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Original article

The landscape of hematology research in Brazil: an analysis of data from citation databases

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ABSTRACT

Introduction: Scientometrics is the field concerned with measuring and analyzing academic literature, using specific metrics and data from bibliometric databases. Hematology is a broad area of science and medicine, from which several landmark scientific discoveries have emerged.

Objective: The aim of this report is to provide a snapshot of the landscape of hematology research in Brazil, based on a comprehensive analysis of published studies in hematology whose authors were affiliated to Brazilian institutions from 1980 to 2020.

Method: Articles, reviews and letters to the editor with at least one author affiliated to a Brazilian institution were retrieved from Incytes/Web of Science or Scopus databases. Importantly, only papers classified in the subject area "Hematology" by the embedded algorithms of each database were included.

Results: Considering all published papers, Brazil is in the 22nd position, contributing with around 1.1% of papers in this period. A clear and sustained increase in publication output can be observed from the early 1990's to the present moment. Publicly-funded higher education institutions were the main contributors to the development and consolidation of the hematology scientific community, which has grown in diversity, with an increasing number of contributions from private institutions. In regard to funding, public agencies have been and remain by large as the most important funder of research in hematology in Brazil.

Conclusion: We suggest that continuous monitoring of the temporal trends of some of the data compiled in our report could potentially contribute to a clearer picture of the development of hematology research in Brazil.

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Introduction

Hematology is a broad field of medicine, encompassing a heterogenous group of benign and malignant diseases, whose pathogenesis involves a vast array of mechanisms such as congenital, oncogenetic and immune-mediated conditions. The field is also strongly connected to clinical pathology, cell/gene-therapy and transfusion medicine. Moreover, hematological patients demand a comprehensive approach, which involves specialized medical care, social and emotional support and also access to high-quality data to guide the most appropriate evidence-based decisions. This wide scope contributed to the relevance of hematology research in the overall biomedical research landscape, as well as to several landmark discoveries that impacted many other areas of biomedical research.[1-3]

Research and development expenditure in Brazil increased steadily from 0.96% in 2004 to 1.34% in 2015, expressed as a proportion of the gross domestic product (GDP). The last available data - 1.26% in 2017- although lower than the United States of America (2.82%) and South Korea (4.55%), is still higher than that of countries such as Argentina (0.54%) and Russia (1.11%) according to United Nations data.[4] This trend allowed a significant increase in the scientific production in Brazil, both in quantitative and in qualitative aspects, accompanied by a consolidation of the scientific community in the country.[5] Unfortunately, recent constraints in research funding in Brazil have become real threats to the maintenance of these positive outcomes.[6,7]

Scientometrics studies are those concerned with measuring and analyzing different aspects of academic literature, using statistical and analytical methods to describe and analyze how books, scientific journals and other types of documents are published.[8,9] In the last years, the field evolved dramatically with the development of new indicators about scientific "papers" (such as articles, reviews and letters to the editor) that allow the scientific community to gain new insights about how science is produced.[10,11] Although the interpretation of these metrics is often contentious, they are largely recognized as important elements in the analysis of scientific production of organizations and countries by funding agencies and higher education ranking systems.[12] The continuous monitoring of these indicators can also contribute to gain new insights and monitor trends regarding the scientific production of specific fields and countries.

Here we describe and analyze a subset of bibliometric indicators extracted from two of the most important citation databases in the field of Hematology, with at least one author affiliated to a Brazilian institution, from 1980 to 2020.

Methods

Data retrieval

Data were retrieved from two of the main databases that provide bibliographic and citation data for several academic disciplines: Incites/Web of Science (WoS) (Clarivate Analytics) and Scopus (Elsevier). Papers were restricted to articles OR letters to the editor OR reviews, published from 1980 to 2020, with at least one author affiliated to a Brazilian institution. This time-window was chosen to include the period the preceded the consistent increase of hematology research observed in the early 1990's in Brazil, with the year of 1980 being the first year covered by InCites Benchmarking and Analytics, from which most indicators were obtained. The association of papers to the field "hematology" was defined as described below. Differences between WoS and Scopus are related to the criteria to include journals, and to the indicators provided. For each paper, full bibliographic data was available from both databases. Data of database access for each analysis is indicated in legends. Of note, minor differences in the total number of papers from WoS in different results are caused by the automatic inclusion (by Incytes/WoS) of papers from the "Emerging Sources Citation Index" database in some of the analyses.

Allocation of papers to the field "Hematology"

Papers were defined as "Hematology" papers by the embedded algorithms from each database, with no manual curation. Briefly, both databases allow users to select papers according to predefined subject areas, including "Hematology". These algorithms are based on the allocation of journals to specific subject areas, so that all articles published in these journals are classified to the same subject area. In addition, for generic journals (e.g. The New England Journal of Medicine, JAMA, etc.), papers are allocated to specific subject areas according to the automated analysis of keywords. While the use of these embedded algorithms do not guarantee the inclusion of all hematology papers published in non-hematology journals, it represents the only feasible strategy to perform a large-scale scientometric analysis, while also avoiding biases in the allocation of papers to specific subject areas. Limitations and strengths of this strategy are further addressed in the discussion.

Established bibliometric indicators

Documents retrieved using these criteria were then analyzed for the following indicators, provided by Incites: (i) absolute number of papers; (ii) times cited; (iii) category-normalized (CN) citation impact, which is calculated dividing the actual count of citations by the expected citation rate for publications with the same document type, year of publication and subject area; (iv) publications in the top 10% ranking (among the most cited papers with similar characteristics). Of note, affiliations were obtained from the databases and in the case of Web of Science/Incytes correspond to how organizations are registered in the database.

Manually curated and/or adapted indicators

Top-cited papers: the 20 most cited papers including at least one author from Brazil were manually classified according to study design and to the proportion of Brazilian/foreign collaborators.

Journals: journals in which these papers were published were counted according to the following categories: (i) papers with more than 50 citations, (ii) WoS- and (iii) Scopus-indexed papers.

Additional indicators: we also report how these papers are distributed according to parameters such as funding agency, institution (defined by the presence of any co-author from a specific institution), and proportion of collaborations with industry and with international institutions.

Benchmarking of scientific output

In order to analyze the scientific production in hematology compared to other areas, the CN-citation (Incytes/WOS) impact of hematology documents was compared to other areas of research including: (i) other areas of biomedical science; and (ii) areas of science and innovation in which Brazil has a consolidated scientific output.

Results

From 1980 to 2020, Brazil produced 4186 papers (Articles, Reviews and Letters) in the field of Hematology according to WoS-indexed journals (as of last database access), which positioned Brazil as the 22nd country in number of papers in the same period (Table 1). Other metrics derived from these documents are shown in Table 2. Of note, when CN-citation impact was used to rank countries, Brazil ranked in the 66th position. A graphical representation of the relationship between number of documents and CN-citation impact in Brazil and selected countries is shown in Figure 1. The number of papers retrieved from Scopus database using similar criteria was 5462 indexed documents.

We also explored "subject areas" of these papers using the embedded classification of areas to which each article is associated (Figure 2). Oncology and Thrombosis & Hemostasis (termed Peripheral Vascular Disease and/or Cardiac & Cardiovascular in the WoS classification systems), were the main subject areas to which "Hematology" papers were linked to. Using this classification, we were also able to compare the CN-citation impact of each of these areas, with transplantation publications presenting the highest normalized impact (Figure 2b).

We next identified the 20 most cited papers including at least one author from Brazil from classified in the "Hematology" subject area by Incytes/WoS, and manually analyzed their characteristics. Only 2 of these papers did not involve any international collaboration. In total, 7/20 were multicentric clinical trials and 3/20 were guidelines from international societies. There were also: one epidemiological study and one review/position paper. The remaining 8/20 papers were classified as experimental/translational studies. Of note, this category included 4 of the 5 papers in which Brazilian-affiliated authors were 1st or last authors. The number of Brazilian-affiliated authors was higher than the number of authors from other countries only in two papers. A similar analysis considering only articles published in the last decade (2010–2020) was performed, and the number of papers in which authors affiliated to Brazilian institutions were in first or last position was 3. These figures are shown in Table 2.

Table 1 – Incites/Web of Science-indexed papers in the field "Hematology", by country (1980 – 2020).

Country	Rank by # of papers * (n)	Papers (n)	CN-citation impact**	Papers in Top 10% (%)
USA	1	135,011	1.35	16.71
UNITED KINGDOM	2	35,604	1.33	15.45
GERMANY	3	34,214	1.32	16.04
ITALY	4	33,606	1.24	13.58
ENGLAND	5	32,058	1.38	15.99
JAPAN	6	30,006	0.83	8.12
FRANCE	7	28,556	1.28	14.85
CANADA	8	18,243	1.39	15.93
NETHERLANDS	9	18,224	1.46	16.90
CHINA MAINLAND	10	13,626	1.10	11.21
SPAIN	11	12,027	1.31	13.97
AUSTRALIA	12	10,383	1.38	15.58
SWEDEN	13	9824	1.37	16.39
SWITZERLAND	14	8416	1.56	18.46
AUSTRIA	15	6850	1.40	16.45
TURKEY	16	6355	0.52	4.28
ISRAEL	17	6260	1.12	12.64
BELGIUM	18	6190	1.51	16.96
INDIA	19	5502	0.47	3.94
DENMARK	20	5448	1.36	15.88
SOUTH KOREA	21	4480	0.94	9.69
BRAZIL	**22**	**4186**	**0.94**	**9.36**
RUSSIA	27	2816	0.64	6.78
ARGENTINA	38	1502	0.86	9.65
SOUTH AFRICA	42	1228	0.87	9.04
MEXICO	43	1217	0.69	6.57

* Documents include articles, reviews and letters to the editor indexed in Incytes/Web of Science; CN-citation impact: Category Normalized Citation Impact; #: absolute number. Content indexed through 2021–04–26 (including documents from the Emerging Sources Citation Index). United Kingdom data includes England, Scotland Wales and Northern Ireland.

Table 2 – Characteristics of the 20 top-cited papers classified in the subject area "Hematology" by Incytes/WoS, and including at least one Brazilian-affiliated authors.

PERIOD	Full period 1980–2020 (*n* = 20)	Last decade 2010–2020 (*n* = 20)
Papers involving international collaboration, yes, n (%)	18 (90%)	
Category, n (%)		
Experimental/translational studies	8	7
Multicentric clinical trials	7	4
Guidelines/recommendations	3	5
Clinical & epidemiological studies	1	3
Review/position papers	1	1
Proportion of Brazilian-affiliated authors from all authors, n (%)	48 (11.2%)	64 (12.1%)
Brazilian-affiliated authors in 1st or last position, n (%)	5 (25%)	3 (15%)

* The table provides data from two specific time frames: the full period of analysis (1980 to 2020) and a sub-analysis encompassing only articles from the last decade, so as to analyze potential changes in recent years.

When the list of most cited papers was expanded to include all papers with more than 50 citations, a total of 406 papers were identified, which were published in 54 different journals. The journals in which these papers with a higher citation rate were published are shown in Figure 3.

We also present the list of journals in which all papers with Brazilian-affiliated authors were published, with separated data from WoS and Scopus dabatases (Table 3). Of note, when the reference dataset was Scopus, the list of journals changed significantly, with the journal Hematology, Transfusion and Cell Therapy (and former "Revista Brasileira de Hematologia e Hemoterapia") ranking 1st with 1183 out of 5462 documents in the same period.

In regard to funding, CNPQ, the Brazilian National Council for Research and Technology was the most frequently listed funding agency of Incites/WoS-indexed publications in Hematology, followed by the National Institutes of Health from the USA and Brazil`s main state funding agency, FAPESP (Sao Paulo Research Agency) (Table 4).

In regard to the institutions to which authors of these papers were affiliated, the 20 more frequently listed in Incites/WoS are shown in Table 5, along with the category-normalized citation impact of these publications.

In order to gain insight on the temporal pattern of publication of each of these institutions, the temporal distribution of these publications was plotted (Figure 4) for institutions with more than 100 indexed documents in the study period. We also plotted the 1st year in which each of these institutions published more than 10 papers per year (Figure 4, inset), allowing a temporal view of the engagement of these institutions in hematology research. A similar analysis comparing hematology with other areas of medical research is shown in Figure 5.

We also evaluated the proportion of international collaborations and of papers involving collaborations with industry from the 10 institutions with more Incites/WoS-indexed papers. Rates from Spain and Australia are also presented for comparison (Figure 6).

Finally, in order to gain additional insights on the relative impact of the Brazilian WoS-indexed scientific production in the category "Hematology", we compared its CN-citation impact with other areas of medical research (Figure 7) as well as with areas of non-medical research in which Brazil has a consolidated scientific output (Figure 8).

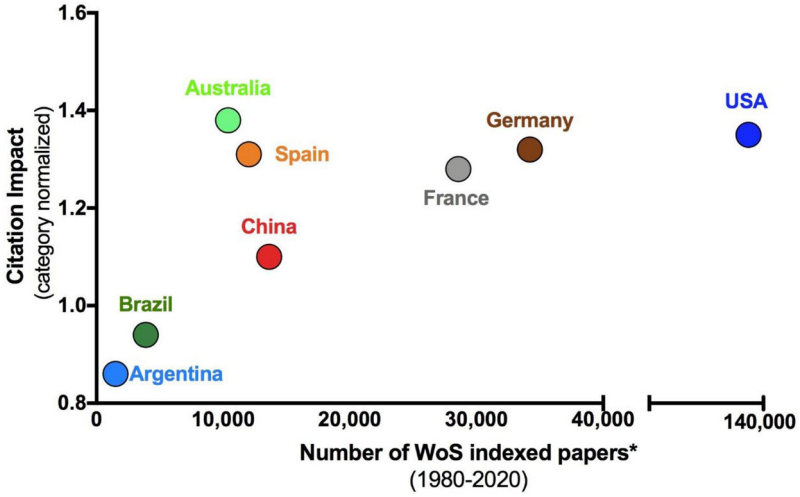

Figure 1 – Comparison of category-normalized citation impact and number of papers between Brazil and selected countries in the field "Hematology" (1980–2020) in Incytes/Web of Science (WoS) indexed documents (original articles, letters and reviews). Content indexed through 2021–04–26 (including documents from the Emerging Sources Citation Index).

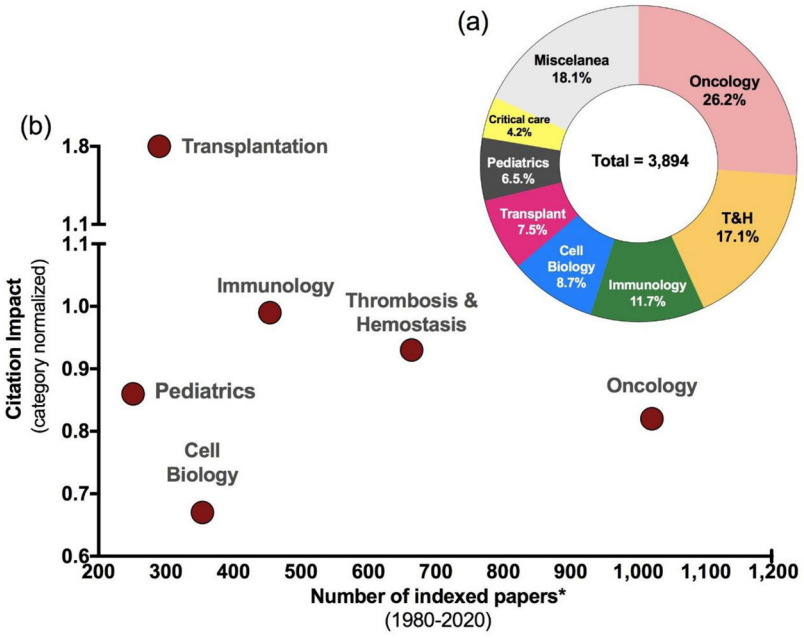

Figure 2 – Main areas of research of documents published by Brazilian authors in the field "Hematology" (1980–2020) in Incytes/Web of Science (WoS), with data from total number of publications (a) and CN-citation impact (b). Areas of research are original WoS categories, except that "Thrombosis & Hemostasis" encompasses the category termed "Peripheral Vascular Disease" in the database. WoS content indexed through 2021–04–12. Of note, since transfusion medicine/hemotherapy are not official WoS categories, we were not able to depict data from this are separately, and they are included in these other categories. To illustrate how papers from this area would compare to other areas, the CN-citation impact of the 158 papers published in the journal Transfusion was 0.7.

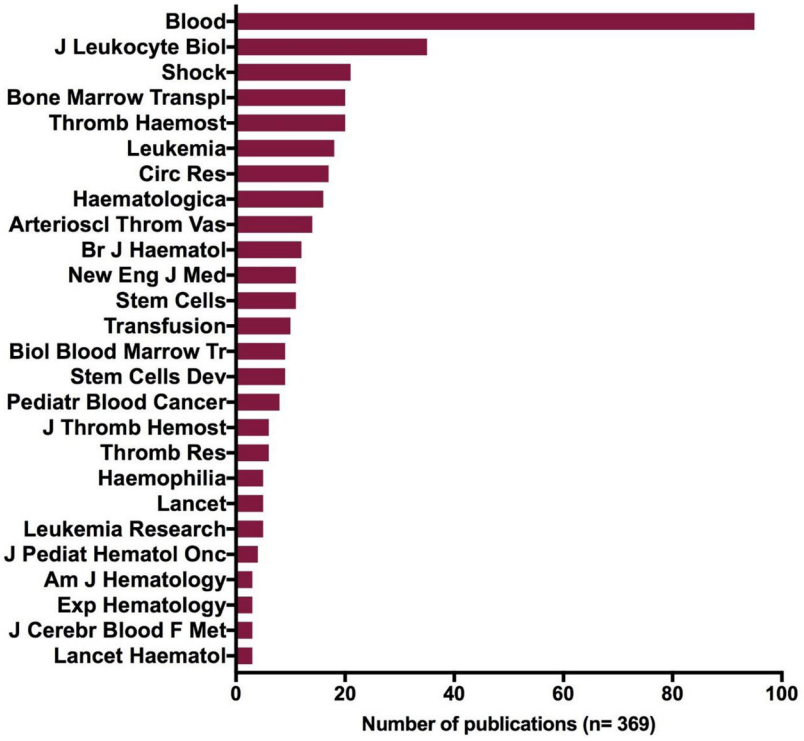

Figure 3 – Journals in which Incites/WoS-indexed documents including Brazilian authors from 1980 to 2020 with 50 or more citations (as of December 27th 2019) were published. Journals with less than 3 publications (*n* = 28 journals) are not listed.

Table 3 – Journals with more publications (top 15) including Brazilian authors in the field "Hematology" (1980–2020) with authors from Brazil.

Incites/Web of Science		Scopus	
Journal	Number of publications	Journal	Number of publications
Blood	202	RBHH*	1007
Journal of Leukocyte Biology	196	Cytokine	257
Shock	163	Blood	202
Transfusion	158	HTCT** (former RBHH*)	176
Bone Marrow Transplantation	150	Immunobiology	174
Leukemia Research	139	Bone Marrow Transplantation	145
Pediatric Blood Cancer	134	Leukemia Research	141
British Journal of Haematology	133	Transfusion	140
Thrombosis Research	132	British Journal of Haematology	136
HTCT** (former RBHH*)	127	Thrombosis Research	131
Heaemophilia	120	Pediatric Blood and Cancer	127
Leukemia & Lymphoma	119	Leukemia and Lymphoma	116
Vox Sanguinis	106	Journal Clin Lab Analysis	113
Annals of Hematology	89	Annals of Oncology	112
Haematologica	89	Haematologica	105
Thrombosis and Haemostasis	89	hemophilia	105

* RBHH: Revista Brasileira de Hematologia e Hemoterapia; ** HTCT: Hematology, Transfusion and Cell Therapy (former RBHH). Differences between Incytes/WoS and Scopus derive from the list of journals included in each of these databases, which in the case of the latter, only incorporated RBHH/HTCT after 2018.

Table 4 – Funding agencies from papers published by Brazilian-affiliated authors in the field "Hematology" (1980–2020) – only Brazilian agencies with at least 100 hits are listed.

Web of Science	
Funding agency	Mentions
National Council for Scientific and Technological Development (CNPq)	618
Sao Paulo Research Foundation (FAPESP)	451
CAPES	306
Carlos Chagas Filho Research Foundation (FAPERJ)	139
Minas Gerais State Research Foundation (FAPEMIG)	108

Discussion

Scientometrics has been defined as the quantitative study of science and technology, and encompasses methods and metrics designed to quantitatively study the scientific literature, also referred to as bibliometrics or infometrics.[8,9] Here, we present a collection of metrics derived from two of the most important citation databases[13] focused on the published scientific output in the subject area "Hematology" in Brazil from 1980 to 2020. The main contribution of our results is to offer a comprehensive overview of the landscape of published academic research in hematology in Brazil, which can also represent a dataset for future comparative research projects.

Considering the total number of papers published in the last four decades, Brazil ranked as the 22nd country, after a list comprised of developed countries from North America and Western Europe, as well as China, Turkey, India and South Korea. In a recent report of a government agency (CAPES), Brazil ranked 13th when papers from all scientific areas published between 2013 and 2018 were counted.[14] If only papers in hematology were considered, Brazil would have ranked 21st (data not shown). Another metric increasingly used to analyze the relevance of the scientific output of a country is the category-normalized citation impact, which measures the citation frequency of scientific papers, normalizing the results to the citation standards from different research areas. Using this metric, Brazil appeared behind countries with similar budgets for science (both in terms of total expenditure or as percentage of the GNP) such as Spain. It should be noted however that the precise rank of Brazil in this metric (66th position) should be analyzed with caution since the CN-citation impact can be artifactually high in countries with very small scientific production. While these results demonstrate that there is certainly room for increasing the overall relevance of hematology research in Brazil, it should be noted that the lively discussed dissociation between quantity and quality is not so straightforward. Accordingly, it has been demonstrated that productivity (number of papers) is strongly correlated with impact (number of citations), including highly-cited papers.[15] Sandstrom & Besselaar speculate that "increased productivity of the research system is not a perverse effect of output-oriented evaluation systems, but a positive development." In fact, it is fair to argue that the consolidation of a scientific community is a complex and stepwise process, and although the skills for producing and publishing in peer-reviewed journals should not be viewed as the major goal, it certainly is a *sine qua non* condition for producing high-impact science. Moreover, one should not forget that Incytes/WoS is the most selective database, including only journals that pass a strict evaluation focused on editorial standards. Monitoring the temporal trends of these metrics is a strategy by which our community could gain additional insights on the relevance of hematology research produced in Brazil.

Table 5 – Incites/Web of Science-indexed documents in Brazil in the field "Hematology", by institution (1980 – 2020). 20 institutions with more indexed documents.

Institution	Papers (n)	CN-citation impact**
USP	1168	0.95
UNICAMP	725	0.90
UNIFESP	517	0.74
UFRJ	367	0.92
UFMG	304	1.01
INCA	246	0.97
Hospital "Albert Einstein"	232	1.02
FIOCRUZ	209	0.91
UFPR	171	1.24
UFRGS	170	0.81
Hospital "Sírio-Libanês"	120	0.97
UNESP	89	0.60
AC Camargo Cancer Center	88	0.81
UERJ	81	0.71
UFCE	70	1.13
UFBA	66	0.66
UFPE	47	0.46
Butantan Institute	41	0.59
UFJF	41	1.10
UFSC	39	0.54

* Documents include articles, reviews and letters to the editor indexed in IncitesWeb of Science (WoS); ** CN-citation impact: Category Normalized Citation Impact. USP: University of Sao Paulo; UNICAMP: University of Campinas; UNIFESP: Federal University of Sao Paulo; UFRJ: Federal University of Rio de Janeiro; UFMG: Federal University of Minas Gerais; INCA: National Institute of Cancer; FIOCRUZ: Oswaldo Cruz Foundation; UFPR: Federal University of Parana; UFRGS: Federal University of Rio Grande do Sul; AC Camargo: A C Camargo Cancer Center; UNESP: State University of Sao Paulo; UERJ: State University of Rio de Janeiro; UFBA: Federal University of Bahia; UFCE: Federal University of Ceara; UFPE: Federal University of Pernambuco; UFSC: Federal University of Santa Catarina; UFJF: Federal university of Juiz de Fora. Institutions are listed based on WOS registered nomenclatures.

In regard to subject areas, oncohematology and thrombosis and hemostasis (T&H) are the two main areas of research, followed by the field of immunology. Unfortunately, the database used to obtain the CN-citation impact does not classify papers in the areas of transfusion medicine/hemotherapy, which is important in hematology research in Brazil, so that these papers are spread in other categories. In regard to the citation impact of these publications, hematopoietic cell transplantation represents only 7.5% of publications but has a very high relative impact of 1.8. There are several possible reasons for this dissociation, and in order to gain insights on these findings, we analyzed the 20 papers that were most frequently cited during the study period. Interestingly, we noted that all but two papers involved international collaborations, and that multicentric clinical studies and guidelines were also very common, representing 50% of these studies. Studies in which authors affiliated to Brazilian institutions were in the first or last position (considered as a proxy of a more prominent role in research initiatives) were only 25% of these studies, most of them in the area of translational research in the areas of stem cell research and T&H. Of note, this proportion did not increase when papers published in the last decade were analyzed, when in fact the rate dropped to 15%. While these results reinforce the association of international collaborations with higher citation rates,[16] as well as the importance of multicenter clinical research, they also highlight the importance of discussing strategies to increase the proportion of Brazilian-affiliated authors in leading positions in these studies.

We also explored the journals in which research from Brazilian-affiliated authors were more frequently published. When Incytes/WoS journals were considered, the list has *Blood* as the top-ranked journal, followed by other traditional hematology papers. In this list, the journal Hematology, Transfusion and Cell Therapy (HTCT; former Revista Brasileira de Hematologia e Hemoterapia- RBHH) is listed in the 10th position, due to the fact that it was only included in this database after 2018. Accordingly, when the same list was obtained from the Scopus database, which includes HTCT and RBHH, publications in this journal ranked 1st, encompassing about 25% of the Brazilian peer-reviewed published research output. These results support the increasing importance of HTCT for hematology research in Brazil. Of note, Scopus includes more journals than Incytes/WoS

In regard to funding, public agencies (CNPq and FAPESP, CAPES, FAPERJ and FAPEMIG) were the main funders, illustrating the prominence of public funds for Hematology research in Brazil. Funders such as the National Institutes of Health were also listed, possibly illustrating international collaborative networks (data not shown). In regard to the 20 institutions to which authors were most frequently affiliated, the list included 14 public universities (70%); 3 public research institutes (15%) and 3 private hospitals/research institutions (15%). These data demonstrate that research in Hematology in the last 4 decades in Brazil was almost exclusively dependent on public funds. Accordingly, an analysis of the temporal pattern of how these institutions contributed to the total published research output demonstrates that the contribution of private institutions is a relatively recent trend. Together, our results support that one of the main contributions of the public higher education and research funding systems in Brazil was the foundation of a community of researchers that are now playing prominent roles in a more diverse set of institutions.

The analysis of Figures 4 and 5 clearly shows a steady increase in the number of published papers after 1995. Although the rate and slope of the increase is not the same for all institutions or medical specialties, the general increase is a fact. We speculate that it is a consequence of the budget increase for both research and for student scholarships in graduate courses ("pós-graduação", as it is called in the Brazilian higher education system) observed in Brazil between 2000 and 2015. It is also interesting to note that the three institutions with more papers in the period are from the State of Sao Paulo, where the most important state-funded research agency in Brazil is located (Sao Paulo Research Foundation – FAPESP). This highlights the importance of stable funding opportunities for the establishment of a more productive research environment. Analyses of these figures also demonstrate that research productivity in Hematology is far below other specialties such as Cardiology, Endocrinology and Oncology. These results are probably due to the relatively low

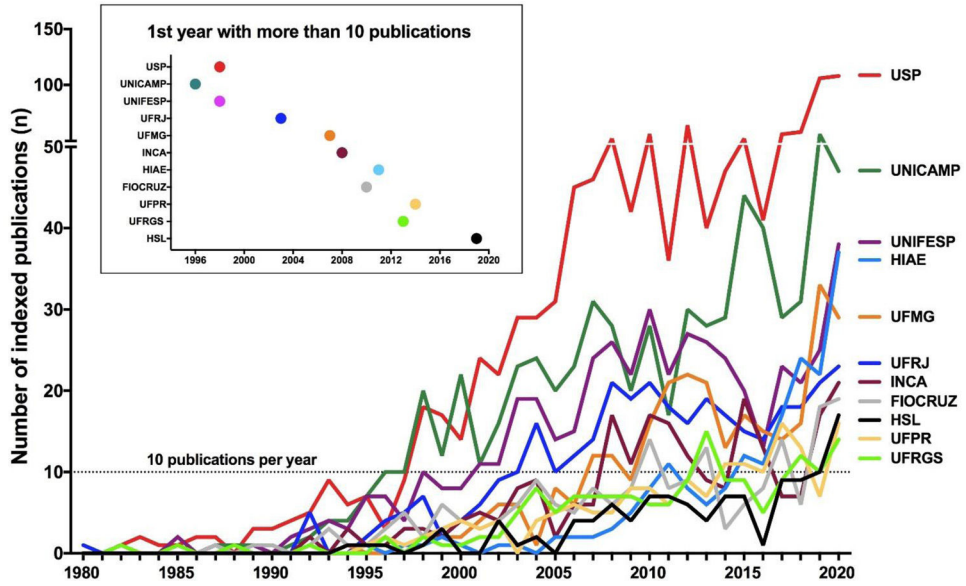

Figure 4 – Temporal distribution of publication of Incytes/WoS documents for institutions with more than 100 indexed documents from 1980 to 2020. In the large panel, number of publications per year. In the inset, year in which each institution surpassed the rate of 10 publications per year. USP: University of Sao Paulo; UNICAMP: University of Campinas; UNIFESP: Federal University of Sao Paulo; UFRJ: Federal University of Rio de Janeiro; UFMG: Federal University of Minas Gerais; INCA: National Institute of Cancer; FIOCRUZ: Oswaldo Cruz Foundation; UFPR: Federal University of Parana; UFRGS: Federal University of Rio Grande do Sul; HIAE: Albert Einstein Hospital; HSL: Sirio Libanês Hospital.

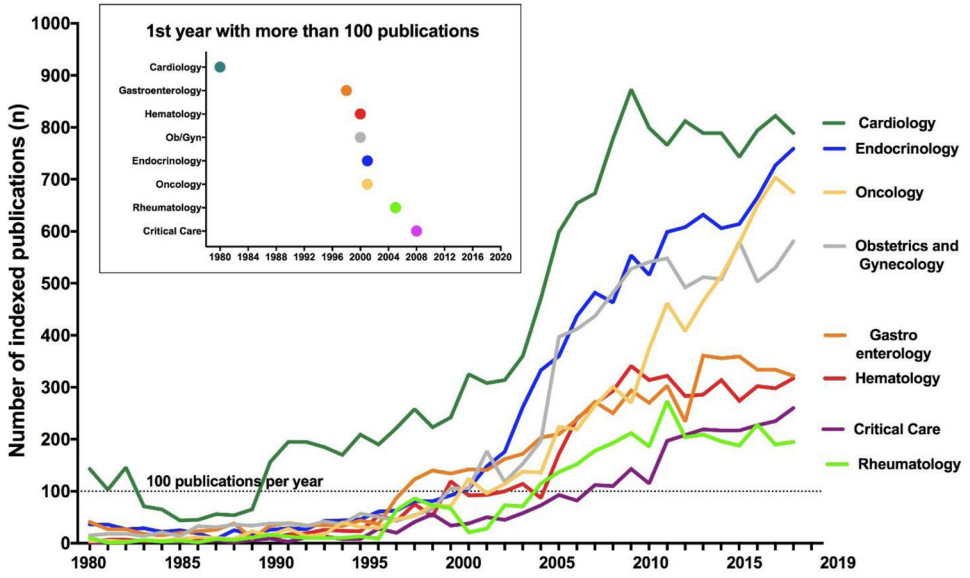

Figure 5 – Temporal distribution of publication of Scopus documents for selected areas of medical research from 1980 to 2020. In the large panel, number of publications per year. In the inset, year in which each area surpassed the rate of 100 publications per year. Ob/Gyn: obstetrics and gynecology. Data retrieved from the Scopus database using the embedded filter of Subject areas.

number of centers performing intense research in Hematology in Brazil (most of them concentrated in a specific geographic area of the country) compared with the other specialties, which also results in a lower number of researchers in Hematology, compared to areas such as cardiology and oncology. Irrespective of the causes, the increase in the number of well-trained physician-scientists in Hematology, as well as a more balanced geographic distribution of

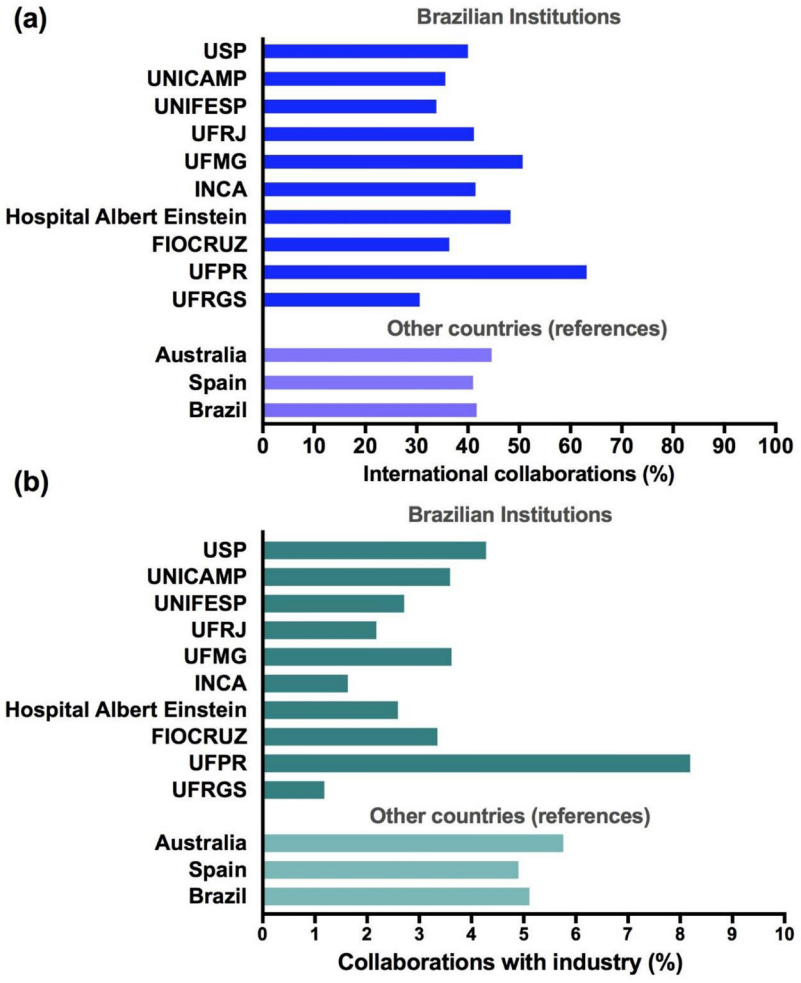

Figure 6 – Proportion of papers involving international (a) and industry (b) collaborations from the 10 institutions with more Web of Science indexed documents in the field "Hematology" (1980–2020). USP: University of Sao Paulo; UNICAMP: University of Campinas; UNIFESP: Federal University of Sao Paulo; UFRJ: Federal University of Rio de Janeiro; UFMG: Federal University of Minas Gerais; INCA: National Institute of Cancer; FIOCRUZ: Oswaldo Cruz Foundation; UFPR: Federal University of Parana; UFRGS: Federal University of Rio Grande do Sul.

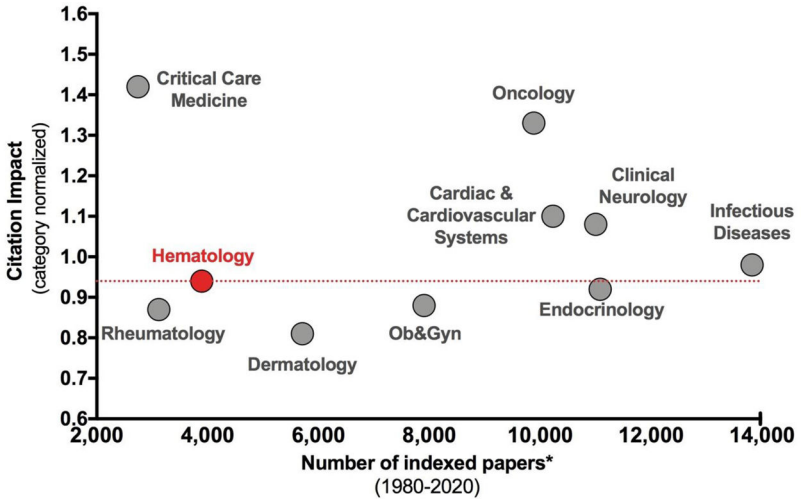

Figure 7 – Comparison of citation metrics between Hematology and selected areas of medical research (1980–2020) in Incytes/ Web of Science indexed documents. Includes WoS content indexed through 2021–05–07.

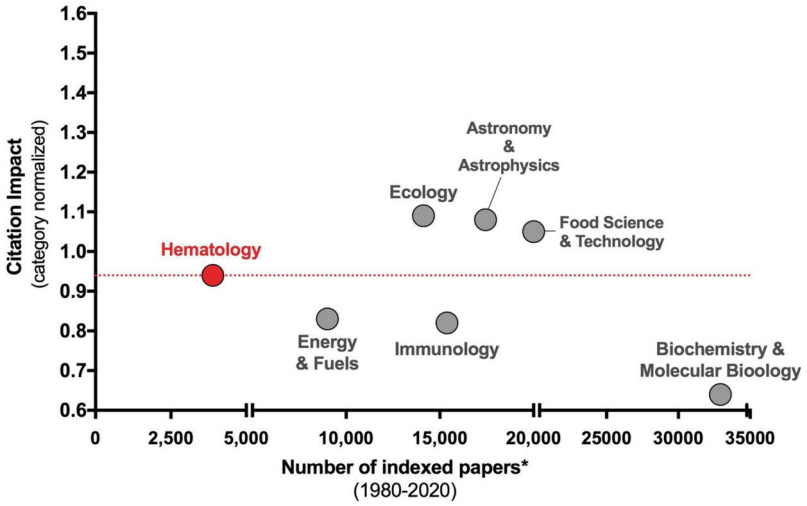

Figure 8 – Comparison of citation metrics between Hematology and selected areas of research (non-clinical sciences) (1980–2020) in Web of Science indexed documents. Includes WoS content indexed through 2021–05–07.

hematology research centers in the whole country should be an important priority for our research community.

We also explored the proportion of papers involving international and industry collaborations, which showed rates that are similar to those of Brazil (as a country) and from other countries such as Spain and Australia. Interestingly, the institution (UFPR) that presented the highest category-normalized citation impact was also the one with the highest proportion of international and industry collaborations, further supporting the association of these two metrics.[16] Finally, we compared the number and the impact of the publication output in hematology with other areas of research in Brazil, not only in biomedical sciences, but also in other traditional fields of Brazilian science such as food, energy and fuels. Again, the embedded algorithms were used to classify papers to each subject area. Although the quantitative contribution of hematology was lower than most of the more traditional biomedical and non-biomedical research areas, the category-normalized impact of hematology papers was in an intermediary position, lower than areas such as critical care medicine, oncology and ecology, but higher than areas such as obstetrics and gynecology, immunology and energy & fuels. A more detailed analysis of the temporal trends of these two metrics could offer a clearer picture of the global contribution of hematology research performed in Brazilian.

Limited data is available about the scientific output of hematology research worldwide, with one report comparing the publication output of China with top-ranked countries from Europe and North America,[17] and one report analyzing hematology and oncology research in Latin America.[18] The latter was based on abstracts presenting at a selected list of scientific meetings from 2000 to 2010, followed by an analysis of the proportion of these abstracts that were eventually published. The main conclusions were that scientific output increased during the study period, with Brazil responsible for around 50% of the regional production, when the study criteria was used. A study exploring the publication output of CNPq-funded researchers from 2006 to 2008 revealed a higher frequency of publication in indexed journals of hematology researchers when compared to other areas.[19] Therefore, to our knowledge our data represents the most comprehensive analysis of hematology research in a specific region, using metrics that can also be applied to other regions.

A key limitation of our study is the reliance on an automated classification of papers for their allocation to the subject area "Hematology", based on the embedded algorithms of Incytes/WoS and Scopus databases, which are based on the category to which journals are linked to, and on the analysis of keywords in case of papers published in general journals. Accordingly, we cannot exclude that other papers that would fit in the broad scope of "Hematology Research" were not included in our analysis. In fact, we were able to identify some of these papers, including a few published in high-impact journals (data not shown). However, it would not be feasible to perform such a study otherwise, since it would require the curation of all papers published by Brazilian-affiliated authors in this period (more than 1000,000 papers). Moreover, since the Incytes/WoS citation database is recognized as one of the most important sources of its kind by the scientific community,[10] and has been used in recent reports about science in Brazil,[5,14] the use of their standardized embedded classification schemes can also be viewed as a strength, as it allows comparisons with other countries, as well as monitoring of the same data in the future. A further limitation derived from the use of embedded classifications and schemata is the fact that we were not able to obtain specific data from University of Sao Paulo in Sao Paulo and in Ribeirao Preto, respectively, which are both listed as University of Sao Paulo. Since they represent two independent and traditional research centers in hematology, it would be interesting to have this information.

Moreover, a cautionary note regarding the comparative analysis of citation impacts between institutions should be considered when interpreting our results. Accordingly, it is widely recognized that this figure can be influenced by the size of the publication output since highly cited papers can have a more pronounced effect on the citation impact of organizations with smaller outputs when compared to those

with higher number of published papers. This inflating effect is acknowledged by WoS.[20] In addition, no single bibliometric indicator can be used alone, as even category normalized metrics are subject to other biases.[21]

In conclusion, hematology research performed in Brazilian institutions represents an important share of the contribution of the Brazilian scientific community to global science. Public higher education institutions were the main contributors to the initial development and consolidation of this scientific community, which is now more diverse, with important contributions from private research institutions. In regard to funding, public agencies remain by large the most important source of funding for research in hematology in Brazil. Although there have been clear improvements in both quantity and quality, we believe that further increases of the international competitiveness of hematology research performed in Brazil would require strategies capable to promote a substantial increment in the number of centers of excellence, with a more homogenous geographical distribution in the country, as well as an urgent increase in the number of physicians scientists that could lead to an consistent increase in the participation of Brazilian-affiliated investigators in leading positions in major international research projects. Finally, monitoring of the temporal trends of some of the metrics presented in our study could also offer a clearer view of the ongoing development of hematology research in Brazil.

Conflicts of interest

The authors declare no conflicts of interest.

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