by Ghasemi-Mobarakeh et al. in 2008 earned the first rank in the number of citations received. Ghasemi-Mobarakeh has a total of 16 papers with a total LCS score of 15 and a GCS of 1543. His highest GCS score is for the paper named "Electrospun poly (epsilon-caprolactone)/gelatin nanofibrous scaffolds for nerve tissue engineering" (GCS=646). This article was about the role of gelatin nanofibrous in nerve tissue engineering, and was published in "Biomaterials Journal". In addition, according to Table 4, the GCS of 3612 or 70.5% of documents, was less than 10, while 508 or 9.9% of publications, had a GCS of one, and 1228 or 24% had no GCS. Also, the GCS of 183 or 3.6% of documents was 50 and more.

According to Table 5, Baharvand et al.'s article is a highly cited document based on the LCS indicator. Balarvand has a total of 325 papers with a total LCS score of 1144 and a GCS of 5664. His highest LCS score is for an article named "Generation of new human embryonic stem cell lines with diploid and triploid karyotypes" (LCS =71). This article was about the derivation and characterization of five human pluripotent embryonic stem cell lines on mouse embryonic fibroblast cells and was published in the 'Development growth and differentiation journal' in 2006. According to our analysis, the LCS of 171, or 3.3% of documents was 10 and more, while 678 or 13.2% had

Table 4. Top 10 high GCS documents on stem cells in Iran up to 2020

Title	Author	Journal	Year	GCS	LCS
Electrospun poly(epsilon-caprolactone)/gelatin nanofibrous scaffolds for nerve tissue engineering	Ghasemi-Mobarakeh L et al.	Biomaterials	2008	646	0
Braveheart, a Long Noncoding RNA Required for Cardiovascular Lineage Commitment	Tabebordbar M et al.	Cell	2013	483	2
Aging of mesenchymal stem cell in vitro	Bonab MM et al.	Bmc Cell Biology	2006	424	0
A protocol for isolation and culture of mesenchymal stem cells from mouse bone marrow	Soleimani M et al.	Nature Protocols	2009	390	24
Aspergillus flavus: human pathogen, allergen and mycotoxin producer	Hedayati MT et al.	Microbiology-Sgm	2007	385	0
Size-dependent genotoxicity of graphene nanoplatelets in human stem cells	Akhavan O et al.	Biomaterials	2012	364	36
Health-related quality of life in breast cancer patients: A bibliographic review of the literature from 1974 to 2007	Montazeri A	Journal of Experimental & Clinical Cancer Research	2008	341	0
Properties of the amniotic membrane for potential use in tissue engineering	Niknejad H et al.	European Cells & Materials	2008	297	21
HAX1 deficiency causes autosomal recessive severe congenital neutropenia (Kostmann disease)	Rezaei N et al.	Nature Genetics	2007	281	3
Screening ethnically diverse human embryonic stem cells identifies a chromosome 20 minimal amplicon conferring growth advantage	Baharvand H et al.	Nature Biotechnology	2011	277	2

Table 5. Top 10 high LCS documents on stem cells in Iran up to 2020

Title	Author	Journal	Year	LCS	GCS
Generation of new human embryonic stem cell lines with diploid and triploid karyotypes	Baharvand H et al.	Development Growth & Differentiation	2006	71	103
Culture condition difference for the establishment of new embryonic stem cell lines from the C57BL/6 and BALB/c mouse strains	Baharvand H et al.	In Vitro Cellular & Developmental Biology-Animal	2004	39	71
Murine mesenchymal stem cells isolated by a low-density primary culture system	Eslaminejad MB et al.	Development Growth & Differentiation	2006	38	79
Size-dependent genotoxicity of graphene nanoplatelets in human stem cells	Akhavan O et al.	Biomaterials	2012	36	364
Differentiation of human embryonic stem cells into hepatocytes in 2D and 3D culture systems in vitro	Baharvand H et al.	International Journal of Developmental Biology	2006	35	224
Nanohydroxyapatite-Coated Electrospun Poly(L-lactide) Nanofibers Enhance Osteogenic	Seyedjafari E et al.	Biomacromolecules	2010	34	106
Feeder- and serum-free establishment and expansion of human-induced pluripotent stem cells	Totonchi M et al.	International Journal of Developmental Biology	2010	32	63
The Healing Effect of Stem Cells Loaded in Nanofibrous Scaffolds on Full Thickness Skin Defects	Biazar E et al.	Journal Of Biomedical Nanotechnology	2013	30	45
Nanofiber-based polyethersulfone scaffold and efficient differentiation of human induced pluripotent stem cells into osteoblastic lineage	Ardeshirylajimi A et al.	Molecular Biology Reports	2013	28	48
Graphene nanogrids for selective and fast osteogenic differentiation of human mesenchymal stem cells	Alzhavan O et al.	Carbon	2013	28	125

[DOI: 10.47176/mjiri.37.33]

LCS of one, and 3168 or 61.8% had no LCS.

5. The growth of scientific output of Iran on the topic of stem cell

The stem cell research emerged in the world in 1981 with publications in the U.S.A., Japan, Germany, the U.K., France, Italy, and Canada (15), however; according to Table 6 and Figure 1, this began in Iran with 2 documents in 1992. Although the first article about stem cell research in Iran was published in 1992, the number of publications in this field increased significantly in 2004 and afterward. This confirms that the research about stem cells in Iran is recent. However considering the publication's number after 2004, its growth rate is fast.

Since 2004, stem cell research has become one of the most important and dynamic fields of medical research in Iran. Based on Table 6 and Figure 1, there is regular growth in the stem cell's scientific output. The thresholds of documents we encountered were 2 documents for the year 1992 and 515 documents for 2019, showing a significant increase over 3 decades. The period from the year 1992 to 2003 shows the lowest rate of production with less than 4 documents for each year. In addition, the year 2018 had the highest rate of production, with 823 documents. Particularly noteworthy is the year 2014, with the highest TLCS and TGCS.

6. Historiography analysis of highly cited papers

In the present study, we attempted to trace the evolution of the stem cell research output in Iran by constructing historiography using the HistCite software. We exported 5123 records into HistCite to obtain their historiography based on local and global citation scores (LCS; GCS). The top 50 papers with LCS citations were selected to make

Table 6. The growth of stem cell scientific output in Iran up to 2020

Year	No. of documents (percent)	TLCS	TGCS
1992	2 (0.0%)	0	38
1995	1 (0.0%)	2	7
1996	1 (0.0%)	0	2
1998	2 (0.0%)	0	13
1999	2 (0.0%)	0	8
2000	1 (0.0%)	0	31
2003	4 (0.1%)	1	220
2004	21 (0.4%)	86	333
2005	34 (0.7%)	68	829
2006	45 (0.9%)	234	1495
2007	83 (1.6%)	246	3114
2008	106 (2.1%)	298	2989
2009	136 (2.7%)	333	2668
2010	189 (3.7%)	459	3079
2011	257 (5.0%)	580	5652
2012	283 (5.5%)	731	4827
2013	343 (6.7%)	943	6003
2014	418 (8.2%)	953	6314
2015	508 (9.9%)	790	5533
2016	631 (12.3%)	855	6123
2017	714 (13.9%)	690	3966
2018	823 (16.1%)	455	2465
2019	515 (10.1%)	32	244
Total	5123	-	-

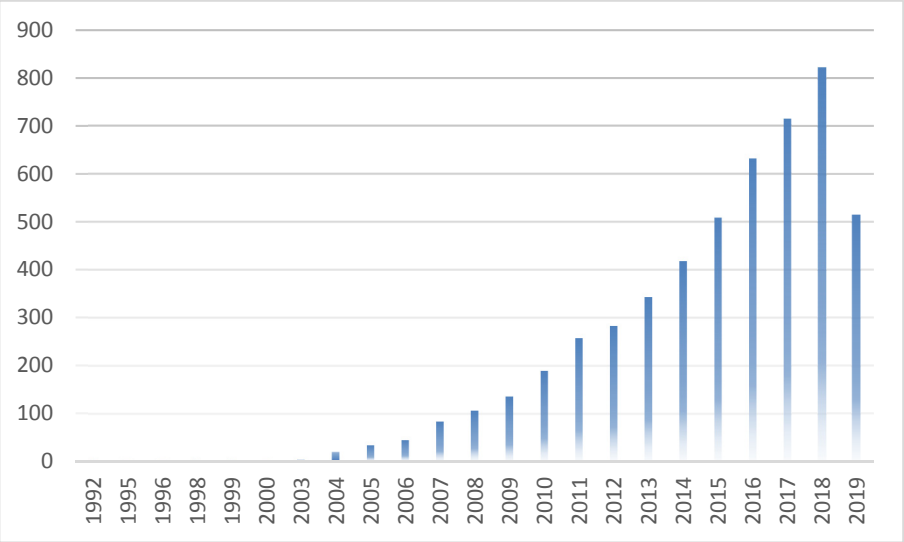

Figure 1. The growth of the documents with stem cell scientific output in Iran

[DOI: 10.47176/mjiri.37.33]

LCS chronological chart (Figure 2), and the top 70 documents with GCS citations were selected to make GCS chronological chart (Figure 3). Each chart has two clusters based on citations between the documents. The documents are indicated in numbered circles. The size of the circles represents the average number of citations received by the document.

The arrow's direction resembles the citations to or from other documents. The most primitive documents are at the top of the histogram, and the recent ones are at the bottom of the graphs.

The LCS chronological chart for stem cell research output up to 2020, including 50 nodes and 52 links, has two main clusters: The first illustrates 21 highly cited documents during the period from 2004 to 2015. Document 81 in our experiment, named "Generation of new human embryonic stem cell lines with diploid and triploid karyotypes," and written by Baharvand et al. in 2006 in "Development Growth and Differentiation" journal with an LCS score of 71 was the first in total ranking of this cluster. Whereas the lowest LCS in this cluster belonged to document 501, authored by Pakzad et al. with an LCS of 17. This article named "Presence of a ROCK Inhibitor in Extracellular Matrix Supports More Undifferentiated Growth of Feeder-Free Human Embryonic and Induced Pluripotent Stem Cells upon Passaging" and published in "Stem Cell Reviews and Reports" journal in 2010. The overall topic of this cluster was the "generation of human embryonic stem cell lines".

The second cluster of LCS presented the publication between 2012 and 2014. This cluster has 6 nodes. The highest score for LCS in this cluster belonged to document 1137, with an LCS of 36. Akhavan et al. published this work on "size-dependent genotoxicity of graphene nanoplatelets in human stem cells" in the "Biomaterials" journal in 2012. Documents number 1193 and 1574, published by Akhavan et al. in 2013, and Akhavan et al. in 2014, have the lowest LCS of 23. The titles of these two articles are "Differentiation of human neural stem cells into neural networks on graphene nanogrids" and "Accelerated differentiation of neural stem cells into neurons on ginseng-reduced graphene oxide sheets" and are presented in "Journal of Materials Chemistry" and "Carbon" journal, respectively. "Genotoxicity in stem cells" and "differentiation of neural stem cells" were the prominent topics in this cluster.

Our investigation revealed that the LCS chronological chart has one smaller cluster with 5 nodes during the period from 2008 to 2012. The documents in this cluster have similar LCS rates: the highest is LCS 21(document 253) and the lowest is 17 (document 931). The other 3 articles have LCS of 18, each. The document 253, authored by Jafarian et al. on "Marrow-derived mesenchymal stem cells-directed bone regeneration in the dog mandible: a comparison between biphasic calcium phosphate and natural bone mineral" and published in "Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology" in 2008. In addition, Behnia et al. brought out document 931 on "Repair of alveolar cleft defect with mesenchymal stem cells and platelet-derived growth factors: A preliminary report" and published in "The Journal of Craniomaxillofacial Surgery" in 2012. Using of "mesenchymal stem cells" in the repair of defective bones was a prominent topic in this cluster.

In this chart, the lowest LCS is 17 (documents 232, 501, 931, 1157), and the highest LCS is 71 (document 81).

The GCS chart for stem cell research output up to 2020, including 70 nodes and 44 links, has two main clusters: The first cluster illustrates 7 highly cited documents during the period from 2005 to 2011. Document 879, named "Screening ethnically diverse human embryonic stem cells identifies a chromosome 20 minimal amplicon conferring growth advantage," and written by Baharvand et al. in 2011 in "Nature Biotechnology" journal, with a GCS score of 277 was the first in total ranking of this cluster. In comparison, the lowest Global Citation Score is obtained by document 756 (GCS = 88) coauthored by Soltanian & Matin in 2011. This article's title is "Cancer stem cells and cancer therapy," and published in "Tumor Biology" journal. The overall topic of this cluster was the "differentiation of human embryonic stem cells" and "cancer therapy".

The second cluster of GCS has 8 nodes, and the highest score with GCS of 364 in this cluster is obtained by document 1137 by Akhavan et al. the title of the document is "Size-dependent genotoxicity of graphene nanoplatelets in human stem cells" and appeared in "Biomaterials" journal in 2012. In contrast, the lowest Global Citation Score in this cluster is 92 for document 1664, coauthored by Meidanchi & Akhavan in 2014. The authors named their paper "Superparamagnetic zinc ferrite spinel-graphene nanostructures for fast wastewater purification," and they published the paper in "CARBON" journal. This is interesting to note that documents with the highest GCS in the chart are out of the main clusters (Figure 3). "Genotoxicity and nanostructures of graphene" were the prominent topics in this cluster.

Moreover, there are two smaller clusters in the GCS chronological chart for stem cell research output in Iran; the first cluster has illustrated between 2005 and 2009. The highest GCS in this cluster belonged to the last document in this cluster (document 408), with a GCS of 229. The document named "Improvement of liver function in liver cirrhosis patients after autologous mesenchymal stem cell injection: a phase I-II clinical trial" and published by Kharaziha et al. in "Europian Journal of Gastroenterology & Hepatology". Document 54 in this cluster has the lowest GCS of 108. This document belonged to Baharvand et al. with the title "The effect of extracellular matrix on embryonic stem cell-derived cardiomyocytes" and was published in "The Journal of Molecular and Cellular Cardiology" in 2005. The overall topic in this cluster was "the effect of mesenchymal or embryonic stem cells on internal diseases".

The second small cluster had 3 articles in 2011 and one article in 2013. Document 683 done by Mohammadi et al. with the title "Magnetic Resonance Imaging Tracking of Stem Cells in Vivo Using Iron Oxide Nanoparticles as a Tool for the Advancement of Clinical Regenerative Medicine" published in "Chemical Reviews" has scored the

[DOI: 10.47176/mjiri.37.33]

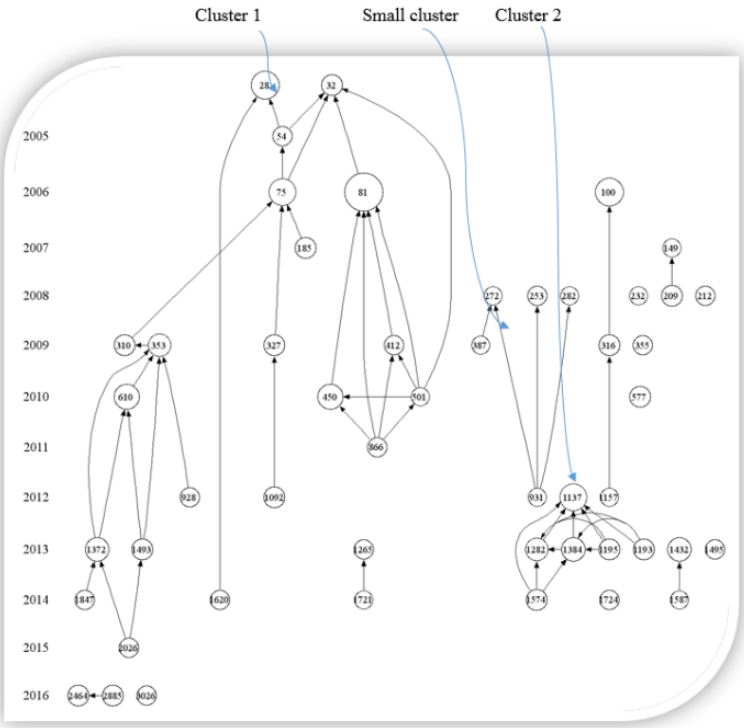

Figure 2. Citation chronological chart for documents based on LCS

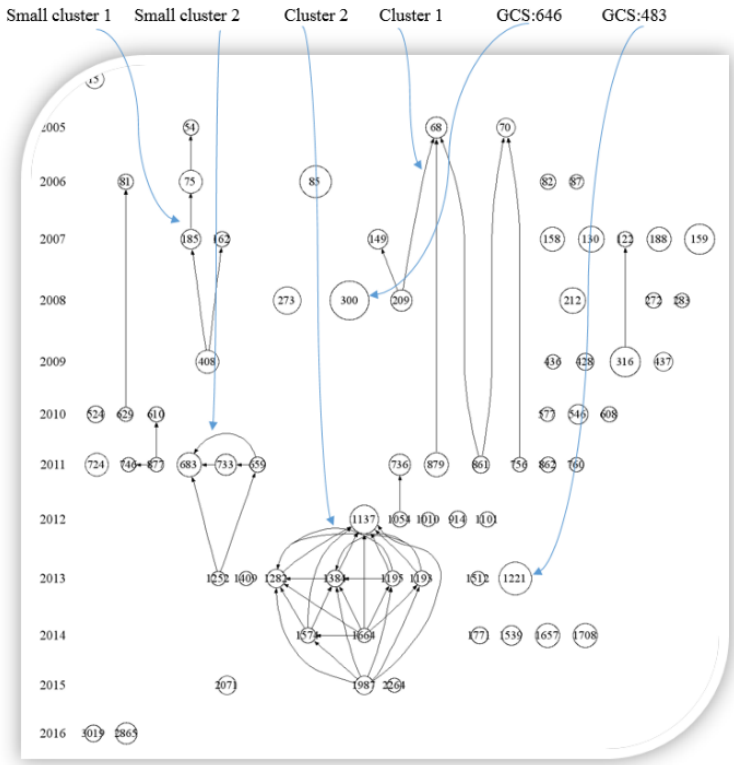

Figure 3. Citation chronological chart for documents based on GCS

highest GCS of 271. In addition, document 1252, written by Hagipour et al. with the title "Therapeutic Benefits from Nanoparticles: The Potential Significance of Nanoscience in Diseases with Compromise to the Blood Brain Barrier" published in "Chemical Reviews" has scored the lowest GCS of 90 in this cluster. This cluster was about "nanoparticles and their therapeutic effects".

In this chart, the lowest GCS is 87 (documents 87, 283), and the highest GCS is 646 (document 300).

7. Distribution of the document's type

Figure 4 presents the distribution of the type of docu-

[DOI: 10.47176/mjiri.37.33]

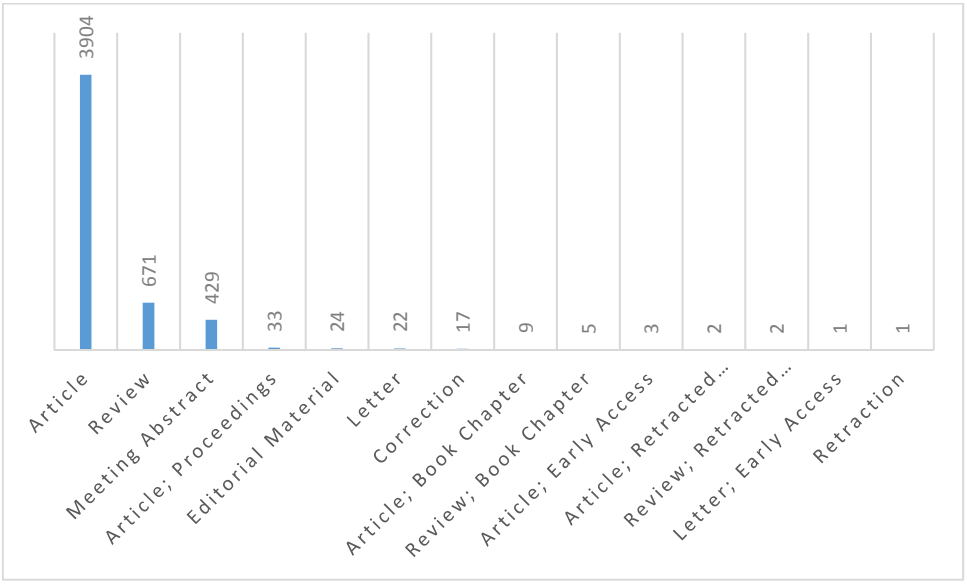

Figure 4. Types of documents

ments produced by Iranian researchers on the topic of stem cell. Of 5123 retrieved items, 76.2% were research articles, followed by 13.1% review articles, 8.4% meeting abstracts, 0.6% proceedings papers, 0.5% editorial materials, and other forms of publication. These findings strongly suggest that Iranian authors tend to disseminate their research findings through scientific journals rather than conferences, etc. This is interesting to note that the conferences are not contained in the studied documents. According the fact that conferences have the newest results of research and have a special place among the document types in scientific outputs, we suggest having a study about Iranian researchers' disinterestedness in contributing to conferences in the field of stem cells. However, it should be noted that one of the reasons may be related to the WOS criteria in the selection of conference papers; because according to WOS, the selection is mostly at the level of the publication and not the event (27).

Discussion

Research on stem cells is an emerging field of medical sciences that, due to its potential for the treatment of far incurable diseases, has attracted a great number of researchers (15). We analyzed the topic of stem cell research output in Iran up to 2020. The investigations exhibited in this study have allowed many results of broad observation on quantitative research on stem cells in Iran and allow us to draw profiles from different viewpoints.

Of 12630 authors on the list, "Soleimani" published the highest number of documents on stem cells with 396 records, followed by "Baharvand" with 325 records. "Soleimani" has the highest GCS of 5890, and the highest LCS of 1411, followed by "Baharvand" with a GCS of 5664, and an LCS of 1144. Thus we distinguished the highest-cited authors from the highest-published ones. Cantos-Mateos et al. (2012) analyzed Spain's stem cell research output during 1997-2007. In their study, the most productive authors' outputs were more than 120 documents (18). In Liu et al. (2011) study, the most productive authors in biodiversity research had 141 and 135 articles (28). In Kumaresan et al. (2014) study LO, C.F. with 60 records, LCS of 1266, and GCS of 1695, were in the first rank of the most productive authors (29). In Senthilkumar et al. (2016) study the most productive author had 80 records while one other author with 55 records had the highest GCS and LCS of 1451 and 56, respectively (30). In the present study and other studies(18, 28-30), a large number of documents have been published with the contribution of a small group of authors. It is noticeable that the authors in the present study have more published works and higher GCS and LCS in comparison with other relative studies.

Based on our findings, 2611 universities and institutions contributed to 5123 total research productivity on stem cells. It is noted that Tehran University of medical sciences with 1220 records, GCS of 13677, and LCS of 2210, contributed the highest number of productions. Moreover, Tarbiat Modares University with 777 records, GCS of 9159, and LCS of 1958, earned the second rank. In a study done by Louni (2014), we can see that Tehran University of medical sciences was the most productive university in pharmaceutical sciences in the Middle East during the study time (31). A study by Janmohammadi et al. (2012) showed that Tehran University of medical sciences contributed the highest number of papers in the orthopedic field from Iran (32).

Of 1248 journals on the list, "Cell Journal" with 186 records, LCS of 208, and GCS of 1098, contributed the highest number of publications. In Cantos-Mateos et al. (2012) study, the first journal in the list contributed to 13.8% of documents (18). In comparison, in our study, the first journal contributed to 3.6% of publications and it is noteworthy that in this study, the number of journals is significant (1248 journals for 5123 documents). However,

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the number of participating documents was too small (53% of investigated journals have published only one document).

The study found that out of 5123 documents on stem cell research in Iran, the most highly cited document based on GCS, published in 2008, has earned GCS of 646. In addition, the most highly cited document, according to LCS, was published in 2006 and had an LCS of 71. In Zhang and Feng's study, the most highly cited document on artificial blood vessels had an LCS of 257 and a GCS of 907 (33). Koo (2017) showed that the most highly cited article on aromatherapy during 1995-2014 had a GCS of 357 (2). In Kumaresan et al. (2014) study the most highly cited document on white spot syndrome virus, based on LCS, had LCS of 53, while based on GCS, the most highly cited document had a GCS of 79 (29). In comparison with other studies, the highly-cited documents in the present study have higher scores in GCS and LCS indicators in the study's subject.

The findings of research productivity in stem cells had the highest publication 823 in 2018, while based on LCS and GCS, the year 2014, with LCS of 953, and GCS of 6314, has the highest rank. In the years before 2004, we had the lowest number of publications, with less than 4 documents. In Cantos-Mateos et al. (2012) study, there was a sharp rise in stem cell research output in Spain between 1997 and 2007. The year 2007 showed the highest rate of production with 395 records, and 1997 showed the lowest with 94 records (18). We can see a visible difference between these two studies' starting years for emerging stem cell research. Therefore, we can say that stem cell research in Iran is younger than in Spain though its growth rate is fast.

The citation chronological chart for documents based on LCS had two main clusters. The first cluster had 21 nodes and its total subject was about "generation and differentiation of new embryonic stem cell lines in order to the treatment of diseases". The most highly cited document in this cluster had an LCS of 71. The second cluster with 6 nodes was about "using of graphene in generation and differentiation of human stem cell lines". The most highly cited document in this cluster had an LCS of 36. In addition, this chart has a smaller cluster with 5 nodes during the period from 2008 to 2012, with the highest LCS of 21 and the lowest LCS of 17. Moreover, the chronological citation chart for documents based on GCS had two main clusters. The first cluster had 7 nodes and its total subject was about "generation and differentiation of stem cells and embryonic stem cells for identifying and treatment of diseases". The most highly cited documents in this cluster had a GCS of 277. The second cluster had 8 nodes and was about "the role of graphene in the differentiation of human stem cells'. The most highly cited document in this cluster had a GCS of 1137. The GCS chronological chart has 2 smaller clusters; the first one has 5 nodes during the period from 2005 to 2009, with the highest GCS of 229 and the lowest GCS of 108. The second small cluster has 4 nodes during the period from 2011 to 2013, with the highest GCS of 271 and the lowest GCS of 90.

The source distribution of documents reveals the fact that the journal articles, with 76.2% occupied the predominant place among the other sources of documents. Other studies confirm the fact that journal articles are the most popular sources for publishing research outputs (1-3, 10, 34).

Limitations

We used the WOS database as a source for gathering our data about stem cell research output in Iran. The reason for choosing WOS is that it is one of the most comprehensive databases (35). In addition, WOS works with HistCite software (which we used for analyzing the data). Moreover, there is no database that covers all published works and that can evaluate all the relationships between them. WOS has some disadvantages: it often provides an underestimation of an academic's citation impact. WOS only includes citations to journal articles published in ISI-listed journals and does not include citations to books, book chapters, dissertations, theses, conference papers, reports, and journal articles published in non-ISI journals. This limitation is most noticeable in social sciences and humanities. However, in the stem cells field, this may give an approximately comprehensive picture.

The other problem with the data obtained from WOS is missing or incomplete data for academicians' names, affiliations, abbreviations, transliterated titles, names, etc. We removed the records with missing or incomplete data.

In addition, WOS has very limited coverage of non-English publications. Therefore, we may miss some significant publications on stem cell research published by Iranian researchers.

The last limitation of this study is that some recently published documents do not have high citation frequency and need adequate time to receive their citations. In addition, the results in this study are expansible because new documents are being published each day and changing the proposed histograms continually.

Conclusion

In this study, we provided an alternative perspective on Iranian researchers' trends in the stem cell field. We conducted a bibliometric analysis of the patterns of authorship, institutional and journal distribution, citation analysis based on GCS and LCS, and documents' types evolutions. Our results suggested that there has been a stable growth in stem cell research outputs in Iran with increasing documents, authors, and citations.

Differentiation, generation, proliferation, and the therapeutic use of stem cells as well as "genotoxicity in stem cells", "mesenchymal stem cells" and "embryonic stem cells" were the most frequently used subjects and study fields in stem cell research in Iran. The top 3.7% of authors, 6.3% of institutions, and 8.6% of journals were responsible for most total stem cells research output. We introduced the most prolific authors, institutions, and journals.

In the citation subject, we introduced the highly cited documents based on GCS and LCS. Also, citation chronological charts were drawn based on GCS and LCS, and the main clusters were identified and analyzed. At last, the

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types of 5123 published works on stem cell research in Iran were distinguished and research articles were realized as the predominant document type.

In conclusion, considering the importance of the stem cell field, this study provides a framework for the weaknesses and strengths of stem cell research in Iran. We hope that our results help researchers to plan future studies and promote their research productions.

Acknowledgments

This study was funded and supported by Iran university of medical sciences (IUMS).

Conflict of Interests

The authors declare that they have no competing interests.

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[DOI: 10.47176/mjiri.37.33]