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Glaucoma Research: A Scientometric Study of Indian Publications Output, 2002-11

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ABSTRACT

The study analyses the Indian publications output in glaucoma research during 2002-11 on different parameters including contribution & citation impact of top most productive countries, India's overall contribution, its growth pattern and citation impact, the share of international collaboration in India's overall research output, contribution of leading countries and identification of leading foreign collaborating partners, Indian contribution & impact of different types of glaucoma, glaucoma research by sub-fields and glaucoma research output by different population age groups, productivity and impact of leading Indian institutions and authors and pattern of communication of Indian output in most productive journals. The Scopus citation database has been used to retrieve the data for 10 years (2002-11) by searching the keywords 'glaucoma or intraocular pressure' in combined Title, Abstract and Keywords field. The Indian publications output in glaucoma research (1078 papers) during 2002-11 increased from 61 papers in 2002 to 207 papers in 2011, witnessing an annual average growth rate of 18.29 %. The average citation impact per paper registered by Indian publications in glaucoma research was 3.03 during 2002-11, which decreased from 3.87 during 2002-06 to 2.49 during 2007-11. The international collaborative share of India in overall glaucoma research was 21.06 % during 2002-11, which increased from 17.92 % during 2002-06 to 23.09 % during 2007-11. The glaucoma's irreversibility, lacking of glaucoma specialists and patients unawareness demand for an economic and effective glaucoma diagnosis system for screening. Disease control and elimination require an adequately trained functional workforce with an enabling infrastructure and technology. The authors suggest that research efforts needs to be strengthened quiet substantially by way of investment in R&D. Both research output and quality of research should be increased and strengthened and international collaborative research may further be widened to learn from the experiences of other countries.

Keywords: Glaucoma research, publications, India, scientometrics

1. INTRODUCTION

The term 'glaucoma' covers a number of different eye conditions, all of which involve damage to the optic nerve. This damage leads to the field of vision having ever larger gaps, which mostly remain unnoticed at first. Your field of vision is the range of what you can see when your eyes are looking straight ahead. In advanced stages, your ability to see things sharply (visual acuity) also gets worse. One common cause is that there is too much pressure inside the eye. This pressure is called intraocular pressure. Intraocular pressure is caused by a fluid in the chambers of the eye between the cornea and the lens. This fluid is called aqueous humor and is produced by the eye itself. It flows continuously from the back (posterior) chamber to the front (anterior) chamber and then back out through a very thin tube (Schlemm's canal). This cycle helps to maintain constant pressure in a healthy eye. The aqueous humor also provides nutrients to the cornea, the iris, and the lens. If the aqueous humor is prevented from draining properly, it starts to collect and pressure within the eye builds up. This presses against the optic nerve and there is a risk that nerve cells die. Whether the increased intraocular pressure does cause damage depends on, among other things, how well the optic nerve can resist this pressure: only some people with high intraocular pressure have an optic nerve that is susceptible to damage. Intraocular pressure is measured in mm Hg (millimeters of mercury), the same unit used for blood pressure. Readings

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between 10 and 21 mm Hg are considered normal. Someone who has glaucoma does not always have above-average intraocular pressure[1].

2. TYPE OF GLAUCOMA

(i) Open-angle glaucoma (also called primary or chronic glaucoma) is caused by the slow clogging of the drainage canals, resulting in increased eye pressure It has a wide and open angle between the iris and cornea. It develops slowly and is a lifelong condition. It is most common form of glaucoma, accounting for at least 90 % of all glaucoma;

(ii) Angle-closure glaucoma, caused by blocked drainage canals, resulting in a sudden rise in intraocular pressure. It is a result of the angle between the iris and cornea closing. It is comparatively a less common form of glaucoma;

(iii) Normal-tension glaucoma (also called low-tension or normal-pressure glaucoma) leads to the damage of optic nerve, even though the eye pressure may not very high; and

(iv) Congenital glaucoma (also called childhood glaucoma and for glaucoma diagnosed in infancy or early childhood), caused by abnormal intraocular fluid drainage from the eye as a result of a blocked or defective trabecular meshwork. It may be due to an hereditary defect or abnormal development during pregnancy. In other cases, an abnormal drainage system may be the result of some other disease in the eye which results in secondary glaucoma[2].

Most other types of glaucoma are variations of open-angle or angle-closure types:

(a) Secondary Glaucoma

Here disease contributes to increased eye pressure, resulting in optic nerve damage and vision loss or may occur as the result of an eye injury, inflammation, tumor, or in advanced cases of cataract or diabetes or it can also be caused by certain drugs such as steroids;

(b) Pigmentary Glaucoma

It occurs when the pigment granules that are in the back of the iris (the colored part of the eye) break into the clear fluid produced inside the eye. These tiny pigment granules flow toward the drainage canals in the eye and slowly clog them. This causes eye pressure to rise;

(c) Pseudoexfoliative Glaucoma

It occurs when a flaky, dandruff-like material peels off the outer layer of the lens within the eye. The material collects in the angle between the cornea and iris and can clog the drainage system of the eye, causing eye pressure to rise;

(d) Traumatic Glaucoma

Injury to the eye immediately or years later may cause traumatic glaucoma. It can be caused by blunt injuries that bruise the eye (called blunt trauma) or by injuries that penetrate the eye;

(e) Neovascular Glaucoma

The abnormal formation of new blood vessels on the iris and over the eye's drainage channels can cause asuch a glaucoma. The new blood vessels block the eye's fluid from exiting through the trabecular meshwork (the eye's drainage canals), causing an increase in eye pressure It is always associated with other abnormalities, most often diabetes. It never occurs on its own;

(f) Irido Corneal Endothelial Syndrome (ICE)

Cells on the back surface of the cornea spread over the eye's drainage tissue and across the surface of the iris, increasing eye pressure and damaging the optic nerve. These corneal cells also form adhesions that bind the iris to the cornea, further blocking the drainage channels[3].

Glaucoma affects about 70 million people worldwide, of whom about 10 per cent are believed to be bilaterally blind. It is estimated that by the year 2020, this number would rise to around 79.6 million. Statistics gathered by the World Health Organisation (WHO) show that glaucoma is the second leading cause of blindness globally, after cataract. Glaucoma, however, presents greater health challenge than cataract because the blindness it causes is irreversible. India has the third largest number of glaucoma patients, after China and Europe/USA. Glaucoma is the third leading cause of blindness in India, but the alarming thing is that by the time a patient is detected to be having glaucoma, 90 % have lost 50 % of their sight In India, it is estimated that glaucoma affects 12 million people accounting for 12.8 % of the countries blindness and by 2020; this is expected to be 16 million. Population-based studies report a prevalence between 2 to 13 % in India. In India, more than 90 % of glaucoma in the community is undiagnosed. Statistics say one in eight persons above the age of 40 years in India is either suffering from glaucoma or is at risk of the disease. Glaucoma can affect any age group, including newborn, infants, children, and elderly[4-6].

3. LITERATURE REVIEW

Glaucoma Society of India was established in 1990 with the aim of disseminating current practice patterns and help ophthalmologists in different parts India upgrade their skills to promote excellence in patent care and help preserve their vision related quality of life. It also organises nation wide glaucoma courses in order to spread basic as well as updated

knowledge of glaucoma diagnosis and management meant for all ophthalmologists: private practitioners, ophthalmologists in private or government teaching institutions and all residents/postgraduates[7].

Few studies were conducted on country distribution of ophthalmology and visual science literature. Davies, Wilson & Hood[8] studied Australia's contribution to vision science domain literature during 1991-95, using ISI's SCI, SSCI, and AHCI databases. Zou, Wu & Wu[9] analysed 961 ophthalmology, optometry and visual science publications of China, using SCI database during 2000–2007. Kumaragurupari, Sieving & Lalitha[10] analysed 2163 publications by Indian ophthalmologists and vision researchers during 2001-2006, with a view access their productivity, analyse trends in journal choice, publication types, research funding and collaborative research. Publications resulting from international collaborations increased from 3% in 2001 to 8 % in 2006. The major focus of Indian publications was on cataract and clinical science articles were most frequently published whereas basic science the least. Only one scientometric study could be identified on glaucoma. Consoli and Ramgoplan[11] analysed 9361 world glaucoma papers published during 1973-2003 appearing in ISI Thompson database. The research output was classified into 26 sub-areas and 5 broad areas. The authors searched glaucoma in the 'Topic' field which includes title, keywords and abstract using institutional addresses of authors as a guide to study intra-organisational and inter-organisational collaboration across research units, health care delivering units and firms.

4. OBJECTIVES

The main objective of this study is to analyse the Indian research output in glaucoma during 2002-11. Objectives were to study:

(i) Contribution & citation impact of top 15 most productive countries,

(ii) India's overall contribution, its growth pattern and citation impact,

(iii) Share of international collaboration in India's overall research output, contribution of leading countries and identification of leading foreign collaborating partners;

(iv) Indian contribution & impact of different types of glaucoma, glaucoma research by sub-fields and glaucoma research output by different population age groups,

(v) Productivity and impact of leading Indian institutions and authors, and

(vi) Pattern of communication of Indian output in most productive journals.

5. METHODOLOGIES AND SOURCE OF DATA

This study used Scopus International Database [http://www.scopus.com/search/] to extract relevant data on glaucoma research of world and other 15 most productive countries for the 10 years (2002-11). An advanced search strategy involving 'glaucoma or intraocular pressure' as the keywords were used to search and download data using 'Title', 'Abstract' and 'Keywords' field, resulting in downloading of 1078 records related to Indian glaucoma research. Separate strategies were developed in terms of keywords for identifying different type of glaucoma research and glaucoma research output by different population age groups. For identifying conjunctivitis research by sub-fields, database classification as provided in Scopus database has been used. For analysing significant institutions, authors and journals, 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 conjunctivitis research during 2002-08, 2009, 2010 and 2011. For example, for papers published in 2002, citation window is three years from 2002-05. For papers published in 2009, citation window is two years from 2009-2011 and for papers published in 2010 citation window is one year 2010-11.

6. ANALYSIS

6.1 Global Publications Output and Citation Impact

Table 1 shows the global publication share of the top 15 most productive countries in glaucoma research varies from 1.39 % to 27.25 % during 2002-11. USA tops the list, with a share of 27.25 % during 2002-11. The China, and UK ranks second and third, followed by Japan and Germany with publications share of 6.75 % and 6.36 % respectively. India ranked at 6th positions (3.09 %).

The developed countries showing increase in their publications share are Spain by 1.08 %, followed by Australia (0.77 %), Turkey (0.39 %), Italy (0.35 %), Canada (0.27 %), and Switzerland (0.07 %) from 2002-06 to 2007-11. In contrast, the developed countries showing decrease in their publications share during the same period are USA by 2.38 %, Japan (2.08 %), Germany (1.64 %), UK (0.76 %), and France (0.61 %). All developing countries have shown rise in their publications share in glaucoma research: China by 6.80%, followed by South Korea (1.06 %), India (0.45 %) and Brazil (0.35 %) from 2002-06 to 2007-11 (Table 1).

India ranks at 6th position among the top 15 most productive countries in glaucoma research with its global publications share of 3.26 % during

2002-11. China and Brazil ranked at 2nd and 13th positions, with global publications share of 8.60% and 2.16 %, respectively during 2002-11. India's global publications share increased from 3 % to 3.45 % from 2002-06 to 2007-11. China and Brazil's global publications share increased from 4.71% to 11.51 % and 1.96 % to 2.31 % from 2002-06 to 2007-11 (Table 1).

Considering the quality of papers published by these 15 most productive countries in terms of citation per paper which varies from 2.24 to 8.59 during 2002-11. The highest citation impact is registered by Italy with 8.59 citations per paper, followed by USA (7.91), Canada (7.48), Australia, etc. Brazil, South Korea, and Spain scored the impact varying from 5.15 to 5.61 citations per paper. Japan, Turkey, India, and China achieved the citations quality less than 5 citations per paper.

6.2 India's Contribution, Citation Impact and International Collaboration

India's contribution in glaucoma research has increased from 61 papers in 2002 to 207 papers in 2011, witnessing an annual average growth rate of 18.29 %. Its cumulative publications output has increased from 424 papers during 2002-06 to 654 papers during 2007-11, witnessing a growth rate of 54.24 %. The average citation per paper registered

Table 1. Publications output, share and rank of top 15 countries in glaucoma research, 2002-11

S. No.	Country	No. of papers			Share of papers (%)			Total citations	Average citation
		2002-06	2007-11	2002-11	2002-06	2007-11	2002-11	2002-11	per paper
1.	USA	4050	4969	9019	28.61	26.23	27.25	71325	7.91
2.	China	667	2180	2847	4.71	11.51	8.60	6371	2.24
3.	UK	1206	1470	2676	8.52	7.76	8.09	17296	6.46
4.	Japan	1124	1111	2235	7.94	5.86	6.75	9344	4.18
5.	Germany	1033	1072	2105	7.30	5.66	6.36	15088	7.17
6.	India	424	654	1078	3.00	3.45	3.26	3667	3.40
7.	Italy	427	638	1065	3.02	3.37	3.22	9145	8.59
8.	Australia	376	649	1025	2.66	3.43	3.10	7588	7.40
9.	Canada	416	608	1024	2.94	3.21	3.09	7664	7.48
10.	Turkey	363	559	922	2.56	2.95	2.79	3706	4.02
11.	Spain	280	579	859	1.98	3.06	2.60	4425	5.15
12.	France	414	437	851	2.92	2.31	2.57	5738	6.74
13.	Brazil	278	438	716	1.96	2.31	2.16	4017	5.61
14.	Switzerland	230	320	550	1.62	1.69	1.66	3849	7.00
15.	South Korea	111	348	459	0.78	1.84	1.39	2523	5.50
Total		**14154**	**18944**	**33098**	**100**	**100**	**100**		

Table 2. India's publications and international collaborative publications Output in Glaucoma Research, 2002-11

Publication year	Total papers	Total citation	Average citation per paper	International collaborative papers (%)
2002	61	182	2.98	7 (11.48 %)
2003	89	344	3.87	13 (14.61 %)
2004	82	315	3.84	16 (19.51 %)
2005	98	381	3.89	27 (27.55 %)
2006	94	418	4.45	13 (13.83 %)
2007	114	581	5.10	26 (22.81 %)
2008	86	456	5.30	22 (25.58 %)
2009	87	351	4.03	21 (24.14 %)
2010	160	191	1.19	40 (25 %)
2011	207	48	0.23	42 (20.29 %)
2002-06	**424**	**1640**	**3.87**	**76 (17.92 %)**
2007-11	**654**	**1627**	**2.49**	**151 (23.09 %)**
2002-11	**1078**	**3667**	**3.03**	**227 (21.06 %)**

by India's research in glaucoma during 2002-11 was 3.03, which has decreased from 3.87 during 2002-06 to 2.49 during 2007-11. India has contributed 21.06 % international collaborative papers share in glaucoma research during 2002-11, which has increased from 17.92 % during 2002-06 to 23.09 % during 2007-11 (Table 2).

In all 45 countries participated in international collaboration with India in glaucoma research during 2002-11, of which contribution of top 14 countries are listed in Table 3. The largest contribution to international collaborative papers of India in glaucoma research comes from United States (with 50.22 % share), followed by UK (21.59 % share), Singapore (7.05 % share), Germany (5.29% share), Italy (3.08 % share), Brazil (2.64% share), Netherlands (3.08 % share), China (2.64 % share), Israel (2.20 % share), Japan (2.2 % share), Canada, Malaysia and Switzerland (1.7 6% share each) and Nepal (1.32 % share). The share of international collaboration has decreased in USA by 15.5 %, Israel by 2.63 %, Nepal by 1.97 %, Switzerland by 1.31 %, Italy by 1.30 % and Japan by 0.64 %, as against increase by 20.59 % in U.K., 4.66 % in Singapore, 3.97 % in Brazil, 2.65 % each in Malaysia and Canada, 2.01% in Germany, 1.99 % in China and 0.68 % in Netherlands from 2002-06 to 2007-11 (Table 3).

Among the international collaborative partners of India as reflected in its international collaborative papers in glaucoma research during 2002-11, the largest contribution (21 papers) comes from University of Melbourne, Australia, followed by John Hopkins Bloomberg School of Public Health, USA (12 papers), Queensland Eye Institute, Australia (11 papers),

Table 3. Major international collaborative partners of India in glaucoma research, 2002-11

S. No.	Collaborating country	International collaborative papers (%)		
		2002-06	2007-11	2002-11
1.	USA	46 (60.53 %)	68 (45.03 %)	114 (50.22 %)
2.	UK	6 (7.89 %)	43 (28.48 %)	49 (21.59 %)
3.	Singapore	3 (3.95 %)	13 (8.61 %)	16 (7.05 %)
4.	Germany	3 (3.95 %)	9 (5.96 %)	12 (5.29 %)
5.	Italy	3 (3.95 %)	4 (2.65 %)	7 (3.08 %)
6.	Brazil	0	6 (3.97 %)	6 (2.64 %)
7.	Netherlands	2 (2.63 %)	5 (3.31 %)	7 (3.08 %)
8.	China	1 (1.32 %)	5 (3.31 %)	6 (2.64 %)
9.	Israel	3 (3.95 %)	2 (1.32 %)	5 (2.2 %)
10.	Japan	2 (2.63 %)	3 (1.99 %)	5 (2.2 %)
11.	Canada	0	4 (2.65 %)	4 (1.76 %)
12.	Malaysia	0	4 (2.65 %)	4 (1.76 %)
13.	Switzerland	2 (2.63 %)	2 (1.32 %)	4 (1.76 %)
14.	Nepal	2 (2.63 %)	1 (0.66 %)	3 (1.32 %)
	Total*	**76 (100 %)**	**151 (100 %)**	**227 (100 %)**

*Total collaborating papers of India. In all collaborating papers of India, there are one or more foreign collaborating countries. As a result, the combined output of 14 foreign collaborating countries listed above in Indian international collaborative output will be more than its total international collaborative papers

Table 4. Foreign collaborating centers with India along with their output in glaucoma research, 2002-11

S. No.	Name of foreign collaborating organisation	Research output
1.	University of Melbourne, Australia	21
2.	John Hopkins Bloomberg School of Public Health, USA	12
3.	Queensland Eye Institute, Australia	11
4.	University of Queensland, Australia	11
5.	Singapore Eye Institute, Singapore	10
6.	Singapore National Eye Center, Singapore	9
7.	Marshfield Clinical Research Foundation, Marshfield, USA	9
8.	John Hopkins School of Medicine, USA	7
9.	University of California, San Diego, USA	7
10.	University of Heidelberg, Germany	6

University of Queensland, Australia (11 papers), Singapore Eye Institute (10 papers), Singapore National Eye Center (9 papers), Marshfield Clinical Research Foundation, Marshfield, USA (9 papers), John Hopkins School of Medicine, USA (7 papers), University of California, San Diego, USA (7 papers), University of Heidelberg, Germany, etc. (Table 4).

6.3 Different Types of Glaucoma Research

Under different type of glaucoma research, the maximum publication output (214) of India during 2002-11 was on open angle glaucoma (with 19.85 % share), followed by closed angle glaucoma (142 papers, 13.17 % share), congenital glaucoma (92 papers, 8.53 % share), normal tension glaucoma (77 papers, 7.14 % share), secondary glaucoma (54 papers, 5.01 % share), neovascular glaucoma (29 papers, 2.69 % share), traumatic glaucoma (12 papers, 1.11 % share), pigmentary glaucoma (5 papers, 0.46 % share), pseudoexfoliative glaucoma (2 papers, 0.19 % share) and Irido Corneal Endothelial syndrome (1 paper, 0.09 % share). In terms of citation impact per paper, the maximum citation impact (7.88) during 2002-11 was in normal tension glaucoma, followed by congenital glaucoma (3.85), open angle glaucoma (3.79), closed angle glaucoma (3.41), secondary glaucoma (3.20), traumatic glaucoma (2.67), pigmentary glaucoma (2.4), neovascular glaucoma (1.83), and pseudoexfoliative glaucoma (0.5) (Table 5).

6.4 Glaucoma Research Output in Context of Different Subjects

India's publication output in glaucoma research during 2001-11 has been published in context of 5 subjects (as reflected in database classification based on journal subject), with highest publications output coming from medicine (949 papers and 88.03 % publications share), followed by pharmacology, toxicology & pharmaceutics (117 papers and 10.85 % publications share), neurosciences (106 papers and 9.83 % publications share), biochemistry, genetics & molecular biology (59 papers and 5.47 % publications share) and health profession (15 papers and 1.39 % publications share). On analysing the quality and impact of glaucoma research output under different subjects, it was found that biochemistry, genetics & microbiology had scored the highest impact (4.12 citations per paper), followed by medicine (3.08 citations per paper), neurosciences (2.48 citations per paper), pharmacology, toxicology & pharmaceutics (2.40 citations per paper) and health profession (2.27 citations per paper)(Table 6).

Table 5. Indian publication output and citation quality in different types of glaucoma research, 2002-11

Type of glaucoma research	2002-11		
	Total papers	Total citation	Average citation per paper
Open Angle Glaucoma	214	812	3.79
Closed Angle Glaucoma	142	484	3.41
Congenital Glaucoma	92	354	3.85
Normal Tension Glaucoma	77	607	7.88
Secondary Glaucoma	54	173	3.20
Neovascular Glaucoma	29	53	1.83
Traumatic Glaucoma	12	32	2.67
Pigmentary Glaucoma	5	12	2.40
Pseudoexfoliative Glaucoma	2	1	0.50
Irido Corneal Endothelial Syndrome	1	0	0
Total of India	**1078**	**2528**	

Table 6. Subject-wise break-up of Indian publications in glaucoma research during 2002-11

Sub-fields	Total papers	Total citation	Average citation per paper (%)
Medicine	949	2921	3.08 (88.03 %)
Pharmacology, Toxicology & Pharmaceutics	117	281	2.40 (10.85 %)
Neurosciences	106	263	2.48 (9.83 %)
Biochemistry, Genetics & Molecular Biology	59	243	4.12 (5.47 %)
Health Profession	15	34	2.27 (1.39 %)
Total*	**1078**	**2528**	

*Total of India in glaucoma research. There is some overlapping of literature under different sub-fields. As a result, the combined output of India under 5 sub-fields will be more than its total research output.

6.5 Glaucoma Research by Population Age Groups

The maximum focus of India glaucoma research in terms of research output during 2002-11 was on adults (539 papers and 50 % share), followed by middle aged (300 papers and 27.83 % share), adolescents (152 papers and 14.10 % share) child (136 papers and 12.62 % share) and aged 80 & over (77 papers and 7.14 % share). The focus of glaucoma research has increased in adults (from 47.17 % to 51.83 %) and aged 80 & over (from 5.19 % to 8.41%) from 2002-06 to 2007-11, as against decrease in middle aged (from 37.74 % to 21.41 %), adolescents (from 16.27 % to 12.69 %) and child (from 14.62 % to 11.31 %) during the similar period (Table 7).

6.6 Research Profile of Most Productive Indian Institutions in Glaucoma Research

The top 15 most productive Indian institutions involved in glaucoma research have published 11 and more papers each during 2001-11. The publications profile of these 15 Indian institutions along with their research output, citations received and h-index values are presented in Table 8. These 15 institutions involved in glaucoma research together have contributed 66.42 % share (with 716 papers) in

Table 7. Glaucoma research output by different age group of population, 2002-11

Population by age group	Number of papers (%)		
	2002-06	2007-11	2002-11
Adults	200 (47.17 %)	339 (51.83 %)	539 (50 %)
Middle Aged	160 (37.74 %)	140 (21.41 %)	300 (27.83 %)
Adolescents	69 (16.27 %)	83 (12.69 %)	152 (14.1 %)
Child	62 (14.62 %)	74 (11.31 %)	136 (12.62 %)
Aged 80 & Over	22 (5.19 %)	55 (8.41 %)	77 (7.14 %)
Total	**424**	**654**	**1078**

There is some duplication in papers under different age groups. As a result, the total of papers by different age groups is slightly higher than actual total papers.

Table 8. Productivity and citation impact of top fifteen major Indian institutions in glaucoma research, 2002-11

S. No.	Name	Total papers	Total citations	Average citations per paper	*h*-Index
1.	All India Institute of Medical Sciences, Dr Rajendra Prasad Center for Ophthalmic Sciences, New Delhi	209	675	3.23	20
2.	L.V. Prasad Eye Institute, Hyderabad	174	701	4.03	20
3.	Post Graduate Institute of Medical Education & Research, Chandigarh	55	154	2.80	12
4.	Vision Research Foundation, Chennai	50	313	6.26	14
5.	Aravind Eye Hospital, Postgraduate Institute of Ophthalmology, Madurai	48	70	1.46	8
6.	Medical Research Foundation, Chennai	47	208	4.43	11
7.	Christian Medical College, Vellore	21	67	3.19	7
8.	Indian Institute of Chemical Biology, Kolkata	19	164	8.63	12
9.	Government Medical College & Hospital, Chandigarh	16	9	0.56	3
10.	Maulana Azad Medical College, Delhi	15	24	1.60	4
11.	Medical College & Hospital, Kolkata	14	75	5.36	6
12.	Bombay City Eye Institute & Research Centre	13	18	1.38	4
13.	Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi	12	15	1.25	4
14.	Iladevi Cataract & Intraocular Lens Research Center, Ahmedabad	12	39	3.25	5
15.	Regional Institute of Ophthalmology, Kolkata	11	13	1.18	2
	Total	**716**	**2545**	**3.55**	**8.8**
	Total of the Country	**1078**			
	Share of Top 15 Institutes in Indian Output	**66.42**	**47.73**		

the cumulative world publications output in glaucoma research, with an average of 47.73 papers per institution. Only five institutions have registered higher publications share than the group average. These are All India Institute of Medical Sciences, Dr Rajendra Prasad Center for Ophthalmic Sciences, New Delhi with 209 papers, followed by L.V. Prasad Eye Institute, Hyderabad (174 papers), PGI, Chandigarh (55 papers), Vision Research Foundation, Chennai (50 papers) and Aravind Eye Hospital, Postgraduate Institute of Ophthalmology, Madurai (48 papers). The average citation per paper registered by the total papers of these 15 institutions is 3.55 during 2002-11. Only 5 Indian institutions have registered higher impact than the group average. Amongst these five Indian institutions, the highest impact of 8.63 citations per paper was scored by the Indian Institute of Chemical Biology, Kolkata, followed by Vision Research Foundation, Chennai (6.26 citations per paper), Medical College & Hospital, Kolkata (5.36 citations per paper), Medical Research Foundation, Chennai (4.43 citations per paper), and L.V. Prasad Eye Institute, Hyderabad (4.03 citations per paper). The average *h*-index value of these 15 most productive institutions was 8.80 during 2002-11. The six Indian institutions have scored higher *h*-index value than group's average of 8.80. Amongst these six Indian institutions, the highest *h*-index value (20) was achieved by All India Institute of Medical Sciences, Dr Rajendra Prasad Center for Ophthalmic Sciences, New Delhi and L.V. Prasad Eye Institute, Hyderabad, followed by Vision Research Foundation, Chennai (14), Post Graduate Institute of Medical Education & Research, Chandigarh and Indian Institute of Chemical Biology, Kolkata (12 each) and Medical Research Foundation, Chennai (11).

Table 9. Productivity & citation impact of India's top fifteen authors in glaucoma research, 2002-11

S. No.	Name	Affiliation	Total papers	Total citations	Average citations per paper	*h*-Index
1.	Ramanjit Sihota	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	76	319	4.20	15
2.	T. Dada	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	56	268	4.79	11
3.	L. Vijaya	Medical & Vision Research Foundation, Chennai	46	289	6.28	14
4.	R. George	Medical Research Foundation, Chennai	47	269	5.72	13
5.	A.K. Mandal	L.V.Prasad Eye Institute, Hyderabad	41	243	5.93	15
6.	M. Baskaran	Medical & Vision Research Foundation, Chennai	32	267	8.34	14
7.	V. Gupta	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	30	169	5.63	8
8.	S. Kaushik	Post Graduate Institute of Medical Education & Research, Chandigarh	25	118	4.72	9
9.	A. Gupta	Post Graduate Institute of Medical Education & Research, Chandigarh	25	131	5.24	10
10.	S.S. Pandav	Post Graduate Institute of Medical Education & Research, Chandigarh	27	85	3.15	9
11.	P. Sony	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	22	106	4.82	7
12.	H.C. Agarwal	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	25	73	2.92	9
13.	R.S. Parikh	Bombay City Eye Institute & Research Centre, Bombay	42	231	5.50	11
14.	R. Saxena	Dr Rajendra Prasad Center for Ophthalmic Sciences, AIIMS, New Delhi	20	58	2.90	8
15.	P. Raju	Medical & Vision Research Foundation, Chennai	20	132	6.60	9
Total			**534**	**2758**	**5.16**	**10.8**
Total of the country			**1078**			
Share of Top 15 authors in country output			**49.54**			

6.7 Contributions and Impact of Most Productive Indian Authors in Glaucoma Research

Fifteen authors having been identified as most productive, who have published 20 and above papers in glaucoma research. The publications profile of these 15 authors along with their research output, citations received and *h*-index values are presented in Table 9. These 15 authors together contributed 534 papers with an average of 35.6 papers per author and account for 49.54 % share in the cumulative Indian publications output during 2002-11. Five authors have published higher number of papers than the group average (150.07). These are: Ramanjit Sihota with 76 papers, followed by T. Dada (56 papers), R. George (47 papers), L. Vijaya (46 papers), and A.K. Mandal (41 papers). Considering the quality/impact of papers, these 15 productive authors have received a total of 2758 citations for 534 papers with an average of 5.16 citations per paper. Seven authors have registered higher impact than the average impact of papers of all authors (5.16). These are: M. Baskaran with 8.34 citations per paper, P.Raju (6.60 citations per paper), L. Vijaya (6.28 citations per paper), A.K. Mandal (5.93 citations per paper), R. George (5.72 citations per paper), V. Gupta (5.63 citations per paper), R. Parikh (5.50 Citations per Paper) and A.Gupta (5.24 citations per paper). Measuring the performance of these authors on the basis of *h*-index, seven authors have achieved the higher *h*-index value than the group average of 10.80. These authors are Ramanjit Sihota and A.K. Mandal with h-index of 15 each, followed by L. Vijaya and M. Baskaran (14), R. George (13), T. Dada, and R.S. Parikh (11 each) (Table 9).

6.8 Research Communication in High Productive Journals

The 15 most productive journals publishing Indian research papers in glaucoma research together contributed 533 papers, which accounts for 49.44% share of the world total output during 2002-11. The cumulative publications output share of these 15 most productive journals showed a decrease in world's publications output from 59.20% during 2002-06 to 43.12% during 2007-11 (Table 10).

Table 10. Media of communication in India, 2002-11

S. No.	Name of journal	No. of papers		
		2002-06	2007-11	2002-11
1.	*Indian Journal of Ophthalmology*	64	82	146
2.	*Eye*	23	31	54
3.	*Journal of Glaucoma*	12	24	36
4.	*Journal of Cataract and Refractive Surgery*	17	17	34
5.	*Ophthalmology*	12	22	34
6.	*British Journal of Ophthalmology*	17	13	30
7.	*Clinical and Experimental Ophthalmology*	16	11	27
8.	*Asian Journal of Ophthalmology*	13	15	28
9.	*Molecular Vision*	12	14	26
10.	*Investigative Ophthalmology & Visual Science*	13	13	26
11.	*European Journal of Ophthalmology*	9	13	22
12.	*Cornea*	8	11	19
13.	*Annals of Ophthalmology*	18	0	18
14.	*Journal of the Indian Medical Association*	10	7	17
15.	*Archives of Ophthalmology*	7	9	16
Total		**251**	**282**	**533**
Total of the India		**424**	**654**	**1078**
Share of top 15 journals in Indian output		**59.2**	**43.12**	**49.44**

7. SUMMARY

India has published 1078 papers in glaucoma research during 2002-11, which has increased from 61 papers in 2002 to 207 papers in 2011, witnessing an annual average growth rate of 18.29 %. In terms of impact and citation quality, the average citation per paper registered by Indian publication output was 3.03 during 2002-11, which has decreased from 3.87 during 2002-06 to 2.48 during 2007-11. Among the top 15 most productive countries in glaucoma research during 2002-11, the US tops

the list, with a share of 27.25% during 2002-11, followed by China (8.60 %), UK (8.09 %), Japan (6.75 %), Germany (6.36 %), etc. India is ranked at 6th position among the top 20 most productive countries in glaucoma research, with its global publication share of 3.26 % during 2002-11. India's global publications share increased from 3 % during 2002-06 to 3.45 % during 2007-11. The international collaborative papers share of India in glaucoma research was 21.06 % during 2002-11, which has increased from 17.92 % during 2002-06 to 23.09 % during 2007-11. In all 45 countries participated in international collaboration with India in glaucoma research during 2002-11. The largest contribution (share) to international collaborative papers of India in glaucoma research comes from US (50.22 %), followed by UK (21.59 %), Singapore (7.05%), Germany (5.29 %), Italy (3.08 %), Brazil (2.64 %), Netherlands (3.08 %), China (2.64 %), Israel (2.2 %), Japan (2.2 %).

Among different types of glaucoma research in India during 2002-11, the largest contribution (share) (19.85 %) comes from open angle glaucoma, followed by closed angle glaucoma (13.17 %), congenital glaucoma (8.53 %), normal tension glaucoma (7.14 %), secondary glaucoma (5.01 %), neovascular glaucoma (2.69 %), traumatic glaucoma (1.11 %), pigmentary glaucoma (0.46%), pseudoexfoliative glaucoma (0.19 % share) and Irido Corneal Endothelial syndrome (0.09 % share). The maximum focus of Indian glaucoma research in terms of research output during 2002-11 was on adults (with 50 %), followed by middle aged (27.83 %), adolescents (14.1 %), child (12.62 %), and aged 80 & over (7.14 %). Among the subfield wise distribution of world glaucoma research during 2002-11, the largest contribution (88.03 %) comes from medicine, followed by pharmacology, toxicology & pharmaceutics (10.85 %), neurosciences (9.83 % share), biochemistry, genetics & molecular biology (5.47 %) and health profession (1.39 %). The top 15 most productive Indian institutions involved in glaucoma research have together contributed 66.42 % share in the cumulative Indian publications output, with an average of 47.73 papers per institution. The average citation per paper and *h*-index registered by the total papers of these 15 institutions was 3.55 and 8.80 during 2002-11.The 15 most productive Indian authors together contributed 49.54 % share in the cumulative Indian publications output during 2002-2011, with an average of 35.6 papers per author. The average citation per paper and *h*-index registered by the total papers of these 15 authors was 5.16 and 10.80 during 2002-11.

With around 12 million people affected by glaucoma in India, but India produced only 1078 research papers during the last ten years. It means the research efforts needs to be strengthened quiet substantially by way of investment in R&D. Both research output and quality of research should be increased and strengthened and international collaborative research may further be widened to learn from the experiences of other countries. The glaucoma's irreversibility, lacking of glaucoma specialists and patients unawareness demand for an economic and effective glaucoma diagnosis system for screening. Disease control and elimination require an adequately trained functional workforce with an enabling infrastructure and technology.

Population awareness of the disease is low and most patients attending eye clinics do not receive a routine comprehensive eye examination that is required to detect glaucoma (and other potentially blinding eye diseases). Such a routine is not taught or practiced by the majority of training institutions either. Glaucoma cannot be managed in isolation. The objective should be to detect and manage all potential causes of blindness and prevention of blindness from glaucoma should be integrated into existing programs. The routine of comprehensive eye examination in every clinic and its teaching (and use) in residency programs should be mandatory for the detection and management of potentially preventable blinding pathology from any cause, including glaucoma. It is suggested that their is need to develop eye care facilities in every district, develop human resources for providing eye care services, improve the quality of service delivery, and secure participation of voluntary organisation in eye care.

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