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Bone Marrow Research in India: A Scientometric Study, 2003-12

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Abstract

Objectives: Analyses the Indian publications output in bone marrow research during 2003-12 on several parameters including contribution and citation impact of most productive countries, India's overall contribution, its growth pattern, citation impact, the share of international collaboration, identification of significant participating countries in India's international collaboration, contribution and impact of different types of bone marrow diseases, analyses of bone marrow research by sub-fields and by different population age groups, productivity and impact of leading Indian institutions and authors.

Methods: The Scopus Citation Database has been used to retrieve the data for 10 years (2003-12) by searching the keywords "bone marrow" in combined Title, Abstract and Keywords field.

Results: The Indian publications output in bone marrow research consisted of 2613 papers during 2003-12, which increased from 174 papers in 2003 to 397 papers in 2012, witnessing an annual average growth rate of 10.04%. The average citation impact per paper registered by Indian publications in bone marrow research was 2.84 during 2003-12, which decreased from 3.53 during 2003-07 to 2.47 during 2008-12. The international collaborative share of India in overall bone marrow research was 11.56% during 2003-12, which increased from 10.43% during 2003-07 to 12.18% during 2008-12.

Conclusions: Keeping in view the severity of bone marrow diseases, there is need to increase efforts in the R and D and improvement of supportive care and also need for establishing national data management infrastructure with updating/monitoring of registries along with better financial and social support initiatives in this area.

Keywords: Bibliometric; Bone marrow; Disease; Publication output; Scientometrics; India

Introduction

Bone marrow, the soft spongy tissue that lies within the hollow interior of long bones is mainly of two types- red bone marrow and yellow bone marrow. It forms around 4% of total body weight (around 2.6 kg in a healthy adult).The main role of bone marrow is to produce red blood cells, white blood cells, platelets, fat cells, granulocytes and lymphocytes [1]. When the bone marrow stops functioning, it produces various diseases which are classified into two major categories: acquired bone marrow failure and inherited bone marrow failure. Acquired bone marrow failure may be caused by a variety of factors including exposure to certain chemicals, environmental toxins, viruses, or by autoimmune responses. Acquired bone marrow failure diseases include aplastic anemia, myelodysplasia, paroxysmal nocturnal hemoglobinuria and pure red cell aplasia. Inherited forms of bone marrow failure arise from specific alterations or abnormalities of genes which include Fanconi anemia, dyskeratosis congenita, Shwachman-Diamond syndrome, and Diamond-Blackfan anemia [2]. For the examination of certain diseases like leukemia, multiple myeloma, myelodysplastic syndrome (MDS), myeloproliferative disorders (MPD), pancytopenia, anemia etc. bone marrow tissue is required. Although symptoms of bone marrow diseases vary but the treatments depend on the disorder which involve medicines, blood transfusions or a bone marrow transplant. With advent of medical science it is possible now to transplant the bone marrow in diseased individuals. This process has shown success in a number of cancer patients.

Among the bone marrow disorders, multiple myeloma is an unusual type of bone marrow cancer which is more aggressive in some people and its treatment varies from person to person. As per WHO estimates, there is approx 452000 incidence cases and 291000 deaths worldwide in respect of multiple myeloma [3]. In India, on the basis of NCRP data, it is estimated that for the year 2010, there will be about 14541 multiple myeloma cases, which are likely to increase to 21754 cases by the year 2020 [4]. Aplastic Anaemia is a rare type of bone marrow problem where the body fails to produce enough red blood cells, white blood cells, or platelets. It is not caused by lack of iron or any other vitamins. It is occasionally inherited but more often happens by chance, or as a result of certain medicines or infections. It often requires specialized treatment in hospital and young people may be offered a donor bone marrow transplant. It can strike people of any age, race, and gender. But it is more common among children, teenagers and also among older adults. The incidence of aplastic anemia peaks in people aged 20-25 years, and a subsequent peak is observed in people older than age 60 years [5]. The annual incidence of aplastic anemia in Europe is two cases per million populations and in USA incidence is 0.6-6.1 cases per million population; No accurate prospective data are available regarding the incidence of aplastic anemia in India. But it is thought to be more common in Asia than in the West [6]. Chronic myeloid leukemia (CML), also known as chronic myelogenous leukemia, is a type of cancer that starts in the blood-forming cells of the bone marrow and invades the blood. Chronic myelogenous leukemia represents 7–20% of all leukemia cases, with a worldwide incidence projected at less than one to two per 100,000 people [7]. As per NCI's SEER Cancer

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Statistics Review, it is estimated that 5,430 people (3,210 men and 2,220 women) will be diagnosed with and 610 men and women will die of chronic myeloid leukemia in 2012. On the basis of cases diagnosed in 2005-2009 from 18 SEER geographic areas incidence rate was 1.6 per 100,000 men and women per year [8].

Acute myeloid leukemia (AML) is a cancer that starts in the cells that are supposed to mature into different types of blood cells. AML starts in the bone marrow and in most cases it quickly moves into the blood. It can sometimes spread to other parts of the body including the lymph nodes, liver, spleen, central nervous system and testicles. In contrast, other types of cancer can start in these organs and then spread to the bone marrow [9]. As per NCI's SEER Cancer Statistics Review, it is estimated that 13,780 men and women (7,350 men and 6,430 women) will be diagnosed with and 10,200 men and women will die of acute myeloid leukemia in 2012. On the basis of cases diagnosed in 2005-2009 from 18 SEER geographic areas the incidence rate was 3.6 per 100,000 men and women per year and the median age at diagnosis for acute myeloid leukemia was 66 years of age [10]. Acute lymphocytic leukemia (ALL), also called acute lymphoblastic leukemia, is a cancer that starts from white blood cells called lymphocytes in the bone marrow. As per NCI's SEER Cancer Statistics Review, it is estimated that 6,050 people (3,450 men and 2,600 women) will be diagnosed with and 1,440 people will die of acute lymphocytic leukemia in 2012. On the basis of cases diagnosed in 2005-2009 from 18 SEER geographic areas the median age at diagnosis for acute lymphocytic leukemia was 14 years of age and incidence rate was 1.6 per 100,000 people per year [11]. In India, Leukemia is the most common childhood cancer, being 25 to 40% of all childhood cancers with 60-85% being ALL and the survival rates for ALL in children is 45% to 55% compared to 60 to 85% in Europe and USA [12].

Bone marrow transplantation is today a life-saving treatment for many incurable diseases like leukemia, aplastic anemia, bone marrow dysplasia, CML and other such disorders. In India, there are thousands of patients with these disorders who could benefit from bone marrow transplantation. Several studies have suggested that allogeneic bone marrow transplantation offers the better chance of cure than conventional chemotherapy. The number of allogeneic bone marrow transplantations carried out in India has been growing steadily in the last decades. As per the data from the Indian Transplant Registry, from negligible numbers in 1990, it has gone up to 2445 allogeneic transplants in 2010, of which, 26% were for thalassemia and other hemoglobinopathies, 18% for aplastic anemia, and 50% for various types of leukemias. At present, India has several private and one major Public Reliance cord blood bank in Mumbai. There are two bone marrow registries in India, DATRI and Marrow Donor Registry India (MDRI) with around 20,000 donors registered with them [12].

Redaelli et.al [7] summaries identify and evaluate the English language articles published between 1990 to 2002 for chronic myeloid leukemia (CML) to describe the clinical epidemiology and treatment patterns of CML literature. Redaelli [13] has conducted a systematic review of relevant studies published in the English language and made the economic analyses of acute myeloid leukemia (AML) published between 1990 and 2002 from electronic data sources using broad search criteria. The published studies investigated pharmacological agents, combination therapies as well as BMT, PBSCT, and the treatment of complications. But there are no specific studies available in the literature dealing with scientometric analysis of publications in the area of bone marrow research. However, the authors have carried out similar scientometric studies in Indian context on other diseases such as tuberculosis [14], malaria [15], asthma [16], measles [17] and diabetes [18,19].

Objectives

The main objective of this study is to analyze the bone marrow research output in India during 2003-12. The study has the following objectives: (i) To study the contribution and citation impact of top 15 most productive countries, (ii) To study the India's overall contribution, its growth pattern and citation impact, (iii) to study the share of international collaboration in India's overall research output and identification and contribution of leading countries; (iv) To study Indian contribution and impact of different types of bone marrow diseases, bone marrow research by sub-fields and by different age groups and (v) To study the productivity and impact of leading Indian institutions and authors .

Methodologies and Source of Data

This study used Scopus International Database [http://www.scopus.com/search] to extract relevant data on bone marrow research of India and other 15 most productive countries for the 10 years (2003-12). An advanced search strategy involving "bone marrow" as the keyword was used to search and download data using Title, Abstract and Keywords field, resulting in downloading of 2613 records related to Indian bone marrow research. Separate strategies were developed in terms of keywords for identifying different types of bone marrow diseases, bone marrow research output by sub-fields and by different age groups. For analyzing significant institutions and authors separate search strategies were developed, which later combined with the main string lead to the generation of the desired output. For citations data, three years, two years, one year and zero year citation windows have been used for computing average citations per paper in bone marrow research during 2003-09, 2010, 2011 and 2012. For example, for papers published in 2003, citation window is three years from 2003-06. For papers published in 2010, citation window is two years from 2010-2012 and for papers published in 2011 citation window is one year 2011-12.

Analysis

Global publication share and rank

The global publication share of the top 15 most productive countries in bone marrow research varies from 1.74% to 32.74% during 2003-12. The United States tops the list, with a share of 32.74% during 2003-12. The China rank at second position with 8.59% share, followed by Japan (8.30%, 3rd rank), Germany (7.45%, 4th rank), U.K. (6.47%, 5th rank), Italy (5.55%, 6th rank), France (4.42%, 7th rank), Canada, Netherlands, Spain, India, Australia and South Korea ranks from 8th to 13th position (with publication share from 2.20% to 3.26%) and Brazil and Switzerland (with publication share from 1.74% to 1.78%) (Table 1).

The largest increase in their publications share is shown by China by 9.04%, followed by South Korea (1.96%), India (1.44%), Brazil (1.17%), Australia (0.76%), Switzerland (0.24%), Italy (0.10%) and Spain (0.05%), as against decrease in USA by 3.20%, followed by Japan (1.26%), France (1.19%), U.K. (0.95%), Germany (0.53%), Netherlands (0.10%) and Canada (0.01%) from 2003-07 to 2008-12. All developing countries on the other hand, have shown rise in their publications share in bone marrow research. India ranks at 11th position among the top 15 most productive countries in bone marrow research with its global publications share of 2.34% during 2003-12. China, South Korea and, Brazil ranked at 2th, 13th and 14th positions, with global publications

Country	Number of Papers			Share of Papers		
	2003	2012	2003-12	2003-07	2008-12	2003-12
USA	3231	3767	36540	34.50	31.30	32.74
China	248	1407	9584	2.65	11.69	8.59
Japan	863	957	9267	9.21	7.95	8.30
Germany	714	853	8313	7.62	7.09	7.45
U.K.	660	734	7218	7.05	6.10	6.47
Italy	486	637	6197	5.19	5.29	5.55
France	481	476	4934	5.14	3.95	4.42
Canada	307	393	3642	3.28	3.27	3.26
Netherlands	256	317	2870	2.73	2.63	2.57
Spain	246	323	2675	2.63	2.68	2.40
India	174	397	2613	1.86	3.30	2.34
Australia	166	304	2559	1.77	2.53	2.29
South Korea	116	385	2451	1.24	3.20	2.20
Brazil	109	280	1984	1.16	2.33	1.78
Switzerland	145	215	1938	1.55	1.79	1.74
World	9366	12036	111610	100.00	100.00	100.00

Table 1: Publications output and share of top 15 countries in bone marrow research during 2003-2012.

Period	World	India				
	TP	TP	TC	ACPP	ICP	%ICP
2003	9366	174	503	2.89	13	7.47
2004	9705	168	543	3.23	20	11.90
2005	10503	191	769	4.03	24	12.57
2006	10821	186	643	3.46	20	10.75
2007	11035	211	824	3.91	20	9.48
2008	11537	255	1105	4.33	29	11.37
2009	11934	304	1370	4.51	35	11.51
2010	12181	326	995	3.05	29	8.90
2011	12492	401	567	1.41	46	11.47
2012	12036	397	113	0.28	66	16.62
2003-07	51430	930	3282	3.53	97	10.43
2008-12	60180	1683	4150	2.47	205	12.18
2003-12	111610	2613	7432	2.84	302	11.56

TP=Total Papers; TC=Total Citations; ACPP=Average Citations per Paper; ICP=International Collaborative Papers

Table 2: Contribution and impact of bone marrow research in India, 2003-2012.

share of 8.59%, 2.20% and 1.78%, respectively during 2003-12. India's global publications share increased from 1.86% to 3.30%, compared to China from 2.65% to 11.69%, South Korea from 1.24% to 3.20% and Brazil from 1.16% to 2.33% from 2003-07 to 2008-12 (Table 1).

India's publication output in bone marrow research

The world publication share in bone marrow research consisted of 111610 papers during 2003-12, which increased from 9366 papers in 2003 to 12036 papers in 2012 and witnessed an annual average growth rate of 2.87%. India's cumulative publication output in bone marrow research consisted of 2613 papers during 2003-12, which increased from 174 papers in 2003 to 397 papers in 2012, with an average productivity of 261.3 papers per year and an annual average growth rate of 10.04%. The cumulative publications output of India in bone marrow research increased from 930 papers during 2003-07 to 1683 papers during 2008-12, witnessing a growth of 80.97%. In terms of impact and citation quality, the average citation per paper registered by India's publication output was 2.84 during 2003-12, which decreased from 3.53 during 2003-07 to 2.47 during 2008-12 (Table 2).

International collaboration in India's publication output

The total number of Indian papers involving in international collaboration during 2003-12 was 302, which accounted for 11.56% share in the cumulative publications output of India in bone marrow research. The share of cumulative international collaborative publications of India in its total output witnessed an increase from 10.43% during 2003-07 to 12.18% during 2008-12 (Table 2). Among the major India's international collaborators, 15 countries have published 9 or more collaborative papers with India during 2003-12. United States was the major collaborating partner of India during 2003-12 accounting for 47.35% share of the total collaborative publications, followed by UK (with 10.60% share), Germany (7.95% share), Canada (6.29% share), Japan (5.96% share), Malaysia (5.63% share), Australia (5.30% share), France (4.97%), Italy (4.97%), Saudi Arabia (3..97%), South Korea, Belgium and Singapore (3.64% each),Switzerland (3.31% and Taiwan (2.98%). Among the 15 collaborating countries, the publication share has increased by 5.64% in Germany, followed by USA (4.45%), Taiwan (4.39%), Saudi Arabia (4.34%), Japan (4..23%), Malaysia (3.74%), Canada (3.2%), Switzerland (1.84%), France (1.25%), Belgium (0.81%) and Australia (0.22%), as against decrease in U.K. by 10.21% followed by Singapore (2.22%), Italy (1.80%) and South Korea (0.71%) from 2003-07 to 2008-12 (Table 3).

Bone marrow research output in context of different subjects

India's publication output in bone marrow research during 2003-12 has been published in context of 7 subjects (as reflected in database classification based on journal subject), with highest publications output coming from medicine (2001 papers and 76.58% publications share), followed by biochemistry, genetics and molecular biology (359 papers and 13.74% publications share), pharmacology, toxicology and pharmaceutics (132 papers and 5.05% publications share), immunology and microbiology (107 papers and 4.09% publications share), environment science (47 papers and 1.80% publications share), agricultural and biological sciences (45 papers and 1.72% publications share) and neurosciences (41 papers and 1.57% publications share) (Table 6). On analyzing the quality and impact of bone marrow research output under different subjects, it was found that immunology and

Collaborating Country	Number of International Collaborative Papers			Share of International Collaborative Papers		
	2003-07	2008-12	2003-12	2003-07	2008-12	2003-12
USA	43	100	143	44.33	48.78	47.35
U.K.	17	15	32	17.53	7.32	10.60
Germany	4	20	24	4.12	9.76	7.95
Canada	4	15	19	4.12	7.32	6.29
Japan	3	15	18	3.09	7.32	5.96
Malaysia	3	14	17	3.09	6.83	5.63
Australia	5	11	16	5.15	5.37	5.30
France	4	11	15	4.12	5.37	4.97
Italy	6	9	15	6.19	4.39	4.97
Saudi Arabia	1	11	12	1.03	5.37	3.97
South Korea	4	7	11	4.12	3.41	3.64
Belgium	3	8	11	3.09	3.90	3.64
Singapore	5	6	11	5.15	2.93	3.64
Switzerland	2	8	10	2.06	3.90	3.31
Taiwan	0	9	9	0.00	4.39	2.98
Total	97	205	302	100.00	100.00	100.00

Table 3: Indian collaboration with different countries in bone marrow research, 2003-12.

microbiology had scored the highest impact (5.91 citations per paper), followed by agricultural and biological sciences (5.40 citations per paper), neurosciences (3.68 citations per paper), biochemistry, genetics and molecular biology (3.53 citations per paper), environment science (3.15 citations per paper), pharmacology, toxicology and pharmaceutics (2.70 citations per paper) and medicine (1.79 citations per paper), etc (Table 4).

Research output in different type of bone marrow diseases

Among the various types of bone marrow diseases in India, the largest number of papers were from bone marrow cancer diseases, namely leukemia (675 papers, 25.83% share), multiple myeloma (353 papers, 13.51%) and lymphoma (268 papers, 10.26% share). Other important diseases include pancytopenia (152 papers, 5.82% share), aplastic anaemia (118 papers, 4.52% share), iron deficiency anaemia (Hemoglobinopathies) (44 papers, 1.68% share), metabolic bone disease (33 papers, 1.26% share), myelodysplastic syndrome (MDS) (32 papers, 1.22% share) and other diseases contributing less than one percent publication share. In terms of citation impact per paper, the largest impact (4.90) was made by mast cell disease, followed by metabolic bone disease (3.21), multiple myeloma (2.34), fanconi anaemia (2.16), iron deficiency anaemia (hemoglobinopathies) (2.0), leukemia (1.93), aplastic anaemia (1.76), lymphoma (1.73) etc. (Table 5).

Bone marrow research output by different population age group

The major focus of India's publication output in bone marrow research by population age group during 2003-12 has been on adults (851 papers, 32.57% share), followed by child (431 papers, 16.49% share), middle aged (327 papers, 12.51% share), adolescent (316 papers, 12.09% share) and aged (254 papers, 9.72% share). The focus of bone marrow research has increased in case of child from 14.73% to 17.47%, as against decrease in adults (from 32.80% to 32.44%), middle aged (from 15.48% to 10.87%), adolescent (from 12.26% to 12.0%) and aged (from 11.18% to 8.91%) from 2003-07 to 2008-12 (Table 6).

Subject	2003-2012			
	TP	TC	ACPP	%TP
Medicine	2001	3583	1.79	76.58
Biochemistry, Genetics and Molecular Biology	359	1268	3.53	13.74
Pharmacology, Toxicology and Pharmaceutics	132	356	2.70	5.05
Immunology and Microbiology	107	632	5.91	4.09
Environment Science	47	148	3.15	1.80
Agricultural. and Biological Sciences	45	243	5.40	1.72
Neurosciences	41	151	3.68	1.57
Total	2613			

Table 4: Subject-Wise Break-up of Indian bone marrow research publications in India during 2003-2012.

Type of Disease	TP	TC	ACPP	%TP
Leukemia	675	1305	1.93	25.83
Multiple Myeloma	353	826	2.34	13.51
Lymphoma	268	464	1.73	10.26
Pancytopenia	152	223	1.47	5.82
Aplastic Anaemia	118	208	1.76	4.52
Iron Deficiency Anaemia (Hemoglobinopathies)	44	88	2.00	1.68
Metabolic Bone Disease	33	106	3.21	1.26
Myelodysplastic Syndrome (MDS)	32	39	1.22	1.22
Fanconi Anemia	25	54	2.16	0.96
Pure Red Cell Aplasia	23	37	1.61	0.88
Cytopenia	13	13	1.00	0.50
Mast Cell Disease	10	49	4.90	0.38
Paroxysmal Nocturnal Hemoglobinuria	9	12	1.33	0.34
Primary Amyloidosis	8	7	0.88	0.31
Dyskeratosis Congentia	6	10	1.67	0.23
Total	2613			

Table 5: Classification of Indian bone marrow literature by type of disease during 2003-12.

Population by Age Group	Number of Papers			% Share of Papers		
	2003-07	2008-12	2003-12	2003-07	2008-12	2003-12
Adult	305	546	851	32.80	32.44	32.57
Child	137	294	431	14.73	17.47	16.49
Middle Aged	144	183	327	15.48	10.87	12.51
Adolescent	114	202	316	12.26	12.00	12.09
Aged	104	150	254	11.18	8.91	9.72
Total	930	1683	2613	100.00	100.00	100.00

Table 6: Bone marrow research output by different population age group, 2003-12.

S.No.	Name	TP	TC	ACPP	H-Index
1	All India Institute of Medical Science, New Delhi	270	593	2.20	17
2	Postgraduate Institute of Medical Education and Research, Chandigarh	153	245	1.60	8
3	Tata Memorial Hospital, Mumbai	96	271	2.82	11
4	Christian Medical College, Vellore	70	268	3.83	12
5	Sanjay Gandhi Postgraduate Institute of Medical Research, Lucknow	60	159	2.65	11
6	Maulana Azad Medical College, Delhi	51	90	1.76	5
7	Amla Cancer Hospital and Research Center, Trissur, Kerala	48	221	4.60	12
8	King Edward Memorial Hospital, Mumbai	45	161	3.58	9
9	Kasturba Medical College, Manipal	43	133	3.09	11
10	Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry	34	18	0.53	3
11	Lady Harding Medical College, New Delhi	33	42	1.27	5
12	Institute of Medical Sciences, Banaras Hindu University, Varanasi	32	125	3.91	6
13	Annamalai University	28	132	4.71	11
14	Indian Institute of Chemical Biology, Kolkata	27	204	7.56	12
15	National Centre for Cell Science, Pune	27	254	9.41	10
	Total	1017	2916	2.87	9.53
	Total of India	2613			
	Share of Top 15 Institutions in India's Output	38.92			
TP =Total Papers; TC = Total Citations; ACPP = Average Citations Per Paper					

Table 7: Productivity and citation impact of top fifteen indian institutions in bone marrow research, 2003-2012.

Research profile of most productive Indian institutions in bone marrow research in India

The top 15 most productive Indian institutions involved in bone marrow research have published 27 and more papers each during 2003-12. The publications profile of these 15 Indian institutions along with their research output, citations received and h-index values are presented in table 7. These 15 institutions involved in bone marrow research together have contributed 38.92% share (with 1017 papers)

S.No	Name	Address	TP	TC	ACPP	H- Index
1	N.Varma	Postgraduate Institute of Medical Education and Research, Chandigarh	43	82	1.91	6
2	M.Mahapatra	All India Institute of Medical Science, New Delhi	37	44	1.19	5
3	S.Bakshi	All India Institute of Medical Science, New Delhi	37	70	1.89	6
4	R.Saxena	All India Institute of Medical Science, New Delhi	34	69	2.03	6
5	T.Singh	Maulana Azad Medical College, Delhi	33	34	1.03	4
6	R.K.Marwaha	Postgraduate Institute of Medical Education and Research, Chandigarh	32	40	1.25	5
7	G.Kuttan	Amla Cancer Hospital and Research Center, Trissur, Kerala	29	143	4.93	10
8	R.Das	Postgraduate Institute of Medical Education and Research, Chandigarh	28	47	1.68	5
9	R.Kumar	All India Institute of Medical Science, New Delhi	28	22	0.79	3
10	J.Ahluwalia	Postgraduate Institute of Medical Education and Research, Chandigarh	27	39	1.44	4
11	K.Kumar	All India Institute of Medical Science, New Delhi	27	48	1.78	5
12	S.Varma	Postgraduate Institute of Medical Education and Research, Chandigarh	26	31	1.19	5
13	K.Ghosh	Institute of Immunohaematology, Mumbai	25	72	2.88	5
14	P.Malhotra	Postgraduate Institute of Medical Education and Research, Chandigarh	23	30	1.30	4
15	A. Srivastava	Christian Medical College, Vellore	22	100	4.55	7
		Total	451	871	1.93	5.33
		Total of India	2613			

Table 8: Productivity and citation impact of india's top twenty authors in bone marrow research, 2003-2012.

in the cumulative publications output of India in bone marrow, with an average of 67.8 papers per institution. Only four institutions have registered higher publications than the group average. These are All India Institute of Medical Sciences, New Delhi with 270 papers, followed Post Graduate Institute of Medical Education and Research, Chandigarh (153 papers), Tata Memorial Hospital, Mumbai (96 papers) and Christian Medical College, Vellore (70 papers). The average citation per paper registered by the total papers of these 15 institutions is 2.87 during 2003-12. Eight Indian institutions have registered higher citation impact than the group average. Amongst these eight Indian institutions, the highest impact of 9.41 citations per paper was scored by the National Centre for Cell Science, Pune followed by Indian Institute of Chemical Biology, Kolkata (7.56 citations per paper), Annamalai University (4.71 citations per paper), Amla Cancer Hospital and Research Center, Trissur, Kerala (4.60 citations per paper) , Institute of Medical Sciences, Banaras Hindu University, Varanasi (3.91 citations per paper), Christian Medical College, Vellore (3.83), King Edward Memorial Hospital, Mumbai (3.58) and Kasturba Medical College, Manipal (3.09 citations per paper). The average h-index value of these 15 most productive institutions was 9.53 during 2003-12. Nine Indian institutions have scored higher h-index value than group's average of 9.53. Amongst these nine Indian institutions, the highest h-index value (17) was achieved by All India Institute of Medical Science, New Delhi followed by Indian Institute of Chemical Biology, Kolkata, Amla Cancer Hospital and Research Center, Trissur, Kerala and Christian Medical College, Vellore (12 each), Annamalai University, Kasturba Medical College, Manipal, Tata Memorial Hospital, Mumbai and Sanjay Gandhi Postgraduate Institute of Medical Research, Lucknow (11 each) and National Centre for Cell Science, Pune (10) (Table 7).

Contributions and impact of most productive Indian authors in bone marrow research

Fifteen authors have been identified as most productive, who have published 22 and above papers in bone marrow research. The publications profile of these 15 authors along with their research output, citations received and h-index values are presented in table 8. These 15 authors together contributed 451 papers with an average of 30.07 papers per author and account for 17.26% share in the cumulative Indian publications output during 2003-12. Six authors have published higher number of papers than the group average (30.07). These are: N. Varma with 43 papers, followed by M. Mahapatra and S. Bakshi (37 papers each), R. Saxena (34 papers), T. Singh (33 papers) and R.K. Marwaha (32 papers). Considering the quality/impact of papers, these 15 productive authors have received a total of 871 citations for 451 papers with an average of 1.93 citations per paper. Four authors have registered higher impact than the average impact of papers of all authors (1.93). These are: G. Kuttan with 4.93 citations per paper, A. Srivastava (4.55 citations per paper), K. Ghosh (2.88 citations per paper) and R. Saxena (2.03 citations per paper). Measuring the performance of these authors on the basis of h- index, five authors have achieved the higher h-index value than the group average of 5.33. These authors G. Kuttan with h-index of 10, followed by A. Srivastava (7), R. Saxena , N. Varma and S. Bakshi (6 each) (Table 8).

Summary and Conclusion

India has published 2613 papers in bone marrow research during 2003-12, which has increased from 174 papers in 2003 to 397 papers in 2012, witnessing an annual average growth rate of 10.04%. In terms of impact and citation quality, the average citation per paper registered by Indian publication output was 2.84 during 2003-12, which has decreased from 3.53 during 2003-07 to 2.47 during 2008-12. India is ranked at 11th position among the top 15 most productive countries in bone marrow research, with its global publication share of 2.34% during 2003-12. India's global publications share increased from 1.86% during 2003-07 to 3.30% during 2008-12. The international collaborative papers share of India in bone marrow research was 11.56% during 2003-12, which has increased from 10.43% during 2003-07 to 12.18% during 2008-12. Among the international collaborator's, United States was India's major collaborator with 47.35% share of international collaborative papers.

Among the various types of bone marrow diseases in India during 2003-12, the largest contribution (675 papers, 25.83% share) was from leukemia and largest citation impact of 4.90 citations per paper was made by mast cell disease. The major focus of Indian bone marrow research by population age groups in terms of research output during 2003-12 was on adults (851 papers, 32.57% share. The focus of bone marrow research has increased in case of child from 14.73% to 17.47% , as against the decrease in other population age groups from 2003-07 to 2008-12. Among the subfield wise distribution of Indian bone marrow

research during 2003-12, the largest contribution (76.58% share) comes from medicine and immunology and microbiology had scored the highest citation impact (5.91citations per paper).

The top 15 most productive Indian institutions involved in bone marrow research have together contributed 38.92% share in the cumulative Indian publications output, with an average productivity of 67.8 papers per institution. The average citation per paper and h-index registered by the total papers of these 15 institutions was 2.87 and 9.53 during 2003-12.The 15 most productive Indian authors together contributed 17.26% share in the cumulative Indian publications output during 2003-2012, with an average productivity of 30.07 papers per author. The average citation per paper and h-index registered by the total papers of these 15 authors was 1.93 and 5.33 during 2003-12.

Conclude that the malfunctioning of bone marrow lead to various diseases like leukemia, multiple myeloma, myelodysplastic syndrome (MDS), aplastic anaemia, etc and symptoms of these bone marrow diseases vary but the treatments depend on the disorder which involve medicines and blood transfusions or a bone marrow transplant. Due to the high cost associated with the medical procedures (e.g., BMT) and because of the multidisciplinary high-level support required, there are only a few centers in the developing world which are performing bone marrow transplants. India is facing a severe shortage of bone marrow transplants with just 700 transplants taking place every year despite over 30,000 patients suffering from thalassemia, leukemia and multiple myeloma [19]. Thus, further research is required for assessment of risk factors in Indian patients; improvement in supportive care; and need for establishing a national data management infrastructure with updating/monitoring of registries along with better financial and social support initiatives. Beside this, there is need to undertake more R and D, develop trained manpower at different levels and create sufficient infrastructure to handle the problems associated with bone marrow research in India.

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