The State of Research and Development in Global Cancer Surgery

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Objective: The objective of this study was to perform an analysis of global cancer surgery research and development trends over the last 10 years across 21 countries.

Background: Surgery is the main modality for cancer cure and control globally. Yet, in comparison to other areas such as cancer drugs, we know little about ongoing research activities to inform policymakers.

Methods: Two subfield filters, surgery research and oncology, were developed and applied to Web of Science. The intersection of these 2 filters identified papers in surgical oncology, and their bibliographic details were downloaded for analysis. This included matching of 5-year citation counts to the papers, impact factor, geographical analysis by country, translational collaboration, involvement in clinical trials, citation on clinical guidelines, and percentage of reviews.

Result: Surgical oncology represents about 9% of all cancer research–low in comparison with surgery's contribution to cancer treatment. The US published the most, followed by Japan which had a high relative commitment to surgery within cancer research, followed by the large West European countries. Although Sweden's papers were relatively basic, it participated the most in clinical trials. Its papers were also the most cited on clinical guidelines, but contained relatively few reviews, where the UK, Greece, and Belgium scored best. Surgical oncology papers are generally not well cited compared with cancer research overall, but on this measure the Netherlands, the US, and Sweden scored best. International collaboration was measured relative to what might have been expected, on this indicator Canada, Switzerland, and the US were the best performers.

Conclusions: Globally, low activity-low funding cycle needs to be addressed by new national and supranational policies to support surgical oncology research.

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Surgery is the main modality of control and cure for solid cancer in developed as well as low-middle income countries (LMIC) and is the only modality in a large proportion of cases globally. Research and development in surgical oncology are essential for improving patient outcomes. With the burden of chronic disease (including cancer) shifting to LMIC, surgery along with radiotherapy will constitute the backbone of cancer management for the majority of patients with solid cancer.[1] There is no high quality intelligence available for the research community or policymakers to monitor existing trends in cancer surgical research, guide decision-making and support the creation of new initiatives. Indeed, in comparison to other modalities such as medicines there is a serious lack of public policy discussion in cancer surgery. Furthermore, cancer surgery is almost absent from any World Health Organization national cancer control policy documents and, unlike radiotherapy with the International Atomic Energy Agency ImPACT programme, there are few supranational champions. What data exist suggests that at national[2] and supranational[3] levels, public sector support for cancer surgery research and development (R&D) is low. If the state of cancer surgery R&D is "fragile" then this has serious implications for patient outcomes and suggests new policy approaches are needed.

The aim of this study was to perform an analysis of global cancer surgery R&D trends over the last 10 years (specifically 21 countries that constitute 90% activity) to determine the health of this domain. A powerful objective method, scientometrics, was used to interrogate cancer surgery R&D trends.[4] In doing so we make a distinction between academic surgery—R&D aimed at the evolution of surgical techniques (the trimuvirate of surgery-imaging-pathology), upon which this work focuses, as opposed to the academic surgeon—who can be active in R&D across a wide range of nonsurgical disciplines, such as fundamental biology.

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METHODS

Selection of Papers and Time Periods

The papers selected from the Web of Science (WoS) were in subfields, surgery (SURGE) and oncology (ONCOL). The bibliographic details of the selected papers yielded a total of 49,111 papers. For the comparison groups of papers in cancer research overall and in all biomedicine (BIOMED), the WoS was interrogated and the world total and those for each of the 21 selected countries (Table 1) were determined year by year. In this paper, the countries are referred to by their International Standards Organization digraph codes, as shown in Table 1. The biomedical papers were specified by means of an "address" filter, based on cognitive words in the papers' addresses: this works well in distinguishing between biomedical and nonbiomedical papers in multidisciplinary journals such as *Nature* and *Science*. The 21 countries were selected on the basis that they had high overall science and technology activity (measured by United Nation's Human Development Index) as well as significant overall cancer research activity (measured by bibliometric outputs).

To study trends, a broad time frame was taken (1997–2008) from which papers were downloaded. Some of the data is presented as a snapshot within this period. For example, for overall outputs data from 2008 is incomplete, thus the timeframe is censored at the start and end. In some cases, the lag in bibliometric data for citations means that the latest dates for comparative data are 2003 or 2004.

Determination of Relative Commitment to Surgical Oncology

This parameter is the ratio of a country's percentage presence in surgical oncology (on an integer count basis) to its percentage

TABLE 1. The 21 Countries Used for Analysis in this Study, With Their ISO Codes

ISO	Country
AT	Austria
AU	Australia
BE	Belgium
CA	Canada
CH	Switzerland
CN	China (PR)
DE	Germany
ES	Spain
FR	France
GR	Greece
IN	India
IT	Italy
JP	Japan
KR	Korea (S)
NL	Netherlands
SE	Sweden
SG	Singapore
TR	Turkey
TW	Taiwan
UK	United Kingdom
US	United States

presence in all oncology. The papers in the file were also subclassified by the cancer site to which they referred, for example, breast, etc.

Potential and Actual Citation Impact, Percent of Reviews

Journals can be characterized by the average number of citations to papers published in them in a given year and received in a given time window. Because the peak year for citations is usually the second or third year after publication, we have taken a 5-year window (ie, the year of publication and 4 subsequent years). The potential citation impact of a paper (PCI) is then the expected number of citations that it would receive if it were an "average" paper, ie, the total number of citations divided by the number of papers. The actual citation impact (ACI) was determined directly from the WoS, with data for citations, year by year. Because a 5-year window was used, the values of ACI were only available for papers published from 1997 to 2004 (8 years). We also determined how many of a country's papers were cited highly enough to put them in the top 1% of the world (66 cites in 5 years), top 2% (50 cites), 5% (32 cites), 10% (22 cites), or top 20% (13 cites). These 5 percentages, when compared with the world values, multiplied by 100 and averaged, are called "world-scale" values. We also determined the amount of surgical oncology research relevant to each of the 14 sites and the percentage of the disability adjusted life years attributable to all malignant neoplasms for 2004 for 10 of the 21 countries. Another measure of merit, or esteem, is the percentage of reviews in a large set of papers. Because these are usually invited from distinguished scientists, their presence provides an additional measure of esteem. This measure needs to be normalized relative to the world mean value.

Research Levels: Clinical or Basic

Biomedical research papers can be classified on a scale from 1 (*clinical*) to 4 (*basic*), both in terms of the journal in which they are published (RL j), and (for a group of, say, 20 or more) in terms of individual titles (RL p).[5] Of the 49,111 papers in the file, the research level (RL) of the journal could be determined for 96%, and 74% of them had either a "clinical" or a "basic" title word that allowed them to be classified individually.

Clinical Trials

To identify papers concerned with clinical trials, their titles were filtered to show which ones contained any of a number of key words associated with such research, for example "double blind," "phase," "study," or "trial." The total was 3042, or 6.2% of the total. Random samples were also taken to validate the accuracy of the terms. These papers were then analyzed by country and by year, to show any time trends. Relatively few of these papers contained the word "phase," which is associated with the clinical trials of new drugs.

International Collaboration for Countries and Institutions

To determine the amount of international collaboration using bibliometrics, it is necessary to take into account that the amount of international collaboration in research has been steadily increasing with time, and it is also more common in basic research than in clinical work. Any comparisons of rates of international collaboration must therefore take account of time and RL, as well as national factors such as possession of a common language or geographical proximity. Filters allow each paper to be fractionated between the country addresses of each author. Once this has been established the amount of collaboration in individual countries was compared with the trendline (which has a negative slope) to give a ratio for observed to expected numbers of international papers as the metric.

The Funding of Surgical Oncology Research

The purpose of this part of the study was 2-fold: to show which organizations were funding the research, and to estimate the resources being devoted to the subject area. For the first task, samples of papers from each of 14 selected countries in each of the two 4-year periods, 1997 to 2000 and 2005 to 2008, were looked up in the British Library and other London libraries, either on-line or by inspection of the printed documents. The random sampling of countries and the total look-up of papers were based on a well-validated statistically driven method described as previously described.[4] The sample sizes were designed to give a total of 1350 papers in each of the 2 quadrennia, but in practice a few of the papers could not be found. In the event, a total of 2686 papers were inspected for funding sources which has previously been demonstrated to give a representative sample of all funding sources

RESULTS

An Analysis of Cancer Surgery Outputs

The annual world outputs of papers in surgical oncology, in all cancer research and in all biomedical research, 1998 to 2007 is shown in Figure 1. It is clear that all 3 curves are closely parallel, with cancer research amounting to one eighth (12.3%) of all biomedical research and surgical oncology accounting for 1 in 11 (8.9%) cancer papers. The US consistently published the most papers, followed by Japan, which had a relatively high commitment to surgical oncology research (about + 40% higher compared to the world average), and then Germany, UK, Italy, France, and The Netherlands. The output of the other East Asian countries (China, Korea, Singapore, Taiwan) has been rising rapidly, but is still well below that of the larger European countries. The effort devoted to surgery within cancer research is low, particularly relative to the extent to which it is the main modality of treatment for the majority of the cancer burden.

A detailed analysis of the relative commitment (RC) to surgery research on particular cancer sites is shown in Table 2. The ones of main interest were breast, colorectal, prostate, stomach, liver, and oral (head and neck). It is expected that each country's RC would reflect to some extent its relative disease burden. For example, Australia is very active in surgical research on skin cancer (MEL), as are the Far Eastern countries on stomach cancer (STO).

Mean potential and actual citation counts over 5 years were determined for the papers published from 1997 to 2004; potential counts are the mean counts for all the papers in the given journal and year, and are a kind of journal impact factor. Table 3 summaries the performance metrics of the 21 countries, 1997 to 2008 (1997–2004 for PCI and ACI). Figures 2 and 3 show the mean 5-year citation scores for all cancer and for surgical oncology papers and the mean world-scale citation indicator for surgical oncology papers. Surgical oncology cite counts are only about two thirds of the average for all cancer (9 cites compared with 13), although a few papers do receive many citations.

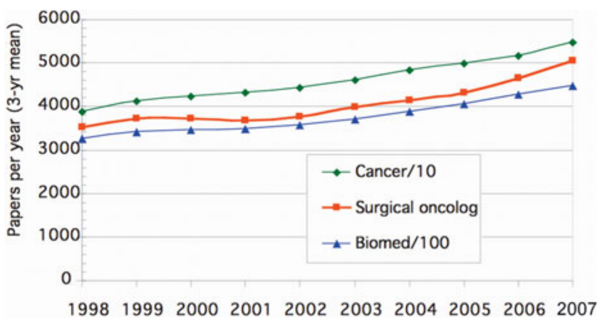

FIGURE 1. The figure shows the growth in the output of world papers in the subject area (red), in cancer research overall (green) and in biomedicine (blue). Annual world outputs of papers (articles + reviews) in surgical oncology, in all cancer research (/10) and in all biomedical research (/100), 1998 to 2007 (3-year running means). Note that the denominators in this graph are different to show relative comparative trends in 1 graph.

The best-performing countries, based on fractional count attribution, were The Netherlands, US, and Sweden. This ranking order also occurred for countries with a high percentage of their papers cited in the top centiles (eg, those with 50 or more cites that were in the top 2%). However, the cancer site involved had a big influence on citation scores, with papers on breast and prostate cancer research attracting many more citations than those on oral cancer.

The 21 countries considered above wrote different proportions of reviews, as shown in Figure 4. The UK, Greece, and Belgium scored best, and Sweden was rather low. Many East Asian countries, with the exception of Singapore and China, have low review levels.

Research Levels of Papers and Journals, and Clinical Trials

Cancer surgery R&D is relatively very clinical, when measured on a scale from 1 (*clinical observation*) to 4 (*basic research*). Australia's papers are the most clinical and Sweden's the most basic (Fig. 5). Figure 5 shows the mean RL values based on individual paper titles and journals in which they were published for the papers from the world and 21 countries. The mean RL for journals publishing cancer surgery R&D is 1.39 and the mean RL for the papers themselves is 1.31; these are much lower (ie, more clinical) than for cancer research overall (values for year 2003 are 2.28 and 2.27, respectively). Most countries are publishing very clinical papers in slightly less clinical journals, and there is no variation in journal RL with time. There is some correlation between the RL and citation impact, for example Sweden has more "basic" output and a high world scale score. However, there are exceptions to this trend.

Of the total research output 6.2% involves clinical trials dealing with cancer surgery, as mentioned earlier. This percentage did not seem to vary with time in any consistent way. Table 4 shows the results: Sweden is by far the most active participant, followed by other Western European countries (but not Germany). Again, China

TABLE 2. Relative Commitment to Research on Particular Cancer Sites within Surgical Oncology for the 21 Countries and 15 Sites 1997 to 2008

	BLA	CER	COL	LIV	LUN	LYM	MAM	MEL	MOU	OES	OVA	PAN	PRO	STO	UTE
AT	1.18	0.31	0.79	0.57	0.70	1.66	1.29	0.94	0.62	1.23	0.92	0.27	1.97	0.50	1.29
AU	0.42	1.11	2.13	1.01	0.45	0.67	2.20	3.03	0.82	0.33	0.65	0.41	0.69	0.37	0.23
BE	1.06	0.55	0.98	1.26	1.85	0.74	1.03	1.10	0.50	0.96	0.65	0.64	1.22	0.84	1.51
CA	1.16	1.00	0.87	0.44	0.64	0.82	1.09	0.99	0.98	0.51	1.45	0.54	1.88	0.36	2.38
CH	1.43	0.66	1.17	0.93	1.22	1.00	0.75	1.17	0.65	0.70	0.97	2.06	0.52	0.71	0.34
CN	0.99	1.29	0.80	2.33	0.93	0.60	0.52	0.24	1.82	1.68	0.70	0.91	0.24	1.72	0.41
DE	1.32	0.55	1.18	0.97	0.67	1.03	0.42	0.58	0.48	1.15	0.45	1.53	1.07	1.10	0.28
ES	2.00	1.11	0.89	0.89	1.47	2.53	0.62	1.06	1.84	0.68	0.98	0.66	0.61	0.77	0.57
FR	0.79	2.70	1.41	1.33	1.22	1.15	0.82	0.76	0.46	0.91	3.17	1.02	0.79	0.79	1.82
GR	1.58	0.75	1.22	0.94	0.89	1.61	1.52	0.97	1.14	0.25	2.21	1.36	0.54	1.21	1.93
IN	1.12	1.69	0.27	0.27	0.04	1.80	1.18	0.56	1.79	0.80	1.11	0.33	0.31	0.34	0.77
IT	0.88	0.86	0.98	1.04	1.58	1.14	1.08	1.29	0.85	0.69	1.46	1.03	0.65	1.10	0.93
JP	0.74	1.11	1.06	2.11	2.08	0.79	0.50	0.24	0.65	2.25	0.51	1.56	0.43	2.14	0.63
KR	0.75	1.27	1.04	1.10	0.97	0.80	0.74	0.26	0.90	0.80	0.62	0.82	0.28	2.51	1.09
NL	0.99	0.49	1.39	0.70	0.78	0.29	1.68	1.84	1.21	1.34	0.66	0.71	0.91	0.63	0.15
SE	1.47	0.60	1.74	0.65	0.27	0.23	1.49	0.61	0.54	0.89	0.00	1.13	1.76	0.81	0.62
SG	1.45	0.66	1.82	1.02	0.44	0.33	1.20	0.36	0.89	0.21	2.32	0.82	0.34	1.19	1.35
TR	1.29	1.35	0.61	0.39	1.10	1.57	0.81	0.87	1.12	0.34	0.73	0.23	0.53	0.61	1.28
TW	1.52	1.99	0.77	1.85	0.94	1.40	0.65	0.18	1.71	0.69	0.26	0.64	0.54	1.35	0.45
UK	0.67	1.06	1.63	0.68	0.60	1.19	1.73	1.42	1.70	0.50	0.52	0.79	0.56	0.56	0.21
US	1.14	0.79	0.59	0.48	0.60	1.00	1.09	1.43	0.99	0.55	1.37	0.86	1.82	0.44	1.55

Values >2 shaded bright green (very high commitment); >1.41 in pale green; <0.71 in pale yellow; <0.5 in pink (very low commitment).
Country codes are in Table 1.
Key for site-specific cancers: BLA (bladder); CER (cervical); COL (colorectal); LIV (hepatic); LUN (leukemia); LYM (lymphoma); MAM (breast); MEL (skin cancer inc malignant melanoma); MOU (head & neck); OES (esophageal); OVA (ovarian, endometrial); PRO (prostate); STO (gastric); UTE (uterine).

TABLE 3. Performance Indicators (all relative to unity) of 21 Leading Countries in Surgical Oncology Research, 1997 to 2008 (1997–2004 for PCI and ACI)

	Rel comm	Clin tr	PCI ratio	ACI ratio	% revs	Int collab
AT	1.13	0.99	1.02	1.08	0.51	1.29
AU	0.96	0.94	0.82	0.72	1.47	1.07
BE	0.85	1.75	0.95	0.91	1.58	1.46
CA	0.78	1.65	1.08	1.14	1.44	1.94
CH	0.82	1.36	1.00	1.08	1.34	1.75
CN	0.66	1.53	1.07	1.10	0.76	0.93
DE	1.16	0.88	0.75	0.78	0.93	1.15
ES	0.65	1.70	0.94	0.85	0.91	0.86
FR	0.86	1.75	0.97	0.96	0.98	0.90
GR	1.04	1.22	0.78	0.57	1.62	0.85
IN	0.95	0.89	0.62	0.34	0.37	0.26
IT	0.97	1.66	0.93	0.89	1.14	1.16
JP	1.42	0.84	0.86	0.69	0.34	0.49
KR	0.96	0.89	0.97	0.84	0.21	0.35
NL	1.03	1.77	1.23	1.48	1.21	1.12
SE	0.69	2.66	1.11	1.29	0.59	1.28
SG	0.88	1.26	0.83	0.75	1.29	0.82
TR	1.68	0.63	0.60	0.36	0.46	0.26
TW	1.26	0.94	0.91	0.65	0.26	0.31
UK	0.89	1.13	0.87	0.84	1.89	1.28
US	0.92	0.89	1.25	1.40	1.43	1.59

Values >2 shaded green; >1.41 shaded light green; <0.71 shaded pale yellow; <0.5 shaded pink.

Country codes are in Table 1.

Key: Rel comm = relative commitment; Clin tr = clinical trials; PCI and ACI = potential and actual citation impact; % revs = percentage reviews; Int collab = international collaboration.

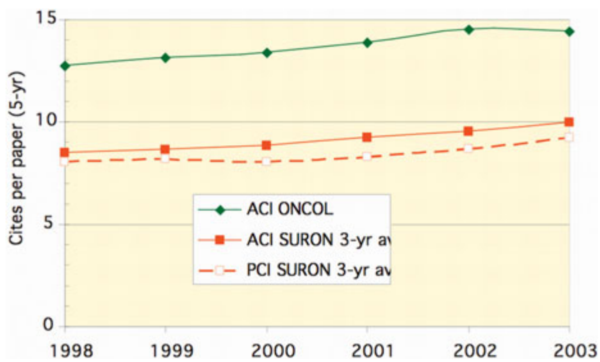

FIGURE 2. Mean 5-year citation scores for all cancer papers (actual citations; ONCOL) and for surgical oncology papers (actual and potential citations; SURON), 1998 to 2003.

is also an active participant, much more so relative to its output than other East Asian countries and the US.

International Collaboration

The amount of collaboration in individual countries was compared with the trendline (which has a negative slope) to give a ratio for observed to expected numbers of international papers. On this criterion, the best performing countries were Canada, Switzerland, and the US (Table 5). The international links followed traditional connections based on language and traditions, and geography, but there were unusually strong links between the UK and Greece, and between Austria and Belgium. China performs relatively well, and much better than Japan and the other Asian countries. There was some evidence in

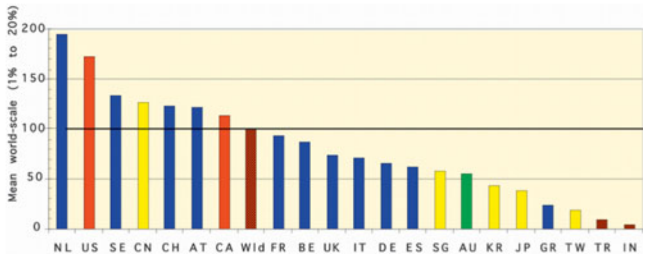

FIGURE 3. Mean world-scale citation indicator (at centiles 1, 2, 5, 10, and 20) for surgical oncology papers 1997 to 2004 from 21 leading countries (for codes, see Table 1); fractional count basis. Blue indicates EU-27; Red, North America; Yellow, East Asia; Brown, other Asian; Green, Australia. Country codes are in Table 1.

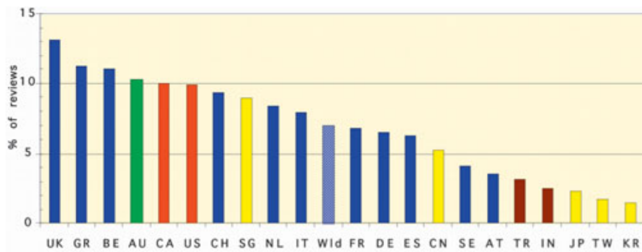

FIGURE 4. Percentages of reviews in surgical oncology literature, 1997 to 2008, for 21 leading countries. Blue indicates EU-27; Red, North America; Yellow, East Asia; Brown, other Asian; Green, Australia. Country codes are in Table 1.

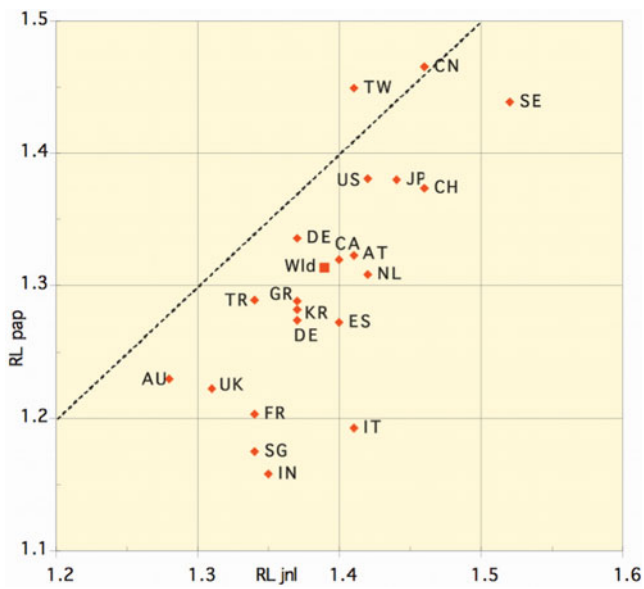

FIGURE 5. Scatter plot of mean RL for individual papers (RL pap) plotted against RL for journals in which they were published (RL jnl) for surgical oncology papers, 1997 to 2008, for the world and 21 leading countries (for codes, see Table 1). Country codes are in Table 1.

TABLE 4. Numbers of Surgical Oncology Papers (*SURON*) and Those Concerned With Reports of Clinical Trials or Studies (*Clint*) From 21 Leading Countries, 1997 to 2008

Country	SURON	Clint	Clint %
SE	727	120	16.5
NL	1551	170	11.0
BE	598	65	10.9
FR	2356	255	10.8
ES	788	83	10.5
IT	2915	299	10.3
CA	1419	145	10.2
CN	1109	105	9.5
CH	664	56	8.4
SG	167	13	7.8
GR	583	44	7.5
UK	3220	225	7.0
Wld*	**49111**	**3042**	**6.2**
AT	700	43	6.1
TW	991	58	5.9
AU	992	58	5.8
US	15729	866	5.5
KR	1036	57	5.5
IN	583	32	5.5
DE	4818	262	5.4
JP	8286	433	5.2
TR	1055	41	3.9

Country codes are in Table 1.
*Wld, world.

TABLE 5. International Collaboration in Surgical Oncology, 1997 to 2008, for 21 Countries: Determined as Percentage of Foreign Contribution to the Fractional Count of a Country's Papers (*Frac*), Estimated From the Trendline (*Est %)* and ratIo of Observed to Expected (*IC %)* Values of International Collaboraton

ISO	Frac	IC (%)	Est. (%)	Ratio
CA	1056	25.61	13.18	1.94
CH	481	27.61	15.73	1.75
US	14567	7.39	4.66	1.59
BE	459	23.22	15.88	1.46
AT	563	19.57	15.22	1.29
UK	2807	12.82	10.00	1.28
SE	587	19.31	15.08	1.28
IT	2568	11.89	10.29	1.16
DE	4342	9.87	8.59	1.15
NL	1335	13.90	12.41	1.12
AU	844	14.92	13.90	1.07
CN	970	12.56	13.45	0.93
FR	2124	9.86	10.91	0.90
ES	689	12.53	14.56	0.86
GR	506	13.15	15.56	0.85
SG	140	16.10	19.73	0.82
JP	8016	3.26	6.60	0.49
KR	987	4.74	13.40	0.35
TW	949	4.24	13.52	0.31
IN	560	3.90	15.23	0.26
TR	1019	3.39	13.29	0.26

Values >1.41 tinted light green (more international collaboration than expected); values <0.5 tinted pink (less international collaboration than expected).
Country codes are in Table 1.

individual countries that institutions with more foreign collaboration published papers of higher citation impact.

The Funding of Surgical Oncology Research

A total of 2682 papers were looked up and their funding acknowledgements determined; of these almost half (1337) were from 1997 to 2000 and the remainder from 2005 to 2008. The majority of all the papers (1916, or 71%) had neither specific (nor implicit) funding acknowledgement. This is much higher than for cancer research as a whole.

Total resources applied to health research, as estimated by the Global Forum for Health Research, shown in Figure 6. The estimated total expenditure for 2008, extrapolated from an inspection of funding sources and correlated with public domain declared expenditures (federal, philanthropic, and private) is about $110 billion from industry, $90 billion from the public sector, and just over $20 billion from the private-nonprofit sector, total about $220 billion.[2] Analysis of the leading funding bodies acknowledged in the total sample of 2682 papers showed that Canada and the US depended heavily on government support, whereas in Europe, private-nonprofit organizations played a rather larger role. We calculated that the overall financial resources being spent on global cancer R&D in 2008 were about $670 million, of which about 10% came from industry.

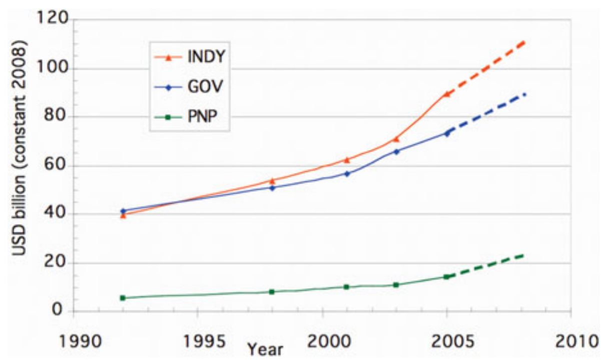

FIGURE 6. Estimates of global expenditure on health research, 1992 to 2005, extrapolated to 2008 (constant 2008 USD). GOV indicated public sector; PNP, private-nonprofit; INDY, commercial.

DISCUSSION

Cancer research is one of the most globally active domains of science with more than 14 billion USD per annum in public and private expenditure.[2] The public policy nexus that funds and carries out this research has a vested interest in understanding what, how and why particular research domains evolve and impact outcomes. In this work we have focused on academic surgery to understand whether there is a need for more policy-making.[6]

Despite surgery being the main modality of control and cure for solid cancers, we have found that the global levels of cancer surgery R&D are very low. While keeping pace with increases in overall cancer research activity over the last 10 years there has been little narrowing of the gap. This will come as no surprise to many. The prevailing culture of cancer research has been driven by the evolution of translational medicine with its focus on medicines and biomarkers.[7] Although worldwide volumes of surgical procedures are huge (187–281 million cases per year) R&D into this modality of care is demonstrably an "orphan" area.[8] Although the relationship between research activity and patient outcomes is complex, what is clear is that low research activity does correlate with poorer outcomes.[4]

Our findings on the RC of each country to site-specific cancer surgery R&D are complex. Some patterns are clear with certain countries with a very high commitment to certain site-specific areas based on high incidence. While low R&D activity in the rarer, solid tumors is understandable from a strategic perspective, where this occurs in the common cancers such as colo-rectal and breast, low R&D is likely to be detrimental to good patient outcomes. The relationship between research activity and outcomes is complicated, but particularly for clinical studies in these areas there is a positive correlation.[9] Sweden is the most active participant in surgical clinical trials (followed by other Western European countries) and has excellent outcomes. Surprisingly, China is also very active, despite its low overall commitment, much more so relative to its output than other East Asian countries and even the US. The fact that China also scores highly with its world-scale score suggests that a greater policy emphasis by this country on its cancer surgery R&D would pay dividends. In particular, in lung cancer surgery,[10] where China has been a fast innovator of surgical technology.

Assessing the "quality" of research is notoriously difficult and controversial. Global cancer surgery R&D cites well below that of all other oncology research domains. Such a reality has an effect on the perceived value of this type of cancer research to major funding organizations and research institutes and skews organizational policy against cancer surgery R&D. However, this global aggregation hides great heterogeneity, with some countries delivering world scale scores above 100 but with many others well below. Understanding the culture, organization and policy frames for cancer surgery R&D in the top performing countries would be a valuable benchmarking exercise for many others.[11] However, there is also evidence that low cites/world-scale scores are also due to cultural bias and nontransferable cancer surgery R&D. In the latter case, for example, India's portfolio includes many research projects on low cost surgical interventions applicable to LMIC but not developed countries. This type of R&D would be infrequently cited by surgical research program in high-income countries. Furthermore some countries, such as the UK, Greece, and Australia, score highly on percentage of reviews which have been found to correlate with the likely impact and utility of the research being conducted.[12] The relationship on the other hand between international collaboration and high impact research is more controversial. While international collaboration in cancer surgery R&D follows traditional cultural-linguistic routes, other interesting links do occur. This suggests that, at least for some countries, international collaboration promotes and reflects high impact research.[13]

In line with previous estimates on global cancer research spend we can estimate that currently only around 5% of the annual global R&D budget into cancer research supports cancer surgery.[2] This extraordinary disconnection between the impact of cancer surgery on control and cure and the very low levels of funding is a major cause for public policy concern. Public policy failure towards cancer surgery R&D has occurred at both national and supranational levels. In the UK, for example, less than 1% of cancer research spending goes towards surgery[6] and in the sixth Framework Programme of the European Union the picture is no better, with no serious research initiatives or funding directed towards cancer surgery.[3] What data we have on the US, and this is not broken down into cancer-specific funding, shows a massive divergence in support from 1992 between departments of surgery and medicine; by 1999 this meant an almost 4-fold difference in funding levels.[14] Low levels of hypothecated research funding and low levels of overall research activity create a reinforcing negative cycle that can only be broken by sustained external investment.

Beyond the "simple" matter of funding, the major public policy issue facing cancer surgery R&D is recognition of both the uniqueness of research programs needed for evolving surgical approaches and for recognition of this within public policy debates. At the level of the World Health Organization there is no funding or policy directed towards cancer surgery[15] and it seems to have been entirely missed off the radar of the European Union. Indeed, in the latter's case, if half the effort currently directed towards screening within national cancer control planning was focused on cancer surgery R&D, the impact on outcomes could be dramatic.[16] Furthermore, the cost of cancer care is also being driven in most major solid tumors by medical technology, particularly within surgery.[17] Strong leadership is required from the academic surgical community, and research funding organizations need to seriously consider their responsibility and commitment to supporting this area if cancer public health is a key strategy. Our data clearly show that the state of research in cancer surgery is "fragile," although it is an active field with huge growth potential. While in an era of compressed public budgets coupled simultaneously with expanding clinical and research needs, the downward pressures on the economics of cancer R&D have the potential to further erode academic surgery, and the evidence shows that this must be resisted.[18] Surgery is the key modality for cancer control[19] and the low activity-low funding cycle needs to be addressed by new policies specifically targeted to this domain. Current research provides a good platform on which to build new approaches.

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