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# Tuberculosis research in India and China: From bibliometrics to research policy

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*India and China lead the world in the incidence of tuberculosis (TB), accounting for 23% and 17% respectively, of the global burden of the disease and hold the 15th and the 18th positions in terms of incidence per 100,000 population. But India accounts for only about 5–6% of the world's research output in this area and China a paltry 1% as seen from papers indexed in three international databases, viz. PubMed, Science Citation Index and Biochemistry and Biophysics Citation Index over the ten-year period 1990–1999. Thus there is a tremendous mismatch between the share of the burden of the disease and share of research efforts. Is such mismatch acceptable? It raises the question 'should resource-poor countries invest in research or should they depend on research performed elsewhere and invest their meagre resources predominantly in health-care measures?' We argue that both India and China should invest much more in research than they do. We have also mapped TB research in the two countries and identified institutions and cities active in research, journals used to publish the findings, use of high impact journals, impact of their research as seen from citations received and extent of international collaboration. Although China performs much less research than India and its work is quoted much less often, it seems to have done far better than India in health-care delivery in TB. Perhaps the Chinese are better able to translate know-how into do-how than the Indians.*

THE nature and extent of health research undertaken in developing countries is a matter of great global concern. Research in developing countries is characterized by a grossly inadequate research capacity and research productivity. In addition, too high a proportion of the research that is done is not sufficiently focused on the health problems of the countries concerned. Unfortunately, these issues have not attracted adequate research attention. This paper is based on the premise that collecting better and more comprehensive data is the first

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step in the development of a health policy. It addresses two issues, both based on the published literature. The first concerns the need for developing countries to perform research in diseases that are of great concern to them, and the second concerns mapping tuberculosis (TB) research in India and China. We try to provide an analysis of the volume, nature and quality of TB research in India and China and attempt to make some concrete suggestions for policy changes.

Approximately 1.86 billion people – about one-third of the world's population – are infected with the TB bacterium. The annual incidence of TB rose from 8 million in 1997 to 8.4 million in 2000, and it is expected to rise further to 10.2 million new cases a year by 2005. Annually, 1.9 million people die from the disease[1]. TB continues to be a major health problem in developing countries where it is now one of the most common causes of death. 'More people than ever will die of the disease this year', said a recent report[2]. It kills more young people and adults than any other communicable disease. It is particularly severe on the poor and its consequences for the developing world are devastating. The situation today, with TB accounting for 26% of all avoidable adult deaths in less-developed countries, is very similar to what it was at the end of the 19th century, when Hermann Biggs of the New York City Department of Health remarked that, compared with TB, 'all other communicable and preventable diseases sink into relative insignificance'[3]. Indeed, as pointed out by Frieden *et al.*[3], the current approach to control TB advocated by WHO and the International Union against Tuberculosis and Lung Disease is strikingly similar to the one pursued by Biggs. The only difference now is that HIV has changed the epidemiology of TB. Globally, 8% of TB cases are due to HIV, but in some countries in sub-Saharan Africa, the figure has risen to 75% (ref. 4).

According to WHO, India has the highest incidence of TB (about 1.83 million cases in 1998) and accounts for 23% of the world's cases[5]. A report from the National Tuberculosis Institute, Bangalore, states that India accounts for nearly 30% of all TB cases in the world[6]. China is a close second with about 1.41 million or 17% of the world's cases. In terms of rate of incidence per 100,000 population many other countries are worse off than India (186 cases for 100,000 people) and China (112.6): Zimbabwe (560.1), Cambodia (540.5), South Africa (437.9), Afghanistan (353.1), Uganda (332.3), Tanzania (308.6), Philippines (306.7), Kenya (296.8), Indonesia (286.6), Ethiopia (268.6), Peru (265), Bangladesh (244.7), Nigeria (243.4) and Vietnam (189.3)[5]. It is heartening therefore that the Global Alliance on Tuberculosis Drug Development, which came into being on 10 October 2000, is combining the resources of charitable foundations (such as the Gates and Rockefeller Foundations and the Wellcome Trust), international organizations (such as WHO, World Bank and UNDP), academia and the pharmaceutical industry to fund projects aimed at discovering new drugs for tuberculosis, that are affordable to the developing world[7,8]. The Stop TB initiative inaugurated in 1998 is trying to put TB at the top of the agenda for politicians and health services. While such global initiatives are welcome, countries like India and China ought to share the burden of research, as it is their people who suffer the most. As the 10/90 Report[9] states, it is necessary for developing countries to develop the research capacity necessary to deal with their own health problems through evidence-based decision-making. This paper provides information on how much research is being carried out in India and China in TB and by which institutions, where this research is published and with what impact – evidence that can help decision-making.

One may argue, 'it is unrealistic, given the economic status of developing countries, to call for expanded support for health-related research. However, available funds could be focused better and addressed to local problems. The fact is that researchers in developing countries generally address issues that bring prestige in the wider world of science, with limited attention to local needs'[10]. An orientation to scientific excellence is understandable, and certainly has some value, but it contributes little to the developing countries that support such research. It is not often realized that good research in any area will bring prestige. For example, Sambhu Nath De's outstanding work on cholera[11–13], which unfortunately went unrecognized in India during his life time, earned him a nomination to the Nobel Prize, a tribute by Eugene Garfield, the peripatetic chronicler of science[14], and a special issue of a premier Indian science journal dedicated to him[15]. The Global Forum for Health Research[9] opines that 'At present, there is a mismatch between the burden of disease and health problems and the technical capacity of developing countries to make use of existing knowledge or generate new knowledge to combat this'. Arunachalam[16,17] has shown that there is a considerable mismatch between India's perceived needs in health research and what Indian researchers are actually performing.

## Why should India and China do TB research?

It may be all right for small countries, dependent on other larger countries for their survival, to depend on health research carried out elsewhere. But neither India nor China can afford to have such an attitude. There are many reasons why TB research is important and should be accorded high priority in countries like India and China. For one, these are countries with highest incidence of TB and deaths due to TB. Advanced countries have very little incentive to invest in TB research – at least till recently. As an exception, the US is making moves to allocate a substantial sum of $640 million for TB research, thanks to a report of the National Academy of Sciences[18] and persistent efforts by Congressman Sherrod Brown[19]. Early last year two new bills focusing on TB battle were introduced into the US Congress. According to Brown, the Comprehensive Tuberculosis Act of 2001 requests $240 million for the National Institutes of Health's anti-TB efforts and $400 million for the Centers for Disease Control and Prevention's budget. The second bill, known as the 'Stop TB Now Act', would authorize $200 million for various organizations involved in fighting the disease in developing countries[20]. Although it is widely accepted that investments in health research have been among the most cost-effective investments over the past several decades and that the 20th century health revolution appears to have resulted far more substantially from the generation and application of new knowledge[21], the great imbalance between investments in health research and the global burden of disease persists[22]. Even though 85% of the global burden of disability and premature mortality occurs in the developing world, less than 4% of global research was devoted to diseases and disorders that dominate the burden of disease in developing countries. By the early 1990s, while TB was responsible for 2.8% of the entire burden of ill-health in the world, research on TB, at US $33 million in 1993, accounted for less than 0.1% of the world's expenditure on health research and development[23]. Funding for health research expressed as expenditure per DALY (disability adjusted life year) in 1990 and 2020 is ridiculously low for TB ($0.68 per DALY in 1990 and $0.61 per DALY in 2020), compared to asthma ($13.22 in 1990 and $10.76 in 2020) and blindness ($10.09 in 1990 and $235.37 in 2020)[22]. Fortunately, after two decades of neglect, research in TB is reviving and research funding in TB has increased from between $19 and $33 million per year during 1991–1993 to nearly $100 million in 1995 (ref. 23).

Second, TB in India (and China) is different from TB in the advanced countries of the West. Jan van Embden of the Netherlands has characterized TB isolates from many parts of the world using molecular typing and has found that while most isolates from the West have ten or more copies of IS 6110 and H37Rv, the sequenced isolate has 16 copies, a significant proportion of isolates from India have 0, 1 or 2 copies of IS 6110. Thus the Indian TB strains appear to be different from those that cause TB in the West (Vijaya, S., Indian Institute of Science, Bangalore, private commun.). The ever-growing emergence of strains of *Mycobacterium tuberculosis* resistant to presently available drugs has made the control of TB, especially in India, China and other developing countries, a difficult proposition. Therefore, the need to develop new drugs against *M. tuberculosis* remains an important one.

Third, multi-drug resistance of TB is on the rise and the current vaccine, BCG, is of limited efficacy, especially in the countries hardest hit[24]. BCG vaccination provides 80% protection in the West, but the Chingleput trial since 1972 has shown that it provides virtually no protection against TB in adults and against non-pulmonary forms of TB in India[25,26]. This complete failure of BCG has also been attributed by some scientists to the unique nature of Indian TB strains. The virulence in animal models, especially using guinea pigs, is similar for Indian and Chinese TB strains, but considerably different from those in the West. Currently TB is rarely seen in the native state in the West. It is mostly associated with HIV/AIDS infection. India and China have a long history of incidence of TB – long before HIV emerged as a problem. TB in India and possibly China is malnutrition-dependent.

Fourth, DOTS (directly observed treatment, short-course), the multi-drug schedule of treatment and currently the main control strategy, lasts at least six months. Given the serious problem of non-compliance by patients in India and other developing countries, DOTS is becoming ineffective. There is a need to develop more rapidly acting drugs. Also, there have been demands to develop a better way to deal with TB than DOTS[27]. There is a need to develop better diagnostic tests for TB to replace the cumbersome and labour-intensive test that has been in use for over a hundred years. There is a need to understand better the health-seeking behaviour and drug adherence of TB patients and the social and economic mechanisms underlying the epidemic of multi-drug-resistant TB in developing countries[24].

How can all these be achieved without indigenous research? Especially when drug companies are reluctant to invest on developing a vaccine for TB and have not produced a new class of TB drugs in more than 30 years (as they see no prospect of getting adequate commercial returns on the investment of approximately $300 million needed for getting each new drug to the market in those parts of the world where TB is most prevalent), public funding of such research is all the more important. This was precisely what the Cape Town meeting of February 2000 convened by the Rockefeller Foundation recommended[28]. It was only in 2001 that AstraZeneca came forward to make an initial investment of $10 million and a recurring investment of $5 million over the next five years to focus on developing drugs for TB at its research centre in Bangalore[29]. According to Paul Nunn[23], the biggest reason why the burden of TB persists is the failure of the public-health community to make better use of existing available tools, which, if properly deployed, can reach cure rates of over 95%. Why it does not happen, and how we can make it happen are questions worthy of research.

## Mapping TB research in India and China

For mapping TB research in India and China, we downloaded papers published from addresses in the two countries from three databases, viz. *PubMed* (web edition), *Science Citation Index* (*SCI*) on CD-ROM and *Biochemistry and Biophysics Citation Index* (*BBCI*) (CD-ROM). The fields downloaded are: names of authors with initials, address, title of the paper, document type, source (journal title, volume, year, page, conference title, etc.) and language. While *SCI* and *BBCI* list the names and addresses of all authors of papers they index, *PubMed* gives the address of only one (usually the first) author. Therefore, a *PubMed* search for Indian papers will miss all multi-authored papers in which the Indian author's address is not given. We used the following keywords in the title field to download papers on TB: Tubercle, tubercul*, Pott's, scroful*, and Mantoux. Addition of terms such as 'BCG' did not bring in many additional records pertaining to TB research. On the contrary, 'BCG' threw up a number of irrelevant entries (relevant to leprosy, for example). As merely giving India (or China) as the search term in the address field will not identify all papers from the country in *PubMed*, we gave the names of all possible cities, towns and states/provinces in India (or China) in the address field, while searching *PubMed*. Such precaution was not necessary, of course, when searching *SCI* and *BBCI*, as these databases invariably include country names in the address field. For our analysis, we considered all papers published in the ten years from 1990 to 1999. The way bibliographic data are presented differs from database to database, and some papers would have been indexed in more than one database. Therefore, special efforts were made to unify the data and to eliminate duplicates. Certain journals changed names during the period under study and certain others merged with other journals. For example, *American Review of Respiratory Disease* was renamed *American Journal of Respiratory and Critical Care Medicine*; *Nuclear Medicine and Biology – International Journal of Radiation Applications and Instrumentation, Part B* changed to *Nuclear Medicine and Biology*; and *Zentralblatt fur Bakteriologie – International Journal of Medical Microbiology, Virology, Parasitology and Infectious Diseases* changed to *International Journal of Medical Microbiology*. These changes were taken care of and the variants of the concerned journals brought under a single entry. For each entry, journal impact factor and country publishing the journal were added by looking up *Journal Citation Reports* (JCR) 1997 (CD-ROM edition). Information on country publishing the journals, which are not listed in *JCR* was found from *Publist*, a web source of information on serials. For each paper citations were looked up from the year of publication till the end of 2000 from both *SCI* and *BBCI*, and the information merged and duplicates eliminated. The extent of international collaboration was estimated by analysing information on multi-authored papers, available for papers indexed in *SCI* and *BBCI*.

We have also carried out similar studies on diabetes[30] and cardiovascular disease research[31] in India and China.

## Findings of the mapping exercise

There were 1010 unique papers from India, consisting of 868 articles, 74 letters, 39 notes, 23 meeting abstracts and six editorials. Of the 201 unique papers from China, 191 are articles, four meeting abstracts, three letters, two notes and one editorial. Of the more than 15,880 TB papers indexed by *PubMed*, India's share is 5.34% and China's 1.11%. China's share of the TB literature indexed in *SCI* (0.49%) and *BBCI* (0.94%) is even lower, whereas Indian research is indexed well in both these databases (5.75% of the 9542 papers in *SCI* and 7.51% of the 959 papers in *BBCI*). India's share in basic new biology-oriented research relating to TB (assuming that papers indexed in *BBCI* are basic) is higher (7.51%) than her share of regular medical/clinical papers (indexed in *PubMed*), although its volume is much less. For both India and China, *PubMed* indexes a larger percentage of the respective country's TB research papers than either *SCI* or *BBCI*. However, as seen in Figure 1, Indian researchers publish a higher per cent of their work (> 53.7%) in journals indexed by *SCI* than Chinese researchers (< 20%). One reason for this is that while virtually the entire research output from India is published in English journals, 73.6% of the Chinese papers are published in Chinese journals and 25% in English journals. If we have not searched *BBCI*, we would have missed only 10 Indian papers and not a single Chinese paper, but we would have missed 61 citations for Indian papers and six for China. Most TB-

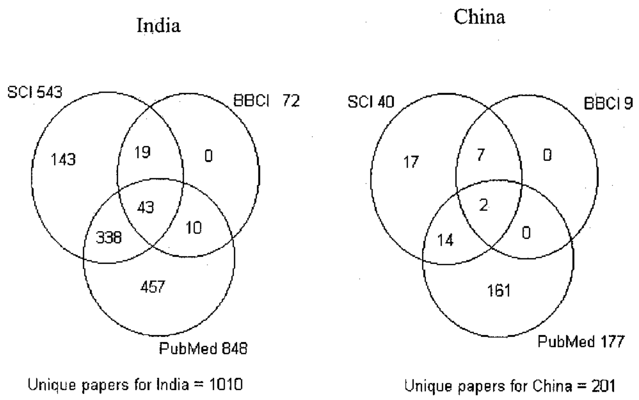


**Figure 1.** Coverage of Indian and Chinese TB papers in three databases (1990–1999).

**Table 1.** Research share of India and China in different fields

| Research share | TB [*PubMed* 1990–99] | CVD | Diabetes | Chemistry [*CA* 2000] | New Biology [*BBCI* 2000] | Mathematics [*MathSciNet* 2000] | All of Science [*SCI* 2000] |
|---|---|---|---|---|---|---|---|
| India (%) | 5.34 | 0.66 | 1.11 | 2.3 | 1.35 | 2.02 | 1.55 |
| China (%) | 1.11 | 1.04 | 0.63 | 9.5 | 2.03 | 10.35 | 2.83 |

**Table 2.** Contribution of India and China to the world literature of TB and per cent share of incidence compared with other countries

| | No. of papers (1990–1999)+ | Percentage world share in research *A* | Percentage world share in TB incidence (estimated for 1999)++ *B* | Ratio (research share/incidence share) *A/B* |
|---|---|---|---|---|
| World | 9796 | | | |
| USA | 3194 | 32.61 | 0.19 | 171.63 |
| UK | 1311 | 13.38 | 0.08 | 167.25 |
| G7 | 6107 | 62.34 | 1.14 | 54.68 |
| EU-15* | 3563 | 36.37 | 1.57 | 23.17 |
| Nordic countries# | 284 | 2.90 | 0.03 | 96.67 |
| Australia | 175 | 1.79 | 0.02 | 89.5 |
| Israel | 50 | 0.51 | 0.01 | 51.0 |
| India | 565 | 5.77 | 21.68 | 0.27 |
| China | 50 | 0.51 | 16.09 | 0.03 |
| Brazil | 116 | 1.18 | 1.40 | 0.84 |
| Mexico | 85 | 0.87 | 0.44 | 1.98 |
| South Africa | 393 | 4.01 | 2.46 | 1.63 |
| Kenya | 40 | 0.41 | 1.45 | 0.28 |

+*Science Citation Index*, CD-ROM edition (disk years); ++Calculated from the data for the year 1999 provided by World Health Organization (ref. 32); *Luxembourg not included; #Denmark, Finland, Norway and Sweden.

related papers indexed in *BBCI* are also indexed in *SCI*. While India's share of 5–6% of the world's literature of TB research and about 1% of China's may look small in comparison with the 23% and 17% of the burden of the disease in 1998 (ref. 5), one may consider India is doing pretty well in TB research, as in other areas like chemistry and mathematics, as seen from *Chemical Abstracts* and *Mathsci*., India's share of the world journal literature is of the order of 2–3% only (Table 1).

In Figure 2 we match the per cent share of world research in TB of India, China and many other countries as seen from *SCI*, with the estimated per cent world share of incidence of TB in 1999. India accounted for more than 21% of the incidence of TB in 1999 (ref. 32), but carried out less than 6% of world TB research in the 1990s. China, with more than 16% of incidence, was responsible for a paltry half per cent of research (Table 2). Other developing countries, such as Brazil, Mexico, Kenya, Nigeria and Egypt have also recorded poor ratios of research to incidence. In contrast, USA and UK, with hardly any incidence (below 0.2%) were responsible for more than 32% and 13% of world research in TB. The G7 countries, accounting for about 1% of incidence, were responsible for more than 62% of world research and the European Union (minus Luxembourg), accounting for less than 1.6% incidence, was responsible for over 36% of world research in TB. Of course, the amount of research a country undertakes does not depend merely on the need for research. There are other factors such as availability of capable researchers, infrastructure and funds.

The distribution of Indian and Chinese papers over the years is shown in Figure 3. We notice a modest rise in the number of papers from India up to 1996 and then a substantial fall up to 1998, followed by a steep rise in 1999. Throughout the ten years, China published far fewer papers than India and her output was steady, around 25 papers a year up to 1997, followed by a steep fall in 1998.

## *Distribution by journal*

Indian researchers have published in 247 journals from 20 countries in the ten years (including 400 papers in 28 Indian journals). Table 3 lists journals published in which the Indian papers were cited not less than 12 times by the end of 2000. Chinese researchers have used 51 journals (including 159 papers in 18 Chinese journals) published from 11 countries. Table 3 also lists some journals often used by Chinese researchers to publish their papers on TB. Only one Chinese journal (*Chinese Medical Journal*) is listed in *JCR* 1997 with an impact factor of 0.127. However, none of the seven papers published in this journal was cited even once. Apart from home country journals, Indian researchers publish their work often in journals published from UK (230 papers in 54 journals), USA (229 papers in 93 journals), the Netherlands (34 papers in 15 journals) and Germany (30 papers in 12 journals). Chinese researchers have published 18 papers in 16 US journals and 10 papers in 6 UK journals.

Journals often used by Indian researchers to publish their findings are *Tubercle and Lung Disease* (75 papers and 224 citations), *Indian Pediatrics* (65 papers, 29 citations), *Journal of the Association of Physicians of India* (42 papers, 15 citations) and *Journal of the Indian Medical Association* (35 papers, 9 citations). Chinese researchers publish many of their papers in *Chung Hua Chieh Ho Ho Hu His Tsa Chih* (114 papers, 9 citations), *Chinese Medical Journal* (7 papers, impact factor 0.127, no citations), *Chung Hua Nei Ko Tsa Chih* (6 papers, 1 citation) and 5 papers each in *Chung Hua Wai Ko Tsa Chih* (5 papers, no citations) and *Tubercle and Lung Disease* (5 papers, 35 citations).

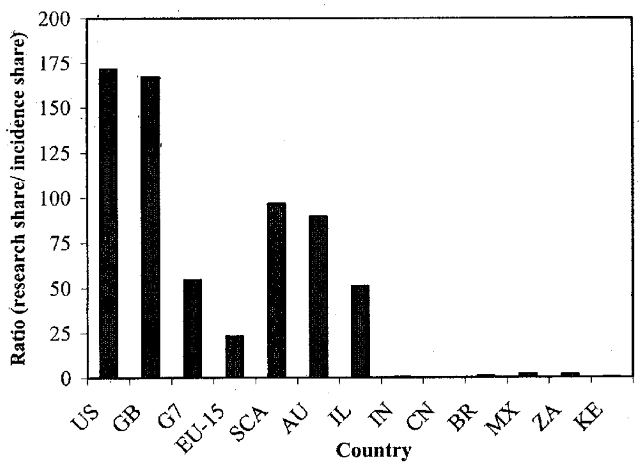


**Figure 2.** Research share/incidence share ratio for selected countries.

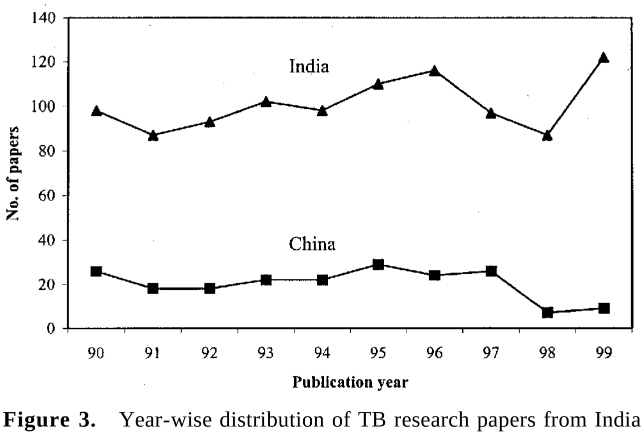


**Figure 3.** Year-wise distribution of TB research papers from India and China.

## *Distribution by journal impact factor*

Both India and China have published a very large percentage of their papers in low-impact journals: 750 Indian papers and 180 Chinese papers in journals of impact factor less than 1.0. Of these, 482 Indian papers have appeared in 47 non-*SCI* journals and 165 Chinese papers have appeared in 23 non-*SCI* journals (impact factor zero). Only a few papers (34 papers from India in 12 journals and 2 papers from China in 2 journals) have appeared in high impact factor (> 5.0) journals and many of these are meeting abstracts and letters (Table 4). From India, there was one article and two letters in *New England Journal of Medicine* (impact factor 27.766), two articles and eight letters in *Lancet* (impact factor 16.135), two meeting abstracts in *FASEB Journal* (impact factor 14.629), one article each in *Journal of Experimental Medicine* (impact factor 14.384) and *Journal of Molecular Biology* (impact factor 5.673), four meeting abstracts in *Gastroenterology* (impact factor 10.250), one letter in *JAMA* (impact factor 9.258), one meeting abstract in *Hepatology* (impact factor 5.849) and one meeting abstract in *Brain Pathology* (impact factor 5.663). From China there was one article each in *Lancet* and *Journal of Immunology* (impact factor 6.937).

## *Distribution by subfield*

We classified the journals into 42 subfields using the deluxe classification provided by the Research Department of the Institute for Scientific Information (ISI), Philadelphia. (This is not the best way to classify; ideally, one should classify each individual article. However, the method adopted is good enough for our purpose.) Unfortunately, 45 journals carrying 381 Indian papers (cited 249 times) and 23 journals carrying 160 Chinese papers (cited 25 times) were not found in the ISI's deluxe classification, probably because these are non-*SCI* journals (Table 5). There is some difference in the emphasis on different subfields in the two countries. India is active in cardiovascular and respiratory systems (101 papers in 6 journals); medical research, general topics (65 papers in 16 journals); microbiology (60 papers in 14 journals); and radiology, nuclear medicine and imaging (40 papers in 17 journals). Chinese researchers have published nine papers in three cardiovascular and respiratory systems and nine papers in three general and internal medicine journals.

## *Distribution by institution*

In all, 196 Indian institutions have published at least one paper in the ten years; 22 of them have published ten papers or more. Table 6 lists the institutions that

**Table 3.** Journals used to publish frequently cited Indian research papers. Citations seen from *SCI* and *BBCI* 1990–2000

| Journal | Country of publication | Impact factor (*JCR* 1997) | No. of papers | No. of cited papers | No. of citations |
|---|---|---|---|---|---|
| **India** | | | | | |
| *Tubercle and Lung Disease* | GB | A | 75 | 38 | 224 |
| *Lancet* | GB | 16.140 | 10 | 7 | 189 |
| *American Journal of Gastroenterology* | US | 2.344 | 13 | 10 | 103 |
| *Clinical Radiology* | GB | 0.946 | 4 | 4 | 67 |
| *Infection and Immunity* | US | 3.713 | 7 | 2 | 57 |
| *Journal of Neurosurgery* | US | 2.999 | 4 | 3 | 57 |
| *Vaccine* | GB | 1.949 | 4 | 3 | 52 |
| *Gene* | NL | 1.838 | 6 | 6 | 51 |
| *Journal of Infectious Diseases* | US | 5.099 | 3 | 3 | 39 |
| *AIDS* | GB | 5.05 | 4 | 1 | 37 |
| *International Journal of Dermatology* | US | 0.676 | 7 | 7 | 37 |
| *Antimicrobial Agents and Chemotherapy* | US | 3.56 | 7 | 3 | 33 |
| *Gut* | GB | 4.546 | 3 | 1 | 32 |
| *International Journal of Leprosy and other Mycobacterial Diseases* | US | 0.784 | 20 | 10 | 31 |
| *Acta Cytologica* | US | 1.425 | 12 | 6 | 30 |
| *Indian Journal of Medical Research* | IN | 0.318 | 28 | 13 | 30 |
| *Indian Pediatrics* | IN | A | 65 | 16 | 29 |
| *Neuroradiology* | DE | 0.754 | 4 | 3 | 29 |
| *Indian Journal of Chest Diseases and Allied Sciences* | IN | A | 31 | 9 | 24 |
| *American Journal of Roentgenology* | US | 2.332 | 9 | 7 | 23 |
| *Chest* | US | 2.341 | 4 | 3 | 23 |
| 136 other journals cited at least once | | | 554 | 262 | 797 |
| 90 other journals with no citation | | | 136 | 0 | 0 |
| Total | | | 1010 | 417 | 1994 |
| **China** | | | | | |
| *Journal of Clinical Microbiology* | US | 3.783 | 2 | 2 | 62 |
| *Tubercle and Lung Disease* | GB | A | 5 | 5 | 35 |
| *Analytica Chimica Acta* | NL | 1.778 | 1 | 1 | 19 |
| *Clinical and Diagnostic Laboratory Immunology* | US | 1.045 | 2 | 2 | 11 |
| *Journal of Immunology* | US | 6.937 | 1 | 1 | 11 |
| *Chung Hua Chieh Ho Ho Hu Hsi Tsa Chih* | CN | A | 114 | 6 | 9 |
| *Lancet* | GB | 16.140 | 1 | 1 | 8 |
| *Protein Science* | US | 4.600 | 1 | 1 | 3 |
| 11 other journals cited at least once | | | 24 | 12 | 14 |
| 32 other journals | | | 50 | 0 | 0 |
| Total | | | 201 | 31 | 172 |

A, not indexed in *JCR* 1997.

publish often. These include All India Institute of Medical Sciences (AIIMS), New Delhi (107 papers and 438 citations), Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh (95 papers and 160 citations), Tuberculosis Research Centre (TRC), Chennai (79 papers and 186 citations), and King Edward Memorial Hospital, Mumbai (35 papers and 71 citations). India's output of TB research papers comes mainly from academia (639 papers) and hospitals (207 papers from 70 hospitals). Fourteen medical universities have published 313 papers, 16 general universities have published 60 papers, and 65 medical colleges 262 papers. Surprisingly, the research departments and councils of the central government, which are strong in physics and chemistry and to some extent engineering, account for only 14% of TB papers. Nine laboratories under the Indian Council of Medical Research have published 97 papers, five laboratories of the Council of Scientific and Industrial Research have published 15 papers, and three laboratories of the Department of Biotechnology have published 16 papers. Bhabha Atomic Research Centre, a constituent of the Department of Atomic Energy, has published 11 papers.

In China also, much of TB research takes place in medical colleges and universities and hospitals. Nearly 118 Chinese institutions have published at least one paper, five of them having contributed five or more papers. Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing (26 papers and 82 citations), 309th Hospital of PLA, Beijing (9 papers, no citations), and National Tuberculosis Control Centre, Beijing (9 papers, 3 citations) are the leading publishers of TB

**Table 4.** Distribution of Indian and Chinese papers by impact factor range of journals (based on *JCR* 1997)

| | India | | | | China | | | |
|---|---|---|---|---|---|---|---|---|
| Impact factor range | No. of journals | No. of papers | No. of cited papers | No. of citations | No. of journals | No. of papers | No. of cited papers | No. of citations |
| 0.000 | 47 | 482 | 157 | 469 | 23 | 165 | 17 | 50 |
| > 0.0–0.5 | 40 | 148 | 51 | 124 | 2 | 8 | 1 | 1 |
| > 0.5–1.0 | 43 | 120 | 69 | 314 | 7 | 7 | 2 | 2 |
| > 1.0 –1.5 | 29 | 56 | 32 | 121 | 5 | 6 | 2 | 11 |
| > 1.5–2.0 | 30 | 56 | 31 | 189 | 2 | 2 | 1 | 19 |
| > 2.0–2.5 | 18 | 51 | 32 | 191 | 3 | 3 | 1 | 1 |
| > 2.5–3.0 | 9 | 18 | 9 | 74 | 2 | 2 | 1 | 2 |
| > 3.0–3.5 | 6 | 9 | 6 | 33 | – | – | – | – |
| > 3.5–4.0 | 5 | 24 | 9 | 111 | 2 | 3 | 3 | 64 |
| > 4.0–4.5 | 3 | 3 | 3 | 24 | 1 | 1 | – | – |
| > 4.5–5.0 | 5 | 9 | 5 | 61 | 2 | 2 | 1 | 3 |
| > 5.0–5.5 | 3 | 10 | 4 | 76 | – | – | – | – |
| > 5.5–6.0 | 3 | 3 | 1 | 2 | – | – | – | – |
| > 6.5–7.0 | – | – | – | – | 1 | 1 | 1 | 11 |
| > 9.0 | 6 | 21 | 8 | 205 | 1 | 1 | 1 | 8 |
| Total | 247 | 1010 | 417 | 1994 | 51 | 201 | 31 | 172 |

**Table 5.** Classification by subfield based on journal title (arranged by no. of citations)

| Subfield | No. of journals | No. of papers | No. of cited papers | No. of citations |
|---|---|---|---|---|
| **India** | | | | |
| Cardiovascular and Respiratory Systems | 6 | 101 | 50 | 273 |
| Medical Research, General Topics | 17 | 66 | 25 | 250 |
| Radiology, Nuclear Medicine and Imaging | 17 | 39 | 27 | 165 |
| Immunology | 17 | 36 | 19 | 164 |
| Microbiology | 14 | 60 | 30 | 119 |
| Neurosciences and Behaviour | 11 | 22 | 14 | 118 |
| Gastroenterology and Hepatology | 4 | 22 | 15 | 117 |
| Dermatology | 5 | 22 | 16 | 70 |
| Molecular Biology and Genetics | 4 | 9 | 8 | 57 |
| Veterinary Medicine/Animal Health | 1 | 4 | 3 | 52 |
| Medical Research, Diagnosis and Treatment | 6 | 22 | 10 | 51 |
| Medical Research, Organs and Systems | 8 | 18 | 7 | 50 |
| Biochemistry and Biophysics | 7 | 11 | 8 | 42 |
| Neurology | 6 | 22 | 8 | 35 |
| Clinical Immunology and Infectious Disease | 3 | 4 | 2 | 30 |
| Pediatrics | 9 | 21 | 8 | 26 |
| Surgery | 8 | 17 | 7 | 25 |
| Research/Laboratory Medicine and Medical Technology | 7 | 12 | 6 | 18 |
| General and Internal Medicine | 4 | 27 | 8 | 15 |
| Urology and Nephrology | 7 | 10 | 5 | 11 |
| Chemistry and Analysis | 1 | 2 | 2 | 10 |
| Reproductive Medicine | 4 | 10 | 4 | 10 |
| 12 other subfields cited at least once | 25 | 60 | 21 | 37 |
| 8 other subfields | 11 | 12 | 0 | 0 |
| Not indexed | 45 | 381 | 114 | 249 |
| Total | 247 | 1010 | 417 | 1994 |
| **China** | | | | |
| Clinical Immunology and Infectious Disease | 1 | 2 | 2 | 62 |
| Cardiovascular and Respiratory Systems | 3 | 9 | 6 | 36 |
| Spectroscopy/Instrumentation/Analytical Sciences | 1 | 1 | 1 | 19 |
| Immunology | 3 | 3 | 3 | 15 |
| General and Internal Medicine | 3 | 9 | 1 | 8 |
| Biochemistry and Biophysics | 1 | 1 | 1 | 3 |
| 4 other subfields cited at least once | 7 | 7 | 4 | 4 |
| 5 other subfields | 9 | 9 | 0 | 0 |
| Not indexed | 23 | 160 | 13 | 25 |
| Total | 51 | 201 | 31 | 172 |

**Table 6.** Institutions contributing to TB research. Citations seen from *SCI* and *BBCI* 1990–2000

| Institution | No. of papers | No. of cited papers | No. of citations |
|---|---|---|---|
| **India** | | | |
| All India Institute of Medical Sciences, New Delhi | 107 | 49 | 438 |
| Tuberculosis Research Centre, Chennai | 79 | 40 | 186 |
| Post Graduate Institute of Medical Education and Research, Chandigarh | 95 | 40 | 160 |
| Christian Medical College and Hospital, Vellore | 28 | 16 | 124 |
| King Edward Memorial Hospital, Mumbai | 35 | 18 | 71 |
| Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow | 31 | 16 | 67 |
| Maulana Azad Medical College, New Delhi | 21 | 9 | 60 |
| National Institute of Immunology, New Delhi | 13 | 8 | 59 |
| Institute of Nuclear Medicine and Allied Sciences, New Delhi | 4 | 2 | 44 |
| Madurai Kamaraj University, Madurai | 4 | 3 | 41 |
| Bombay Leprosy Project, Mumbai | 1 | 1 | 37 |
| WHO, South-East Asian Regional Office, New Delhi | 2 | 1 | 37 |
| Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram | 23 | 12 | 36 |
| Indian Institute of Science, Bangalore | 16 | 7 | 30 |
| Bhabha Atomic Research Centre, Mumbai | 11 | 4 | 29 |
| National Institute of Mental Health and Neurosciences, Bangalore | 11 | 6 | 29 |
| Foundation for Research in Community Health, Mumbai | 6 | 4 | 27 |
| St John’s Medical College, Bangalore | 8 | 6 | 27 |
| University College of Medical Sciences, New Delhi | 21 | 9 | 26 |
| 89 other institutions cited at least once | 358 | 166 | 466 |
| 88 other institutions | 135 | 0 | 0 |
| Private address | 1 | 0 | 0 |
| Total | 1010 | 417 | 1994 |
| **China** | | | |
| Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing | 26 | 5 | 82 |
| South-Central University for Nationalities, Wuhan | 1 | 1 | 19 |
| Nanjing Medical University, Nanjing | 2 | 2 | 13 |
| Beijing Research Institute of Tuberculosis Control, Beijing | 3 | 1 | 11 |
| Beijing Chest Hospital, Beijing | 2 | 1 | 10 |
| Shanghai Medical University, Shanghai | 2 | 1 | 8 |
| National Institute for Control of Pharmaceuticals and Biological Products, Beijing | 1 | 1 | 3 |
| National Tuberculosis Control Centre, Beijing | 9 | 1 | 3 |
| Shanghai Municipal Coordinating Group of Investigation on the Efficacy of Rifapentine, Shanghai | 1 | 1 | 3 |
| Tsing Hua University, Beijing | 1 | 1 | 3 |
| 16 other institutions cited at least once | 28 | 16 | 17 |
| 92 other institutions | 125 | 0 | 0 |
| Total | 201 | 31 | 172 |

papers. We have identified both Indian and Chinese institutions publishing papers in high-impact factor journals (Table 7). Researchers at AIIMS have published six papers in journals of impact factor higher than 9.0 and 15 papers in journals with impact factor higher than 3.5. PGIMER has published eight papers, and TRC, five papers in journals with impact factor higher than 3.5. By and large, Indian researchers have published most papers in low-impact factor journals. The Chinese have published most of their work – a much higher percentage than India’s – in low-impact journals.

## *Distribution by city and state*

As shown in Figure 4, about 61% of all Indian papers come from four cities, viz. New Delhi (280 papers), Mumbai (120), Chennai (112) and Chandigarh (99). More than 68% of all papers come from four states, viz. Delhi (280 papers), Maharashtra (158), Tamil Nadu (152) and the Union Territory of Chandigarh (99). Table 8 lists Indian cities and states involved in TB research. Beijing (75 papers), Shanghai (18), Chengdu (11) and Nanjing (10) are the cities publishing large number of papers in TB in China. Apart from Beijing and Shanghai municipalities, the provinces that are active in TB research are Hubei (12 papers), Jiangsu (12) and Sichuan (11).

## *Highly cited papers*

In all, the 1010 Indian papers in our dataset have harvested 1994 citations and the 201 Chinese papers 172

**Table 7.** Distribution of papers by institution and impact factor range of journals

| Institution / Impact factor range → | A | B | C | D | E | F | G | H | I | J | K | L | M | N | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **India** | | | | | | | | | | | | | | | |
| All India Institute of Medical Sciences, New Delhi | 51 | 6 | 11 | 7 | 5 | 8 | 3 | 1 | 4 | 2 | 2 | 1 | | 6 | 107 |
| Post Graduate Institute of Medical Education and Research, Chandigarh | 31 | 10 | 16 | 7 | 10 | 10 | 1 | 2 | 2 | 1 | | | 2 | 3 | 95 |
| Tuberculosis Research Centre, Chennai | 33 | 27 | 2 | 1 | 7 | 2 | 2 | | 4 | | 1 | | | | 79 |
| King Edward Memorial Hospital, Mumbai | 20 | 1 | 4 | 3 | | 2 | 1 | | | | 2 | | | 2 | 35 |
| Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow | 5 | 4 | 11 | 4 | 2 | 2 | 1 | 1 | | | 1 | | | | 31 |
| Christian Medical College and Hospital, Vellore | 8 | 1 | 9 | 1 | 1 | | 3 | 2 | | | 2 | | | 1 | 28 |
| Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram | 12 | | | 4 | 3 | 2 | | | 1 | | | 1 | | | 23 |
| Maulana Azad Medical College, New Delhi | 12 | 1 | 4 | 4 | | | | | | | | | | | 21 |
| University College of Medical Sciences, New Delhi | 7 | 5 | 5 | 1 | 3 | | | | | | | | | | 21 |
| Safdarjang Hospital, New Delhi | 8 | 6 | 3 | 2 | 1 | | | | | | | | | | 20 |
| Banaras Hindu University, Varanasi | 12 | 7 | | | | | | | | | | | | | 19 |
| Indian Institute of Science, Bangalore | | 5 | 1 | | 1 | 2 | 1 | 1 | 3 | | 2 | | | | 16 |
| G.B. Pant Hospital, New Delhi | 8 | | 1 | | 1 | | 1 | 1 | | | | | | 2 | 14 |
| Lady Hardinge Medical College, New Delhi | 7 | 4 | 1 | 1 | | | | | | | | | | | 13 |
| Topiwala National Medical College, Mumbai | 7 | 3 | 2 | | 1 | | | | | | | | | | 13 |
| Kasturba Medical College and Hospital, Manipal | 8 | 3 | 2 | | | | | | | | | | | | 13 |
| Jawaharlal Institute of Postgraduate Medical Education and Research, Pondicherry | 9 | 2 | 2 | | | | | | | | | | | | 13 |
| National Institute of Immunology, New Delhi | 1 | 4 | 4 | | 1 | 2 | | | 1 | | | | | | 13 |
| Bhabha Atomic Research Centre, Mumbai | 6 | 1 | 1 | 1 | | 2 | | | | | | | | | 11 |
| National Institute of Mental Health and Neurosciences, Bangalore | 3 | 3 | | 1 | 2 | | | | 1 | | | 1 | | | 11 |
| Lokmanya Tilak Municipal Medical College, Mumbai | 6 | 3 | 2 | | | | | | | | | | | | 11 |
| Sir J. J. Group of Hospitals, Mumbai | 3 | 1 | 1 | 2 | | 1 | | | | | | 2 | | | 10 |
| Total | 257 | 97 | 82 | 39 | 38 | 33 | 13 | 8 | 16 | 3 | 10 | 5 | 2 | 14 | 617 |
| **China** | | | | | | | | | | | | | | | |
| Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing | 22 | 1 | 2 | | | | | | 1 | | | | | | 26 |
| National Tuberculosis Control Centre, Beijing | 8 | | | | | | | | 1 | | | | | | 9 |
| 309th Hospital of PLA, Beijing | 8 | 1 | | | | | | | | | | | | | 9 |
| First Affiliated Hospital, West China University of Medical Sciences, Chengdu | 4 | | | | | 1 | | | | | | | | | 5 |
| Shanghai Tuberculosis Control Centre, Shanghai | 4 | | | | | | | | | | 1 | | | | 5 |
| Changchun Tuberculosis Hospital, Changchun | 4 | | | | | | | | | | | | | | 4 |
| Peking Union Medical College Hospital, Beijing | 4 | | | | | | | | | | | | | | 4 |
| Institute of Dermatology, Chinese Academy of Medical Sciences, Nanjing | 3 | | | | | | | | | | | | | | 3 |
| Nanfang Hospital, First Military Medical University, Guangzhou | 2 | 1 | | | | | | | | | | | | | 3 |
| Bethune International Peace Hospital of PLA, Shijiazhuang | 3 | | | | | | | | | | | | | | 3 |
| Beijing Research Institute of Tuberculosis Control, Beijing | 3 | | | | | | | | | | | | | | 3 |
| Xuan Wu Hospital, Capital Institute of Medicine, Beijing | 2 | | | | | | | | | 1 | | | | | 3 |
| Total | 67 | 3 | 2 | | | 1 | | | 2 | 1 | 1 | | | | 77 |

| | | | | |
|---|---|---|---|---|
| A 0.000 | D > 1.0–1.5 | G > 2.5–3.0 | J > 4.0–4.5 | M > 5.5–6.0 |
| B > 0.0–0.5 | E > 1.5–2.0 | H > 3.0–3.5 | K > 4.5–5.0 | N > 9.0 |
| C > 0.5–1.0 | F > 2.0–2.5 | I > 3.5–4.0 | L > 5.0–5.5 | |

citations, as seen from *SCI* 1990–2000 and *BBCI* 1992–2000. Among these, 61 citations to Indian papers and six to Chinese papers would have been missed had we not consulted *BBCI* (Figure 5). About 417 of the 1010 Indian papers published from 196 institutions located in 68 cities/towns and 31 of the 201 Chinese papers published from 118 institutions in 47 cities were cited at least once. Fifty-three papers from India (including one letter and nine notes) and six papers from China have been cited ten times or more up to the end of 2000. These include 14 papers from AIIMS five each from TRC and PGIMER, and three each from Christian

**Table 8.** Cities and states contributing to TB research

| India | | | | China | | | |
|---|---|---|---|---|---|---|---|
| City | No. of papers | State | No. of papers | City | No. of papers | Province | No. of papers |
| New Delhi | 280 | Delhi | 280 | Beijing | 75 | Beijing | 75 |
| Mumbai | 120 | Maharashtra | 158 | Shanghai | 18 | Shanghai | 18 |
| Chennai | 112 | Tamil Nadu | 152 | Chengdu | 11 | Hubei | 12 |
| Chandigarh | 99 | Chandigarh | 99 | Nanjing | 10 | Jiangsu | 12 |
| Bangalore | 48 | Uttar Pradesh | 86 | Wuhan | 9 | Sichuan | 11 |
| Lucknow | 44 | Karnataka | 70 | Changchun | 6 | Liaoning | 8 |
| Vellore | 30 | Kerala | 33 | Shenyang | 5 | Guangdong | 6 |
| Thiruvananthapuram | 28 | West Bengal | 22 | Guangzhou | 5 | Henan | 6 |
| Calcutta | 19 | Punjab | 18 | Tianjin | 5 | Jilin | 6 |
| Varanasi | 19 | Rajasthan | 18 | Xian | 4 | Shandong | 6 |
| Hyderabad | 14 | Andhra Pradesh | 16 | Nanchang | 4 | Heilongjiang | 5 |
| Manipal | 13 | Pondicherry | 13 | Changsha | 4 | Hunan | 5 |
| Pondicherry | 13 | Haryana | 9 | Bengbu | 3 | Tianjin | 5 |
| 55 other cities | 171 | 7 other states | 36 | 33 other cities | 42 | 10 other provinces | 26 |
| Total | 1010 | | 1010 | | 201 | | 201 |

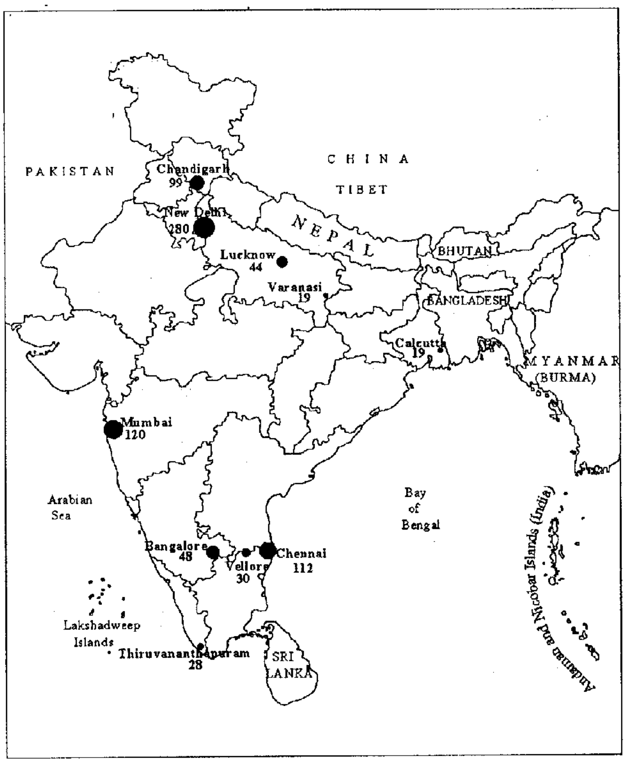


**Figure 4.** Indian cities contributing to TB research.

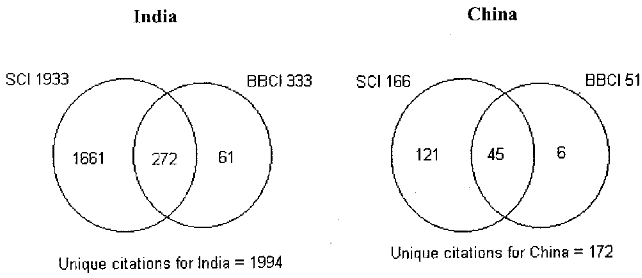


**Figure 5.** Coverage of citations in the two databases.

Medical College, Vellore, and Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow. The two highest cited Indian articles are by P. Shankar *et al.* of AIIMS, and both of them were published in *Lancet*, one as a letter and the other as an article. These deal with the use of polymerase chain reaction in the identification of *M. tuberculosis* and the rapid diagnosis of tuberculosis meningitis. Not only do India and China publish very little, but their publications also have very little impact.

The diachronous distribution of citations to the highly cited papers is given in Table 9. Papers that received the first citation in the year of publication (1, 2, 4, 5, 8 and 12) have consistently been cited every year till 2000.

## *International collaboration*

As seen from Table 10, 7.41% of Indian papers (41 of the 553 papers for which information on multiple authorship was available) and 45% of Chinese papers (18 of the 40 papers for which information on multiple authorship was available) have resulted from collaboration with foreign authors. Overall, as seen from *SCI* 1998 (CD-ROM edition) data, 17.6% of Indian papers and 28.5% of Chinese papers in all of science and technology are internationally coauthored[33]. In mathematics and related fields such as statistics, as seen from *Mathsci* 1993–1998, 15.1% of Indian papers are internationally coauthored[34]. Thus the extent of international collaboration for TB in India is rather low.

In all, researchers from 28 Indian institutions and 18 Chinese institutions have coauthored papers with

**Table 9.** Diachronous distribution of citations to highly-cited TB papers from India and China

| No. | 1990 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 2000 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 5 | 19 | 12 | 17 | 20 | 13 | 3 | 8 | 8 | 6 | 111 |
| 2 | 1 | 8 | 7 | 8 | 4 | 10 | 8 | 2 | 6 | 3 | 2 | 59 |
| 3 | | 2 | | 3 | 8 | 5 | 3 | 5 | 6 | 1 | 4 | 37 |
| 4 | | 1 | 3 | 1 | 4 | 2 | 7 | 3 | 11 | 3 | 2 | 37 |
| 5 | | | | | | 5 | 6 | 6 | 10 | 5 | 5 | 37 |
| 6 | | | | 3 | 2 | 3 | 6 | 3 | 7 | 6 | 2 | 32 |
| 7 | | | | | 4 | 4 | 5 | 6 | 4 | 3 | 6 | 32 |
| 8 | | | | 2 | 4 | 3 | 10 | 4 | 3 | 2 | 2 | 30 |
| 9 | | 2 | 3 | 1 | 5 | 7 | 5 | | 2 | 3 | | 28 |
| 10 | | 2 | 4 | 1 | 5 | 4 | 8 | | | | 3 | 27 |
| 11 | | | | 2 | 5 | 4 | 3 | 4 | 5 | 3 | 1 | 27 |
| 12 | | | 2 | 1 | 3 | 3 | 3 | 5 | 3 | 1 | 2 | 23 |
| 13 | | 3 | 2 | | | 4 | 3 | 2 | 4 | 2 | 2 | 22 |
| 14 | | 1 | 5 | 2 | 3 | 3 | | 2 | 1 | | 4 | 21 |
| Total | 1 | 24 | 45 | 36 | 64 | 77 | 80 | 45 | 70 | 40 | 41 | 523 |
| 15 | | | | | | | 7 | 9 | 15 | 16 | 12 | 59 |
| 16 | | | | | | | | 1 | 2 | 10 | 6 | 19 |
| 17 | | | | | | | | | 2 | 5 | 4 | 11 |
| 18 | | | | | | | | | | 1 | 10 | 11 |
| 19 | | | | 1 | 2 | 1 | 2 | | | | 5 | 11 |
| 20 | | | | | | | | | 1 | 4 | 5 | 10 |
| 21 | | | | | | | 1 | 2 | 1 | 1 | 4 | 9 |
| 22 | | | | 2 | 1 | 2 | 2 | | | | 1 | 8 |
| Total | | | | 3 | 3 | 3 | 12 | 12 | 21 | 37 | 47 | 138 |

Bibliographic details of Nos 1–22 (1–14, Papers from India; 15–22, Papers from China).

| No. | Cited paper | No. of times cited | Institution |
|---|---|---|---|
| 1. | Shankar, P. *et al.*, *Lancet*, 1991, **337**, 5–7. | 111 | All India Institute of Medical Sciences, New Delhi |
| 2. | Shankar, P. *et al.*, *Lancet*, 1990, **335**, 423–423. | 59 | All India Institute of Medical Sciences, New Delhi |
| 3. | Stanford, J. L. *et al.*, *Vaccine*, 1990, **8**, 525–530. | 37 | Bombay Leprosy Project, Mumbai |
| 4. | Brahmajothi, V. *et al.*, *Tubercle*, 1991, **72**, 123–132. | 37 | Madurai Kamaraj University, Madurai |
| 5. | Aisu, T. *et al.*, *AIDS*, 1995, **9**, 267–273. | 37 | WHO, South-East Asia Regional Office, New Delhi |
| 6. | Shah, S. *et al.*, *Gut*, 1992, **33**, 347–351. | 32 | Christian Medical College and Hospital, Vellore |
| 7. | Rajshekhar, V. *et al.*, *J. Neurosurg.*, 1993, **78**, 402–407. | 32 | Christian Medical College and Hospital, Vellore |
| 8. | Wallis, R. S. *et al.*, *Infect. Immunol.*, 1993, **61**, 627–632. | 30 | Tuberculosis Research Centre, Chennai |
| 9. | Gupta, R. K. *et al.*, *Clin. Radiol.*, 1990, **41**, 120–127. | 28 | Institute of Nuclear Medicine and Allied Sciences, New Delhi |
| 10. | Sehgal, V. N. *et al.*, *Int. J. Dermatol.*, 1990, **29**, 237–252. | 27 | Maulana Azad Medical College, New Delhi |
| 11. | Khanolkaryoung, S. *et al.*, *Infect. Immunol.*, 1992, **60**, 3925–3927. | 27 | National Institute of Immunology, New Delhi |
| 12. | Bhargava, D. K. *et al.*, *Am. J. Gastroenterol.*, 1992, **87**, 109–112. | 23 | All India Institute of Medical Sciences, New Delhi |
| 13. | Dwivedi, M. *et al.*, *Am. J. Gastroenterol.*, 1990, **85**, 1123–1125. | 22 | Motilal Nehru Medical College, Allahabad |
| 14. | Kumar, L. *et al.*, *Pediatr. Infect. Dis. J.*, 1990, **9**, 802–806. | 21 | Post Graduate Institute of Medical Education and Research, Chandigarh |
| 15. | Vansoolingen, D. *et al.*, *J. Clin. Microbiol.*, 1995, **33**, 3234–3238. | 59 | Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing |
| 16. | Wang, J. *et al.*, *Anal. Chim. Acta*, 1997, **337**, 41–48. | 19 | South-Central University for Nationalities, Wuhan |
| 17. | Cole, R. A. *et al.*, *Tubercle Lung Dis.*, 1996, **77**, 363–368. | 11 | Beijing Research Institute of Tuberculosis Control, Beijing |
| 18. | Zhang, M. *et al.*, *J. Immunol.*, 1999, **162**, 2441–2447. | 11 | Nanjing Medical University, Nanjing |
| 19. | Zhang, L. X. and Kan, G. Q., *Tubercle Lung Dis.*, 1992, **73**, 162–166. | 11 | Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing |
| 20. | Zhou, A. T. *et al.*, *Clin. Diagn. Lab. Immun.*, 1996, **3**, 337–341. | 10 | Beijing Chest Hospital, Beijing |
| 21. | Zhang, L. X. *et al.*, *Tubercle Lung Dis.*, 1995, **76**, 100–103. | 9 | Beijing Tuberculosis and Thoracic Tumor Research Institute, Beijing |
| 22. | Lu, C. Z. *et al.*, *Lancet*, 1990, **336**, 10–13. | 8 | Shanghai Medical University, Shanghai |

**Table 10.** Distribution of TB papers from India and China by number of nations in the byline

| No. of nations in the byline | No. of papers | No. of papers |
|---|---|---|
| | India | China |
| 1 | 512 | 22 |
| 2 | 29 | 13 |
| 3 | 6 | 3 |
| 4 | 1 | 1 |
| 5 | 3 | 2 |
| 6 | 1 | 0 |
| 9 | 1 | 0 |
| Total no. of papers | 553 | 40 |
| No. internationally collaborated | 41 | 18 |
| Percentage papers internationally collaborated | 7.69 | 45 |
| No. of international links | 69 | 27 |
| Internationalization index | 12.94 | 67.5 |

foreign authors. Indian researchers have collaborated with authors from USA in 18 papers and authors from UK in 14 papers. Chinese researchers have collaborated with those from the US in 9 papers and with those from Belgium in 4 papers. TRC and AIIMS have collaborated with foreign laboratories in 11 and 5 papers, respectively. National Institute of Immunology, New Delhi, and National Institute of Mental Health and Neurosciences, Bangalore, have collaborated with foreign authors in four papers each. Three papers from Tuberculosis Hospital, Chao-Yang and two each from Beijing Research Institute of Tuberculosis Control, Beijing, Nanjing Medical University, Nanjing, and Second Hospital, Da-Qing, have foreign coauthors.

Of the 41 internationally coauthored papers from India, Indian researchers are first authors in only 16 papers. Among the 18 internationally coauthored papers from China, Chinese researchers are first authors in only five. The very high fraction of papers with first authors from outside India leads to the possibility of much of such collaborative research being 'Safari research' or research where scientists from advanced countries use local researchers merely to collect data, specimen and cases[35].

## Conclusion

While China has achieved the biggest improvement in case detection under the DOTS programme and maintained high cure rates; India (along with Bangladesh, Pakistan and the Philippines) is among the countries with the greatest number of cases without access to good treatment[5]. Although China performs much less research than India and its work is quoted much less often, it seems to have done far better than India in health-care delivery in TB. Perhaps the Chinese are better able to translate know-how into do-how than the Indians. Does it mean that countries like India and China should receive knowledge on TB control from international sources (such as WHO and advanced country research institutions) and simply get on with the job? Certainly not, and our reasons for saying so have already been discussed under the section 'Why should India and China do TB research?'

Both China and India need to invest in TB research far more than they do now. Fortunately, the overall climate for research and combating TB is improving. The formation of Global Alliance for TB Drug Development, bringing together public agencies and private corporations as well as international agencies[8,36], the recent initiative of the *British Medical Journals* (BMJ) and WHO persuading leading commercial publishers to make their journals available on the web to scientists and doctors in the developing world either at no cost or at a very low cost[37], the G8 countries which met at Genoa in July 2001 coming forward to persuade multinational drug companies to sell TB drugs at a low cost to developing countries[38], companies like AstraZeneca coming forward to invest in TB drug research in India[29], the Global Forum for Health Research holding international consultations and highlighting the need for immediate and focused action[9], the admission by Gro Harlem Brundtland, WHO Director General, that DOTS was no longer enough and 'it is high time to find new and more effective drugs' for controlling TB[36], Oxfam attacking the world's largest pharmaceutical company over its drug pricing policies and deploring the lack of systematic policies to make medicines more freely available to developing countries[39] – all these are indeed heartening news on the policy front. On the research front, the elucidation of the complete genome of *M. tuberculosis* has opened up several new avenues of research such as new anti-tuberculosis drug development targeted at newly recognized enzymes, or the development of new vaccines aimed at hitherto unknown antigens[23]. To capitalize on this development, leaders of the world's largest drug companies, together with heads of the US National Institutes of Health and representatives of the Wellcome Trust, are discussing the possibility of forming public–private partnerships to fund genomic research[40]. Indeed, although significant obstacles remain, the prospects for the development of new and effective drugs against TB are much greater than at any time in several decades[41]. Both India and China, with their increasingly better showing in new biology research and drug development in recent years, should get into this consortium. Recently, the National Institute of Allergy and Infectious Diseases (NIAID) has developed a global TB research agenda that can succeed only if NIAID can secure the cooperation and partnership of endemic country scientists and national TB control programmes[42]. India and China should join hands with NIAID as equal partners in joint research programmes.

India and China also should do all they could to provide High Bandwidth Internet access to all the higher education institutions, research laboratories and hospitals so that scientists and doctors in these countries can take maximum advantage of worldwide information available on the web, including the more-than-1000 biomedical journals that commercial publishers have promised to make freely available to them on the web commencing January 2002 (ref. 37).

Unlike in USA and to some extent western Europe, there is very little collaboration between clinical researchers, working mostly in hospitals and medical colleges, and basic life-science researchers, working mostly in universities and government-run research laboratories in India and China. Indeed, in USA much of basic research in life sciences takes place in hospitals and medical research institutions. Fortunately, in India, considerable amount of TB research takes place in academic laboratories. For example, TB research at the Indian Institute of Science (IISc), Bangalore, has a history of over three decades, and currently, at least half a dozen faculty members are active in TB research. What is more, they are collaborating with institutions such as TRC and the National Tuberculosis Institute, Bangalore. Private Foundations such as Sir Dorabji Tata Centre for Research in Tropical Diseases located in the campus of IISc hold annual symposia and invite academic and clinical researchers to share their experiences. The first of these symposia, held in March 2000, was on TB.

Health-policy experts emphasize the need for an appropriate health surveillance system to measure and monitor health status[43]. We believe a surveillance system that monitors national research output and its impact is equally important. Indeed, TB research in India is much better placed than research in other areas. That is how India's share in TB research is over 5% of the entire world's research, compared to between 2 and 3% in most other fields. Even so, health and research policy-makers need to prioritize research areas, as the funds available continue to be inadequate. There is a great need for research to be integrated into national health-policy debates. As much as possible, objective, quality research and epidemiology should be the foundation of these debates[44]. Also, there is often the danger of research in such crucial areas not addressing the problems the control programme managers would want to. Should India and China spend bulk of their TB research budget on laboratory-based research aimed at, say the elucidation of the physiology of the organism and the response of the human host or on health-policy research and TB service delivery? Is it necessary to distinguish health priorities from health research priorities[45]? From a global perspective, it is said that failure to invest in basic research has led to a grim situation and operational research to establish the feasibility of DOTS-Plus efforts should be another priority[46]. Doctors, researchers and policy-makers in India and China should be sensitized to such issues.

The Harvard report[46] also emphasizes the need for NGOs, health-care professionals, patient organizations and many other groups to forge novel coalitions to bring TB under control. India and China, as the two countries most affected, should join and play an active part in such coalitions. India and China should play increasingly important roles in making the world TB-free.

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