

World glaucoma research: A quantitative analysis of research output during 2002-11

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This study analyses the global publications output in glaucoma research during 2002-11 on several parameters. The Scopus Citation Database has been used to retrieve the data for 10 years (2002-11) by searching the keywords “glaucoma or intraocular pressure”. Among the top 15 most productive countries in glaucoma research, India ranks at 6th with global publication share of 3.26% and an annual average publication growth rate of 6.94%. Its global publication share has increased over the years, rising from 2.58% in 2002 to 4.81% in 2011. The average citation impact per paper registered by world publications in glaucoma research was 6.26 during 2002-11, which decreased from 7.54 during 2002-06 to 5.23 during 2007-11. In order to further improve the global research output and research quality, there is a need to promote research into glaucoma and delivery of glaucoma care and further intensify research collaboration among the leading countries. There is a need for primary care practitioners and policy-makers to evolve relevant policies for detection, diagnosis, management and prevention of glaucoma among patients.

Keywords: Glucoma, Eye disease, Publications, Scientometrics

Introduction

Glaucoma is an eye condition that develops when too much fluid pressure builds up inside the eye. The condition tends to be inherited and may not show up until later in life. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to the brain. If damage to the optic nerve from high eye pressure continues, glaucoma will cause loss of vision. Glaucoma usually occurs when intraocular pressure increases. This happens when the fluid pressure in the eye's anterior chamber, the area between the cornea and the iris, rises. Normally, this fluid, called aqueous humor, flows out of the eye through a mesh-like channel. If this channel becomes blocked, fluid builds up, causing glaucoma¹.

There is different type of glaucoma: (i) Open-angle glaucoma: It is caused by the slow clogging of the drainage canals, resulting in increased eye pressure. Has a wide and open angle between the iris and cornea. “Open-angle” means that the angle where the iris meets the cornea is as wide and open as it should be. It is also called primary or chronic glaucoma and is the most common form, accounting for at least 90% of all glaucoma cases; (ii) Angle-closure glaucoma: It is caused by blocked drainage canals, resulting in a sudden rise in intraocular pressure. Has a closed or narrow angle between the iris and cornea. It is also

called acute glaucoma or narrow-angle glaucoma. Unlike open-angle glaucoma, angle-closure glaucoma 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: In this type of glaucoma the optic nerve is damaged even though the eye pressure is not very high. Also called low-tension or normal-pressure glaucoma and (iv) Congenital Glaucoma (Childhood Glaucoma) - It is the common term used for a glaucoma diagnosed in infancy or early childhood and is caused by abnormal intraocular fluid drainage from the eye as a result of a blocked or defective trabecular meshwork (the mesh-like drainage canals in the eye). It may also be due to a 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. In these cases, the glaucoma may be associated with recognizable iris (the colored part of the eye), corneal, or other eye problems².

Most other types of glaucoma are also found, which are generally variations of open-angle or angle-closure types: (a) Secondary glaucoma: Here diseases causes or contributes to increased eye pressure, resulting in optic nerve damage and vision loss. It can occur as the result of an eye injury, inflammation, tumor, or in advanced

cases of cataract or diabetes or may be caused by certain drugs such as steroids; (b) Pigmentary Glaucoma: It is a form of secondary open-angle glaucoma and 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: This form of secondary open-angle glaucoma 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 may cause secondary open-angle glaucoma and can occur immediately after the injury or years later or may 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 a form of secondary open-angle glaucoma. It is always associated with other abnormalities, most often diabetes. 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 and (f) Irido Corneal Endothelial Syndrome (ICE) - This rare form of glaucoma usually appears in only one eye, rather than both. 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. Irido Corneal Endothelial Syndrome occurs more frequently in light-skinned females³.

Glaucoma is the third most common cause of blindness and is responsible for 10% of blindness worldwide. Recent estimates suggest that in 2010 approximately 60.5 million people were affected by glaucoma and about 8.4 million were blind from the disease. Primary open angle glaucoma (44.7 million cases worldwide) is considered more common than primary angle closure glaucoma (15.7 million), but the latter is more likely to cause blindness among affected persons, and thus accounts for almost half of total glaucomatous vision loss. The projections for 2020 are that almost 80 million people will be affected by glaucoma⁴.

Several studies were conducted on world, regional distribution and country distribution of ophthalmology and visual science literature. In terms of world output distribution, Mandal, Benson & Fraser⁵ studied ophthalmic literature contribution of world geographical regions, including developed and developing countries during 1998-2000. Ohba⁶ analyzed 55591 world ophthalmic publications during 1988-2002 and found 49.5% of the total publications to be from North America, followed by 31.3% from Western Europe, 15.1% from Asia and Oceania, 2.2% from Middle East, 0.85% from Central and South America, 0.53% from Eastern Europe, and 0.47% from Africa. Guerin, Flynn, Brady & O'Brien⁷ studied 7754 world ophthalmic publications from 67 countries during 2002-2006. Among regional studies, Ragghianti, Rosa, Martins & Gallo⁸ undertook a comparative study of 1216 scientific publications in ophthalmology & visual science from Argentina, Brazil, Chile, Paraguay and Uruguay during 1995-2004. The total publications tripled from 1995 to 2004 and research on humans showed a significant increase in Argentina and Brazil. Ugolini, Cimmino, Casilli & Mela⁹ studied European Union (EU) contribution to ophthalmology literature during 1995-1997. The impact of ophthalmologic research in the EU is compared with that produced in other countries and trends of research are highlighted through the keywords analysis. Davis, Wilson & Hood¹⁰ compared the Australian productivity in ophthalmology and visual sciences with countries of similar scientific stature, or of language and of commonwealth status. Among country-specific studies, Davis, Wilson & Hood¹⁰ studied Australia's contribution to vision science domain literature during 1991-95, using ISI's SCI, SSCI, & AHCI databases. Zou, Wu & Wu¹¹ analyzed 961 ophthalmology, optometry and visual science publications of China, using SCI database during 2000-2007. Kumaragurupari, Sieving & Lalitha¹² analyzed 2163 publications by Indian ophthalmologists and vision researchers during 2001-2006, with a view access their productivity, analyze 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 Ramgopalan¹³

analyzed 9361 world glaucoma papers published during 1973-2003 appearing in ISI Thomson 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-organizational and inter-organizational collaboration across research units, health care delivering units and firms.

Objectives of the study

- To study the patterns of growth in glaucoma research output
- To study the contributions, citation impact and international collaboration share of top 15 most productive countries
- To assess the productivity and impact of leading institutions and authors
- To identify the pattern of communication in most productive journals.

Methodology

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 33098 records related to glaucoma research. For identifying glaucoma research by sub-fields, database classification as provided in Scopus database has been used. For analyzing significant institutions, authors and journals, separate search strategies were developed, which were 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 glaucoma 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 were used.

Analyses

Global publications output and citation impact

The global publication share of the top 15 most productive countries in glaucoma research varies from

1.39% to 27.25% during 2002-11. The United States tops the list with a share of 27.25% during 2002-11. China and United Kingdom ranks second and third (with 8.60% and 8.09% share) followed by Japan and Germany ranking at 4th to 5th position with publications share of 6.75% and 6.36% respectively. India, Italy, Australia and Canada ranks at 6th to 9th positions (their global publications share ranging from 3.09% to 3.26%). Turkey, Spain, France, Brazil, Switzerland and South Korea ranks at 10th to 15th positions (their global publications share ranging from 1.39% to 2.79%) (Table 1).

The countries showing increase in their publications share from the year 2002 to the year 2011 are Australia (1.48%), followed by Spain (1.36%), Turkey (1.15%) and Canada (1.14%). In contrast, the developed countries showing decrease in their publications share during the same period are Germany by 2.38%, Japan (1.84%), USA (1.54%), France (0.66%), Italy (0.33%), Switzerland (0.04%) and U.K. (0.03%) All developing countries have shown rise in their publications share in glaucoma research: China by 7.89%, followed by India (2.23%), South Korea (1.22%) and Brazil (1.09%) from the year 2002 to the year 2011 (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 with global publications share of 8.60% and 2.16%, respectively during 2002-11. India's global publications share increased from 2.58% to 4.81% from the year 2002 to the year 2011. China and Brazil's global publications share increased from 3.21% to 8.60% and 1.14% to 2.23% from the year 2002 to the year 2011 (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 citations per paper), Canada (7.48 citations per paper), Australia (7.40 citations per paper), Germany (7.17), Switzerland (7.00 citations per paper), France (6.74 citations per paper) and U.K. (6.46 citations per paper). Brazil, South Korea and Spain had varying impact from 5.15 to 5.61 citations per paper. Japan, Turkey, India and China achieved the citations quality less than 5 citations per paper (Table 1).

Publications growth in glaucoma research

The world's cumulative publication output in glaucoma research consisted of 33098 papers during

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

Sl. No.	Country.	Number of Papers			Share of Papers			Total Citations	ACPP
		2002	2011	2002-11	2002	2011	2002-11	2002-11	2002-11
1.	USA	675	1162	9019	28.54	27.00	27.25	71325	7.91
2.	China	76	478	2847	3.21	11.11	8.60	6371	2.24
3.	UK	170	308	2676	7.19	7.16	8.09	17296	6.46
4.	Japan	181	250	2235	7.65	5.81	6.75	9344	4.18
5.	Germany	181	227	2105	7.65	5.27	6.36	15088	7.17
6.	India	61	207	1078	2.58	4.81	3.26	3667	3.40
7.	Italy	87	144	1065	3.68	3.35	3.22	9145	8.59
8.	Australia	53	160	1025	2.24	3.72	3.10	7588	7.40
9.	Canada	50	140	1024	2.11	3.25	3.09	7664	7.48
10.	Turkey	42	126	922	1.78	2.93	2.79	3706	4.02
11.	Spain	41	133	859	1.73	3.09	2.60	4425	5.15
12.	France	71	101	851	3.00	2.35	2.57	5738	6.74
13.	Brazil	27	96	716	1.14	2.23	2.16	4017	5.61
14.	Switzerland	40	71	550	1.69	1.65	1.66	3849	7.00
15.	South Korea	24	96	459	1.01	2.23	1.39	2523	5.50
	World Output*	2365	4304	33098	100.0	100.0	100.0	207227	6.26

ACPP=Average Citation Per Paper

* World Output of all the countries of the world

2002-11, with an average number of 3309.8 papers per year and an annual average growth rate of 6.94%. The cumulative world's publications output in glaucoma research increased from 14154 papers during 2002-06 to 18944 papers during 2007-11, witnessing a growth of 33.84% (Table 2).

The annual average publication growth of developed countries varied from 4.35 to 28.30 and developing countries from 7.49 and 20.34. Among developed countries, the highest annual average publication growth rate (28.30) was achieved by U.K., followed by Spain (15.01), Canada (14.78), Turkey (14.14), Australia (13.93), Switzerland (7.47), USA (6.53), Italy (6.25), France (4.63), Japan (4.35) and Germany (3.60). Among developing countries, the highest annual average publication growth rate (20.34%) was achieved by South Korea, followed by Brazil (18.45%), India (18.29%) and China (7.49%) (Table 3).

Different types of glaucoma research

Under different types of glaucoma research, the maximum publication output (6617) of world during 2002-11 was on open angle glaucoma (with 19.99% share), followed by closed angle glaucoma (2591 papers, 7.83% share), normal tension glaucoma (2380 papers, 7.19% share), congenital glaucoma (1316 papers, 3.98% share), neovascular glaucoma (987 papers, 2.98%), secondary glaucoma (928 papers, 2.80% share), traumatic glaucoma (2 98 papers, 0.90%

Table 2—Growth of world glaucoma research, 2002-11

Period	TP	Period	TP
2002	2365	2009	3722
2003	2535	2010	3859
2004	2779	2011	4304
2005	3092	2001-06	14154
2006	3383	2007-11	18944
2007	3421	2002-11	33098
2008	3638		

TP=Total Papers

Table 3—Annual average growth rate of glaucoma research of top 15 countries, 2002-11

Country	Growth Rate	Country	Growth Rate
USA	6.53	Canada	14.78
China	7.49	Turkey	14.14
UK	28.30	Spain	15.01
Japan	4.35	France	4.63
Germany	3.60	Brazil	18.45
India	18.29	Switzerland	7.47
Italy	6.25	South Korea	20.34
Australia	13.93	World	6.94

share), pigmentary glaucoma (184 papers, 0.56% share), pseudoexfoliative glaucoma (136 papers, 0.41% share) and Irido Corneal Endothelial syndrome (7 papers, 0.02% share). In terms of citation impact per paper, the maximum citation impact (5.81) during 2002-11 was in normal tension glaucoma, followed by pigmentary glaucoma (5.36), open angle glaucoma (5.33), traumatic glaucoma (5.05), neovascular

glaucoma (4.65), congenital glaucoma (3.82), closed angle glaucoma (3.57), pseudoexfoliative glaucoma (3.32), secondary glaucoma (2.55) and Irido Corneal Endothelial syndrome (2.14) (Table 4).

International collaborative share of different countries

The international collaborative share of different countries in their national outputs in glaucoma research varied from 14.47% to 41.37%, with highest publication share (41.37%) coming from Australia, followed by Canada (40.04%), France (37.60%), South Korea (35.29%), Switzerland (34.55%), U.K (32.51%), Brazil (29.33%), Germany (28.74%), Japan (27.38%), Italy (25.73%), Spain (23.98%), USA (23.35%), India (21.06%), Turkey (18.22%) and China (14.47%) (Table 5).

Table 4—World publication output & citation quality in different types of glaucoma research, 2002-11

Type of glaucoma research	2002-11		
	TP	TC	ACPP
Open angle glaucoma	6617	35240	5.33
Closed angle glaucoma	2591	9258	3.57
Normal tension glaucoma	2380	13825	5.81
Congenital glaucoma	1316	5028	3.82
Neovascular glaucoma	987	4593	4.65
Secondary glaucoma	928	2370	2.55
Traumatic glaucoma	298	1504	5.05
Pigmentary glaucoma	184	987	5.36
Pseudoexfoliative glaucoma	136	451	3.32
Irido Corneal Endothelial Syndrome	7	15	2.14
Total	33098		

Table 5—International collaborative publication share of top 15 countries in glaucoma research, 2002-11

Sl. No.	Country	2002-11		
		TP	ICP	%ICP
1	USA	9019	2106	23.35
2	China	2847	412	14.47
3	UK	2676	870	32.51
4	Japan	2235	612	27.38
5	Germany	2105	605	28.74
6	India	1078	227	21.06
7	Italy	1065	274	25.73
8	Australia	1025	424	41.37
9	Canada	1024	40	40.04
10	Turkey	922	68	18.22
11	Spain	859	206	23.98
12	France	851	320	37.60
13	Brazil	716	210	29.33
14	Switzerland	550	190	34.55
15	South Korea	459	162	35.29

Glaucoma research output in context of different subjects

World's publication output in glaucoma research during 2001-11 has been published in context of 7 subjects (as reflected in database classification based on journal subject) with highest publications output coming from medicine (29614 papers and 89.47% publications share), followed by neurosciences (4501 papers and 13.60% publications share), pharmacology, toxicology & pharmaceuticals (1959 papers and 5.92% publications share), biochemistry, genetics & molecular biology (1652 papers and 4.99% publications share), health profession (689 papers and 2.08% publications share), veterinary science (438 papers and 1.32% publications share) and immunology and microbiology (268 papers and 0.81% publications share). On analyzing the quality and impact of glaucoma research output under different subjects, it was found that immunology and microbiology had scored the highest impact (13.13 citations per paper) followed by biochemistry, genetics & microbiology (9.87 citations per paper), pharmacology, toxicology & pharmaceuticals (5.97 citations per paper), neurosciences (5.12 citations per paper), medicine (4.98 citations per paper), health profession (2.80 citations per paper) and veterinary science (1.63 citations per paper) (Table 6).

Glaucoma research by population age groups

The maximum focus of glaucoma research in terms of research output during 2002-11 was on adults (12940 papers and 39.10% share), followed by middle aged (9412 papers and 28.44% share), aged 80 & over (4046 papers and 12.22% share), adolescents (2717 papers and 8.21% share) and child (2292 papers and

Table 6—Subject-wise break-up of world publications in glaucoma research during 2002-11

Subfields	TP	TC	ACPP	% TP
Medicine	29614	147478	4.98	89.47
Neurosciences	4501	23054	5.12	13.60
Pharmacology, Toxicology & Pharmaceuticals	1959	11691	5.97	5.92
Biochemistry, Genetics & Molecular Biology	1652	16300	9.87	4.99
Health Profession	689	1931	2.80	2.08
Veterinary Science	438	713	1.63	1.32
Immunology & Microbiology	268	3572	13.33	0.81
Total*	33098			

*Total of world in glaucoma research. There is some overlapping of literature under different sub-fields. As a result, the combined output of world under 7 sub-fields will be more than its total research output

Table 7—Glaucoma research output by different age group of population

Population by Age Group	Number of Papers			Percentage of Papers		
	2002-06	2007-11	2002-11	2002-06	2007-11	2002-11
Adults	4908	8032	12940	34.68	42.40	39.10
Middle Aged	5235	4177	9412	36.99	22.05	28.44
Aged 80 & Over	1782	2264	4046	12.59	11.95	12.22
Adolescents	1036	1681	2717	7.32	8.87	8.21
Child	1000	1292	2292	7.07	6.82	6.92
Total	14154	18944	33098	100.00	100.00	100.00

Table 8—Productivity & citation impact of top fifteen major world institutions in glaucoma research, 2002-11

Sl. No.	Name	TP	TC	ACPP	H-Index
1	University of Melbourne, Centre for Eye Research, Australia	298	2289	7.68	31
2	Harvard Medical School, Boston, USA	293	3098	10.57	37
3	UCL, Institute of Ophthalmology, London	265	2175	8.21	34
4	New York Eye and Ear Infirmary, New York, USA	257	1825	7.10	30
5	University of Miami, Leonard M Miller School of Medicine, Miami, Florida, USA	252	2599	10.31	37
6	Wills Eye Hospital, Philadelphia, USA	244	1532	6.28	25
7	Chinese University of Hong Kong, Department of Ophthalmology & Visual Science, Hong Kong	229	1588	6.93	30
8	Sun Yat-Sen University, Zhongshan Ophthalmic Centre, Guangzhou, China	225	785	3.49	19
9	Capital Medical University, Beijing Tongren Hospital, Beijing, China	216	675	3.13	15
10	Universitat Enlangen-Nurnberg, Enlangen, Germany	213	1559	7.32	31
11	Ruprecht-Karls-University of Heidelberg, Heidelberg, Germany	212	2552	12.04	34
12	John Hopkins University, The Wilmer Eye Institute, Baltimore, USA	200	2820	14.10	38
13	Singapore National Eye Center, Singapore	198	1581	7.98	31
14	Sao Paulo University, Rubens Siqueira Center, Sao Paulo, Brazil	196	1220	6.22	23
15	University of Toronto, Department of Ophthalmology & Vision Science, Toronto, Canada	185	1218	6.58	28
	Total	3483	27516	7.90	29.53
	Total of the Country	33098			
	Share of Top 15 Institutions in World Output	10.52			

TP = Total Papers; TC = Total Citations; ACPP = Average Citations Per Paper

6.92% share). The focus of glaucoma research has increased in adults (from 34.68% to 42.40%), adolescents (from 7.32% to 8.87%) from 2002-06 to 2007-11, as against decrease in middle aged (from 36.99% to 22.05%), aged 80 & over (from 12.59% to 11.95%) and child (from 7.07% to 6.82%) during the similar period (Table 7)

Research profile of most productive institutions in glaucoma research

The top 15 most productive institutions involved in glaucoma research have published 185 or more papers each during 2001-11. The publications profile of these 15 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 10.52% share (with 3483 papers) in the cumulative world publications output in glaucoma research, with an average of 232.2

papers per institution. Only six institutions have registered higher publications share than the group average. These are University of Melbourne, Centre for Eye Research, Australia with 298 papers, followed by Harvard Medical School, Boston, USA (293 papers), UCL, Institute of Ophthalmology, London (265 papers), New York Eye and Ear Infirmary, New York, USA (257 papers), University of Miami, Leonard M Miller School of Medicine, Miami, Florida, USA (252 papers) and Wills Eye Hospital, Philadelphia, USA (244 papers). The average citation per paper registered by the total papers of these 15 institutions is 7.90 during 2002-11. Only 7 Indian institutions have registered higher impact than the group average. Amongst these seven Indian institutions, the highest impact of 14.10 citations per paper was scored by the John Hopkins University, The Wilmer Eye Institute, Baltimore, USA, followed by Ruprecht-Karls-

University of Heidelberg, Heidelberg, Germany (12.04 citations per paper), Harvard Medical School, Boston, USA (10.57 citations per paper), University of Miami, Leonard M Miller School of Medicine, Miami, Florida, USA (10.31 citations per paper), UCL, Institute of Ophthalmology, London (8.21 citations per paper), Singapore National Eye Center, Singapore (7.98 citations per paper) and University of Melbourne, Centre for Eye Research, Australia (7.68 citations per paper). The average h-index value of these 15 most productive institutions was 29.53 during 2002-11. The six Indian institutions have scored higher h-index value than group's average of 9.47. Amongst these six Indian institutions, the highest h-index value (38) was achieved by John Hopkins University, The Wilmer Eye Institute, Baltimore, USA, followed by Harvard Medical School, Boston, USA and University of Miami, Leonard M Miller School of Medicine, Miami, Florida, USA (37 each), Ruprecht-Karls-University of Heidelberg, Heidelberg, Germany and UCL, Institute of Ophthalmology, London (34), University of

Melbourne, Centre for Eye Research, Australia and Universitat Enlangen-Nurnberg, Enlangen, Germany (31 each), New York Eye and Ear Infirmary, New York, USA and Chinese University of Hong Kong, Department of Ophthalmology & Visual Science, Hong Kong (30).

Most productive authors in glaucoma research

Fifteen authors having been identified as most productive, who have published 92 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 2251 papers with an average of 150.07 papers per author and account for 6.80% share in the cumulative world publications output during 2002-11. Six authors have published higher number of papers than the group average (150.07). These are: R.N. Weinreb with 280 papers, followed by J.B. Jonas (247 papers), R. Ritch (209 papers), T. Aung (176 papers), J.M. Liebmann (173 papers), T. Aung (176 papers), J.M. Liebmann

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

Sl. No.	Name	Address	TP	TC	ACPP	H-Index
1	R.N. Weinreb	University of California, Department of Ophthalmology, Hamilton Glaucoma Center, San Diego, USA	280	3440	12.29	46
2	J.B. Jonas	Ruprecht – Karls - University of Heidelberg, Medical Faculty of Mannheim, Department of Ophthalmology, Germany	247	2716	11.00	34
3	R. Ritch	New York Eye and Ear Infirmary, New York, USA	209	1329	6.36	26
4	T. Aung	Singapore Eye Research Institute, National University of Singapore	176	1253	7.12	25
5	J.M. Liebmann	New York Eye and Ear Infirmary, New York, USA	173	1155	6.68	25
6	D.S.C. Lam	Chinese University of Hong Kong, Department of Ophthalmology & Visual Science, Hong Kong	169	1141	6.75	27
7	M. Araie	University of Tokyo, School of Medicine, Department of Ophthalmology, Tokyo, Japan	137	831	6.07	22
8	F.A. Medeiros	University of California, Department of Ophthalmology, La Jolla, CA, USA	121	1669	13.79	31
9	L.M. Zangwill	University of California, Department of Ophthalmology, Hamilton Glaucoma Center, San Diego, USA	121	1860	15.37	35
10	W.C. Stewart	PRN Pharmaceutical Research Network, Charleston, SC, USA	116	582	5.02	20
11	P.J. Foster	Moorefields Eye Hospital, Glaucoma Department, London, UK	108	1032	9.56	26
12	D.S. Friedman	John Hopkins University, Wilmer Eye Institute, Baltimore, USA	103	1324	12.85	31
13	P.A. Sample	University of California, Department of Ophthalmology, Hamilton Glaucoma Center, San Diego, USA	102	1253	12.28	29
14	J. Flammer	University Hospital of Basel, Department of Ophthalmology, Glaucoma Service, Switzerland	97	708	7.30	21
15	J. Caprioli	UCLA, Jules Stein Eye Institute, Glaucoma Division, Los Angeles, CA, USA	92	922	10.02	22
	Total		2251	21215	9.42	25.93
	Total of the Country		33098			
	Share of Top 15 Authors in World Output		6.8	150.07		

TP =Total Papers; TC = Total Citations; ACPP = Average Citations Per Paper

(173 papers) and D.S.C. Lam (169 papers). Considering the quality/impact of papers, these 15 productive authors have received a total of 21215 citations for 2251 papers with an average of 9.42 citations per paper. Seven authors have registered higher impact than the average impact of papers of all authors (9.42). These are: L.M. Zangwill with 15.37 citations per paper, F.A. Medeiros (13.79 citations per paper), D.S. Friedman (12.85 citations per paper), R.N. Weinreb (12.29 citations per paper), P.A. Sample (12.28 citations per paper), J.B. Jonas (11.0 citations per paper) and J. Caprioli (10.02 Citations per Paper). Measuring the performance of these authors on the basis of h- index, nine have achieved the higher h-index value than the group average of 25.93. These authors are R.N. Weinreb with h-index of 46, followed by L.M. Zangwill (35), J.B. Jonas (34), F.A. Medeiros and D.S. Friedman (31 each), P.A. Sample (29), D.S.C. Lam (27), R. Ritch and P.J. Foster (26 each)(Table 9).

Most productive journals

The 15 most productive journals publishing world research papers in glaucoma research together contributed 12240 papers, which accounts for 36.98% 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 37.28% during 2002-06 to 36.76% during 2007-11 (Table 10)

Summary

The world has published 33098 papers in glaucoma research during 2002-11, which has increased from 2365 papers in 2002 to 4304 papers in 2011, witnessing an annual average growth rate of 6.94%.

In order to further increase the global research output, there is a need to promote and invest in research in glaucoma and delivery of glaucoma care. Research is the key to future progress towards elimination of glaucoma blindness and visual disability. For increasing the research quality, there is a need to further increase research collaboration among the leading countries. To guide the current primary care practitioners and policy-makers, there is a need for evolve policies for detection, diagnosis, management and prevention of glaucoma. It is important to keep a control on major causes of glaucoma, besides strengthening appropriate human resource development and development of modern infrastructure and appropriate technology. There is

Table 10—Most productive journals in glaucoma research, 2002-11

Sl. No.	Name of the Journal	Number of Papers		
		2002-06	2007-11	2002-11
1	<i>Investigative Ophthalmology & Visual Science</i>	525	763	1288
2	<i>Ophthalmology</i>	555	680	1235
3	<i>Journal of Glaucoma</i>	489	693	1182
4	<i>British Journal of Ophthalmology</i>	502	529	1031
5	<i>International Journal of Ophthalmology</i>	166	846	1012
6	<i>American Journal of Ophthalmology</i>	543	468	1011
7	<i>Eye</i>	380	538	918
8	<i>Journal of Cataract and Refractive Surgery</i>	464	451	915
9	<i>Archives of Ophthalmology</i>	387	394	781
10	<i>Graefe S Archive for Clinical and Experimental Ophthalmology</i>	226	354	580
11	<i>European Journal of Ophthalmology</i>	185	322	507
12	<i>Clinical and Experimental Ophthalmology</i>	225	277	502
13	<i>Japanese Journal of Clinical Ophthalmology</i>	270	212	482
14	<i>Experimental Eye Research</i>	169	230	399
15	<i>Kinische Monatsblatter Fur Augenheikunde</i>	191	206	397
	Total	5277	6963	12240
	Total of the world	14154	18944	33098
	Share of top 15 journals in world output	37.28	36.76	36.98

need to promote glaucoma awareness through community wide awareness programmes and through large-scale service organizations. It is also important to provide in-depth education to ophthalmologists and allied personnel in the form of educational packages regularly. Research is the key to future progress towards elimination of glaucoma blindness and visual disability.

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