Global funding for cancer research between 2016 and 2020: a content analysis of public and philanthropic investments

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Summary

Background **Cancer is a leading cause of disease burden globally, with more than 19·3 million cases and 10 million deaths recorded in 2020. Research is crucial to understanding the determinants of cancer and the effects of interventions, and to improving outcomes. We aimed to analyse global patterns of public and philanthropic investment in cancer research.**

Methods **In this content analysis, we searched the UberResearch Dimensions database and Cancer Research UK data for human cancer research funding awards from public and philanthropic funders between Jan 1, 2016, and Dec 31, 2020. Included award types were project and programme grants, fellowships, pump priming, and pilot projects. Awards focused on operational delivery of cancer care were excluded. Awards were categorised by cancer type, cross-cutting research theme, and research phase. Funding amount was compared with global burden of specific cancers, measured by disability-adjusted life-years, years lived with disability, and mortality using data from the Global Burden of Disease study.**

Findings **We identified 66 388 awards with total investment of about US$24·5 billion in 2016–20. Investment decreased year-on-year, with the largest drop observed between 2019 and 2020. Pre-clinical research received 73·5% of the funding across the 5 years ($18 billion), phase 1–4 clinical trials received 7·4% ($1·8 billion), public health research received 9·4% ($2·3 billion), and cross-disciplinary research received 5·0% ($1·2 billion). General cancer research received the largest investment ($7·1 billion, 29·2% of the total funding). The most highly funded cancer types were breast cancer ($2·7 billion [11·2%]), haematological cancer ($2·3 billion [9·4%]), and brain cancer ($1·3 billion [5·5%]). Analysis by cross-cutting theme revealed that 41·2% of investment ($9·6 billion) went to cancer biology research, 19·6% ($4·6 billion) to drug treatment research, and 12·1% ($2·8 billion) to immuno-oncology. 1·4% of the total funding ($0·3 billion) was spent on surgery research, 2·8% ($0·7 billion) was spent on radiotherapy research, and 0·5% ($0·1 billion) was spent on global health studies.**

Interpretation **Cancer research funding must be aligned with the global burden of cancer with more equitable funding for cancer research in low-income and middle-income countries (which account for 80% of cancer burden), both to support research relevant to these settings, and build research capacity within these countries. There is an urgent need to prioritise investment in surgery and radiotherapy research given their primacy in the treatment of many solid tumours.**

Funding **None.**

Introduction

Cancer is one of the leading causes of death worldwide. GLOBOCAN 2020 estimates suggest that in 2020, almost 10 million deaths were deemed attributable to cancer and 19·3 million new cancer cases were diagnosed, a value projected to increase to 28·4 million by 2040.[1] Low-income settings typically have greater mortality rates and a rising proportion of the global burden. For example, women living in transitioning (low-income) countries have a 17% higher mortality rate than do women in high-income countries (15·0 deaths from breast cancer per 100 000 people and 12·8 deaths per 100 000 people).[1,2]

Cancer research is essential to understand evolving patterns of cancer burden and to inform policies aimed at providing more effective, efficient, and equitable oncology care. This necessitates an understanding of the landscape of cancer research spending, for which a comprehensive global analysis has not, to our knowledge, been previously reported.

Research in context

Evidence before this study

We searched PubMed for publications in English from database inception to Dec 1, 2022, for publications on global cancer research funding. Searches were deliberately broad and included the terms "cancer research" AND "global" AND ("investment" OR "grant" OR "funding" OR "award").

We identified several publications describing patterns of cancer research investment; however, these were restricted either to a relatively small proportion of public and philanthropic funding bodies, or to specific geographical areas (eg, Europe).

No comprehensive description of public and philanthropic cancer research investment exists worldwide, and published data do not describe the distribution of funding according to tumour site, phase of research, and cross-cutting research. Furthermore, allocation of resources in relation to the global burden of disease and to overarching cancer control strategic priorities is not clear.

Added value of this study

To our knowledge, this study is the first comprehensive analysis to report the amounts and distribution of public and philanthropic global cancer research funding between 2016 and 2020, with consideration of the initial impact of the COVID-19 pandemic. Compared with previous studies, we demonstrate decreasing cancer research investment and show that most research investment is dedicated to pre-clinical or medicinal research, with only a small proportion invested in the primary treatment modalities of surgery and radiotherapy. Furthermore, despite the known rapidly increasing burden of cancer in low-income and middle-income countries, only a fraction of cancer research investment is in cancer as a global health problem.

Implications of all the available evidence

Current research investment does not align well with the global distribution of cancer (with overarching cancer control strategies), nor with primary effective treatment modalities for many cancers. There is an urgent need to review research investment priorities globally to align with population needs—finite resources must be invested wisely to achieve maximum improvements in mortality and alleviation of the cancer burden.

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For more information on **Cancer Research UK** see www.cancerresearchuk.org

Earlier studies have indicated increasing investment in cancer research globally. A 2021 study of projects funded by the International Cancer Research Partnership (ICR Partners) demonstrated an increase in research investment from US$5·562 billion in 2006 to $8·511 billion in 2018.[3] The ICR Partners represent only a small proportion of global cancer funding bodies; however, a further study identified 4693 organisations who provide cancer research funding, with almost half classified as not-for-profit organisations and only 12% classified as governmental organisations.[4] Of these, 44% of funders were based in the USA, 21% in Europe, and 16% in Asia.

Although published work to date provides some insight into the scale and distribution of cancer research investment, it is typically restricted either to specific regions or to relatively few funding organisations. An analysis of European cancer research investment between 2010 and 2019 estimated that cancer biology and treatment were the research types that received the greatest investment, and breast cancer was the cancer type receiving the highest amount of funding.[5] Although this analysis was relatively detailed, European patterns might not be reflective of global patterns of cancer research investment.

We aimed to systematically analyse global public and philanthropic cancer research funding between Jan 1, 2016 and Dec 31, 2020, categorised by cancer type and cross-cutting themes, including phase of research. We explored the nature and phase of funded research in the context of trends in global cancer incidence and outcomes. Award data were assessed against global burden of disease metrics, providing a comprehensive picture of global cancer research funding over a 5-year period.

For more on **ICR Partners** see www.icrpartnership.org

Methods

Search strategy and selection criteria

The methods used here have been developed by MGH and RA for previous research investment analyses.[6,7] In this content analysis, details of research awards from public and philanthropic funders related to cancer research between Jan 1, 2016 and Dec 31, 2020, were obtained from the UberResearch Dimensions database. This database includes 6 million grant awards worth US$2·3 trillion from 656 funders worldwide, covering health and non-health research. Cancer Research UK data were estimated separately on the basis of their annual summary reports. Keyword searches and filters in English identified research studies relating to human cancer. This includes awards that Dimensions had labelled as being related to cancer, plus a series of other keywords (appendix pp 2–3). Included award types were project and programme grants, fellowships, pump priming, and pilot projects. Awards focused on non-human oncology (eg, veterinary), infrastructural funding, equipment grants, or funding for conferences were excluded, as well as those focused on operational delivery of cancer care rather than research.

For more on the **UberResearch Dimensions database** see www.dimensions.ai

See **Online** for appendix

Awards were individually examined to confirm their inclusion according to the aforementioned criteria. They were classified according to anatomical site of primary tumour. A label of ''multiple'' was applied to awards that specifically mentioned multiple cancer types (eg, combined breast and ovarian cancer research). Awards that were related to oncology but did not specify a particular type of cancer were classified as ''cancer—general'' (including pre-clinical research not related to specific cancer types). Further classification included whether the research concerned metastatic disease, patient age group (child, adult, older population [if applicable]), and cross-cutting research theme (cancer biology; biomarkers; diagnosis, screening, and monitoring; drug treatment; immuno-oncology; global health; psychosocial; radiotherapy; surgery). The cancer biology theme included all non-clinical research, either applicable to a specific tumour type or to the biology of cancer more broadly. The drug treatment theme included studies of drug discovery and drug resistance mechanisms as well as drug treatment trials. The diagnostic, screening, and monitoring themes included risk and prevention research, imaging studies, screening studies and studies of treatment follow-up including large-scale, population-based outcome studies. Psychosocial studies included those addressing psychological, cognitive, or behavioural interventions; quality of life studies; and survivorship issues. Surgical studies included surgical techniques, devices, and interventional radiology trials. Radiotherapy studies included radiobiology research, clinical trials of radiotherapy, and combination studies that included radiotherapy as the key component of research. The global health theme included studies with a focus on the low-income and middle-income settings, as defined by the World Bank country income classification.

For more on the **World Bank income classification system** see https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

Awards were defined by phase of research along the research pipeline, as per earlier studies.[6,7] Awards could be classified as pre-clinical (ie, laboratory-based research); phase 1–4 clinical trials; public health (focusing on populations, epidemiology, or behavioural sciences), or cross-disciplinary (defined as covering more than one stage of the research continuum, such as pre-clinical research progressing to a phase 1 study). Further details are presented the appendix (p 2).

Data analysis

Awards were categorised by co-authors. All classification queries were reviewed and checked by SAMcI and MGH. To remove errors and minimise subjectivity, a further 10% of all data were double-checked by MGH for inter-rater reliability, with review of inclusion criteria and classification categories. Remaining uncertainties were then reviewed by SAMcI. Any disagreements were resolved by consensus between MGH and SAMcI. Datasets and provisional analyses were shared with co-authors for review and comment. Duplicate data was identified by co-authors at categorisation and removed by author MGH as part of validation.

Research awards were adjusted for inflation in the original currency and converted to 2020 US$ using the mean exchange rate in the award year. Funding levels were considered by the total funding amount committed at the year of the award, rather than the annual breakdown within each year of an award.

Funding amount was missing from 3732 (5·6%) of 66 388 individual awards, totalling $552·9m (2·4%). Efforts were made to source funding amounts, including writing to principal investigators, writing to funders, and reviewing maximum award amounts for this type of award on the funder website.[6] Cancer Research UK do not provide individual award funding data. We compiled estimates for these awards using annual reports from 2016 to 2020 inclusive, and visualisation data from the Cancer Research UK website (appendix pp 4–5).

Burden of disease data, specifically mortality, disability-adjusted life years (DALYs), and years lived with disability (YLD) were sourced from the Global Burden of Disease (GBD) study.[8] Comparisons were made across cancer types by calculating investment per mortality, DALY, or YLD. For example, for assessment of DALYs in relation to bladder cancer, the sum of bladder cancer research investment was divided by DALYs in 2019 resulting in an investment per DALY. Descriptive statistics were used to investigate the relationship between research investment and disease burden, using GBD 2019 study data. Ranking of each cancer type was derived from order of funding per burden metric. Combined ranking is the sum of each ranking score. We used Microsoft Excel (v16.68) for data preparation and Stata SE (version 16) for data analysis.

Role of the funding source

There was no funding source for this study.

Results

The final dataset included 66 388 awards for cancer research between Jan 1, 2016 and Dec 31, 2020, with a total investment of $24·5 billion. The median award size (excluding Cancer Research UK awards) was $90 576 (IQR 38 663–316 416; table 1).

By type of science along the research pipeline (not including Cancer Research UK data), pre-clinical research received about $18 billion (73·5%) of investment across 57 816 (87·1%) awards. Phase 1–4 clinical trials received about $1·8 billion (7·4%) from 2427 (3·7%) awards, and public health research received about $2·3 billion (9·4%) across 4809 (7·2%) awards, with cross-disciplinary research receiving about $1·2 billion (5·0%) of funding across 1336 (2·0%) awards. For comparison, distribution of investment in infectious diseases research from our previous analysis[6] is shown in the appendix (p 6).

When classified by tumour type and site, general cancer research received about $7·1 billion (29·2%) of total funding across 17 581 awards (26·5%). This was more than twice the funding for the most highly funded

	Number of awards (n=66 388)	Funding ($US 24 451 417 116)	Median funding ($US)	Mean funding ($US)
Type of science (excluding Cancer Research UK data)				
Pre-clinical research	57 816 (87·1%)	17 969 719 237 (73·5%)	87 689 (38 663–263 304)	314 183 (885 349)
Phase 1–4 trials	2427 (3·7%)	1 802 086 858 (7·4%)	301 250 (59 658–729 375)	749 932 (1 574 177)
Public health research	4809 (7·2%)	2 286 966 656 (9·4%)	99 391 (38 459–421 080)	485 555 (1 338 086)
Cross-disciplinary research	1336 (2·0%)	1 225 644 480 (5·0%)	329 417 (81 535–855 760)	918 774 (2 947 519)
Site of cancer				
Bladder	731 (1·1%)	208 101 857 (0·9%)	56 638 (35 000–164 320)	271 609 (728 409)
Bone	699 (1·1%)	213 449 408 (0·9%)	81 409 (36 854–201 320)	296 892 (1 036 170)
Brain	3575 (5·4%)	1 341 358 513 (5·5%)	105 237 (39 872–373 282)	357 082 (714 391)
Breast	7146 (10·8%)	2 732 461 588 (11·2%)	95 469 (39 243–402 315)	364 694 (789 856)
Cancer (general)	17 581 (26·5%)	7 127 890 199 (29·2%)	102 010 (39 872–338 904)	411 469 (1 446 547)
Cervical	778 (1·2%)	221 377 352 (0·9%)	60 227 (35 231–194 288)	278 197 (691 238)
Cholangiocarcinoma	211 (0·3%)	28 975 497 (0·1%)	42 444 (37 504–90 315)	139 305 (426 158)
Colorectal	3971 (6·0%)	1 250 675 380 (5·1%)	82 789 (37 861–247 101)	280 365 (644 656)
Haematological	5281 (8·0%)	2 295 537 884 (9·4%)	121 061 (46 410–449 260)	412 226 (1 201 920)
Head and neck	2267 (3·4%)	488 894 517 (2·0%)	41 650 (36 640–117 416)	210 104 (563 056)
Liver	2842 (4·3%)	589 266 188 (2·4%)	77 000 (33 472–108 385)	200 731 (506 269)
Lung	4120 (6·2%)	1 284 540 483 (5·3%)	78 401 (36 640–177 909)	280 730 (678 243)
Mesothelioma	140 (0·2%)	46 630 600 (0·2%)	117 416 (41 080–392 842)	333 075 (690 148)
Multiple cancers	3972 (6·0%)	2 120 387 780 (8·7%)	120 942 (42 444–466 322)	543 410 (1 468 287)
Other	1189 (1·8%)	467 159 643 (1·9%)	38 663 (38 663–297 495)	313 621 (774 672)
Ovarian	1563 (2·4%)	525 279 183 (2·1%)	83 602 (38 054–348 040)	307 027 (625 598)
Pancreatic	2290 (3·4%)	834 323 932 (3·4%)	83 139 (38 907–229 194)	325 827 (812 544)
Prostate	2777 (4·2%)	1 257 476 285 (5·1%)	128 000 (40 375–477 266)	428 329 (7 935 660
Renal	684 (1·0%)	195 958 550 (0·8%)	77 000 (37 257–213 940)	253 977 (618 093)
Skin	1793 (2·7%)	766 667 040 (3·1%)	137 093 (41 621–449 568)	408 342 (782 547)
Testicular	49 (0·1%)	11 858 646 (<0·1%)	110 706 (40 304–298 292)	252 311 (34 3705)
Thyroid	382 (0·6%)	69 829 408 (0·3%)	43 968 (34 197–89 703)	175 405 (422 939)
Upper gastrointestinal	2347 (3·5%)	373 317 556 (1·5%)	44 893 (31 833–89 484)	342 619 (135 971)
Year of award				
2016	14 062 (21·2%)	6 589 817 367 (27·0%)	103 604 (42 746–394 126)	449 140 (1 087 850)
2017	13 164 (19·8%)	5 538 156 223 (22·6%)	98 374 (41 265–364 392)	397 383 (1 163 685)
2018	15 063 (22·7%)	5 433 819 553 (22·2%)	89 227 (38 054–329 499)	348 258 (873 193)
2019	13 324 (20·1%)	3 980 993 827 (16·3%)	85 799 (38 459–247 049)	283 548 (963 880)
2020	10 029 (15·1%)	2 908 630 946 (11·9%)	77 000 (38 663–250 439)	270 578 (1 145 327)
Funder country (UK data includes $1·2 billion Cancer Research UK funding)				
Australia	1073 (1·6%)	717 764 311 (2·9%)	439 547 (250 323–608 889)	674 590 (2 304 325)
Canada	4086 (6·2%)	686 040 249 (2·8%)	80 750 (23 409–152 344)	174 831 (447 828)
China	15 168 (22·8%)	1 077 214 855 (4·4%)	58 086 (30 768–87 689)	71 018 (121 584)
European Commission	835 (1·3%)	1 323 023 904 (5·4%)	239 093 (185 072–2 361 314)	1 590 173 (2 338 774)
Germany	1209 (1·8%)	209 654 656 (0·9%)	115 401 (103 275–157 527)	178 733 (377 847)
Japan	12 493 (18·8%)	1 006 071 774 (4·1%)	39 872 (37 728–43 968)	81 331 (305 378)
UK	2511 (3·8%)	2 393 188 623 (9·8%)	203 445 (134 194–419 157)	494 032 (1 654 973)
USA	16 503 (24·9%)	14 016 920 819 (57·3%)	432 619 (189 338–1 004 250)	849 355 (1 565 062)
Other	12 510 (18·8%)	3 021 538 399 (12·4%)	116 431 (42 834–317 132)	249 178 (583 226)

(Table 1 continues on next page)

individual specific cancer type, which was breast cancer. Thereafter, the highest-funded cancer types were haematological, brain, lung, prostate, colorectal, pancreatic, and skin. The remaining cancer types received less than 3% of the total funding awarded, with about $2·1 billion (8·7%) invested in research focused on multiple cancer types (table 1).

Analysis of research investment by cross-cutting theme (total investment about $23·3 billion, excluding Cancer Research UK funding for which granularity for

	Number of awards (n=66 388)	Funding ($US 24 451 417 116)	Median funding ($)	Mean funding ($)
(Continued from previous page)				
Selected funders				
Canadian Institute for Health Research	1922 (2·9%)	338 540 298 (1·4%)	75 480 (14 131–215 919)	176 139 (313 404)
European Commission	1028 (1·5%)	1 599 115 016 (6·5%)	238 866 (185 072–2 331 612)	1 555 559 (2 251 361)
German Research Foundation	1006 (1·5%)	699 649 448 (2·9%)	114 832 (110 706–117 527)	114 362 (2578)
Japan Society for Promotion of Science	11 560 (17·4%)	584 600 670 (2·4%)	39 661 (37 455–41 621)	54992 (91 266)
National Health and Medical Research Council, Australia	683 (1·0%)	447 919 056 (1·8%)	499 621 (333 939–650 885)	655811 (1 288 754)
National Natural Science Foundation, China	14 756 (22·2%)	1 023 455 142 (4·2%)	53 377 (30 768–87 305)	69358 (121 731)
UK Medical Research Council	478 (0·7%)	268 597 528 (1·1%)	266 280 (146 435–672 867)	561919 (724 254)
US National Institutes of Health	11 034 (16·6%)	11 071 022 703 (45·3%)	497 006 (240 683–1 302 454)	1003355 (1 754 031)
Wellcome Trust	196 (0·3%)	146 859 523 (0·6%)	279 662 (125 881–764 588)	749283 (1 633 634)
Cancer Research UK	Not known	1 167 000 000 (4·8%)	Not known	Not known
Metastatic disease (does not include Cancer Research UK funding)				
Yes	7768 (11·7%)	2 283 495 507/23 284 417 116 (9·8%)	81 635 (37 455–230 243)	293 961 (712 502)
No	57 874 (87·2%)	21 000 921 609/23 284 417 116 (90·2%)	92 304 (39 082–325 031)	362 873 (1 082 329)
Age group (does not include Cancer Research UK funding)				
Paediatric	2154 (3·2%)	908 348 665/23 284 417 116 (3·9%)	129 948 (48 450–363 713)	421 703 (1 103 762)
Adult	5617 (8·5%)	3 086 156 735/23 284 417 116 (13·3%)	153270 (40 432–520 837)	549 431 (1 148 270)
Older than 65 years	224 (0·3%)	82 976 465/23 284 417 116 (0·4%)	119 163 (39 872–461 832)	370 430 (921 466)
All ages	4918 (7·4%)	2 396 109 564/23 284 417 116 (10·3%)	95 634 (39 661–426 128)	487 212 (1 792 448)
Not applicable	52 729 (79·4%)	16 810 825 687/23 284 417 116 (72·2%)	87 375 (38 460–264 778)	318 815 (927 690)
Cross-cutting theme (does not include Cancer Research UK funding)				
Biomarkers	3073 (4·6%)	1 070 320 671/23 284 417 116 (4·6%)	91 445 (38 663–319 540)	348 298 (1 058 955)
Cancer biology	30 001 (45·2%)	9 599 563 884/23 284 417 116 (41·2%)	85 799 (38 460–244 929)	319 974 (1 086 756)
Diagnosis, screening, and monitoring	6540 (9·9%)	2 981 241 799/23 284 417 116 (12·8%)	107 326 (40 375–412 059)	455 847 (1 078 507)
Drug treatment	13 367 (20·1%)	4 566 202 096/23 284 417 116 (19·6%)	89 484 (38 459–301 980)	341 602 (1 064 964)
Global health	165 (0·2%)	105 765 442/23 284 417 116 (0·5%)	329 634 (80 528–842 514)	641 002 (862 323)
Immuno-oncology	6669 (10·0%)	2 805 923 089/23 284 417 116 (12·1%)	114 832 (40 432–434 214)	420 741 (956 277)
Psychosocial and survivorship	2738 (4·1%)	1 166 131 716/23 284 417 116 (5·0%)	97 473 (37 455–416 207)	425 906 (905 026)
Radiotherapy	2192 (3·3%)	653 377 456/23 284 417 116 (2·8%)	80 188 (37 440–230 512)	298 073 (727 230)
Surgery	897 (1·4%)	335 891 763/23 284 417 116 (1·4%)	117 416 (39 661–449 568)	374 461 (615 465)
Male or female health (does not include Cancer Research UK funding)				
Female (breast, ovarian, cervical)	9366 (14·1%)	3 260 118 123/23 284 417 116 (14·0%)	90 852 (38 460–383 705)	348 080 (757 808)
Male (prostate, testicular)	2796 (4·2%)	1 189 334 931/23 284 417 116 (5·1%)	127 752 (40 375–476 503)	425 370 (788 425)

Data are n (%), n/N (%), median IQR, or mean (SD). Median of total funding was $90 576 (IQR 38 663–316 416) and mean was $354 718 (SD 1 045 644).

Table 1: Allocation of $24·5 billion of global cancer research investment

this parameter was unavailable) revealed about $9·6 billion (41·2% of total investment) for cancer biology research, and about $4·6 billion (19·6%) for studies on drug treatment (table 1). Data available for Cancer Research UK funding are summarised in the appendix (pp 4–5). Diagnosis, screening, and monitoring research received about $3·0 billion (12·8%), which included a wide range of studies for early detection, diagnosis, and follow-up of cancer. Immuno-oncology accounted for about $2·8 billion (12·1%) of research investment, with about $1·2 billion (5·0%) for survivorship and psychosocial research. Radiotherapy (about $0·7 billion, 2·8%) and surgery (about $0·3 billion, 1·4%) accounted for small proportions of the total research investment. Global health studies in oncology received about $0·1 billion (0·5% of all global cancer research funding). Excluding Cancer Research UK data, there were 7768 (11·7%) awards relating to research on metastatic disease, totalling about $2·3 billion (9·8% of total research funding).

By year of funding, we found an annual reduction in global oncology research funding, with about $6·6 billion awarded in 2016 (27% of total research funding over this time period), falling year-on-year to $2·9 billion (11·9%) in 2020 (the onset of the COVID-19 pandemic; table 1; figure, A). Although overall investment fell during this period, the proportion of funding on each phase of research remained relatively consistent across all 5 years (figure, B).

By country, the USA provided $14.0 billion (57·3% of the total cancer research funding). The biggest individual funder was the US National Institutes of Health. The next largest funder countries were the UK and the European Commission. Although China contributed 15 168 awards (22·8%) and Japan 12 493 (18·8%), median award size for both countries was smaller than US or UK awards (China, $58 086 [IQR 30 768–87 689] *vs* Japan, $39 872 [37 728–43 968]) and thus their contributions to the global funding total were similar: 4·4% for China and 4·1% for Japan (table 1). The full list of funders by country is presented in the appendix (pp 7–15).

We ranked investment levels by global burden of disease for 18 individual cancer sites, according to DALYs, YLD, and mortality (table 2). By all burden metrics, brain cancer ranked highest (ie, 1) across DALY, YLD, and mortality when compared with research investment. Lung cancer was overall least well-funded for research compared with burden of disease, ranking lowest overall, lowest in DALYs and mortality, and 14th (out of 18) for YLD. Thyroid cancer ranked second-lowest overall, and the lowest for investment according to YLD.

When ranked according to investment per DALY, brain cancer received the largest amount ($134·48 per DALY), followed by breast cancer ($122·40 per DALY; table 2). The lowest ranked cancers (funding per DALY) were cholangiocarcinoma ($9·57) and lung cancer ($5·89). When ranked by investment per mortality burden, brain and breast cancer ranked highest (brain, $4729·36; breast, $3603·21), with haematological cancer ($170·70) and lung cancer ($133·25) the lowest. By investment per YLD, brain and liver cancer ranked highest (brain, $8999·98; liver, $2088·61), and testicular ($168·91) and thyroid ($109·39) cancers ranked lowest.

Discussion

To our knowledge, this study represents the first comprehensive global analysis of cancer research funding, covering about $24·5 billion of global investment, from 66 388 public and philanthropic awards. This research provides a detailed summary of research funding before and during the first year of the COVID-19 pandemic.

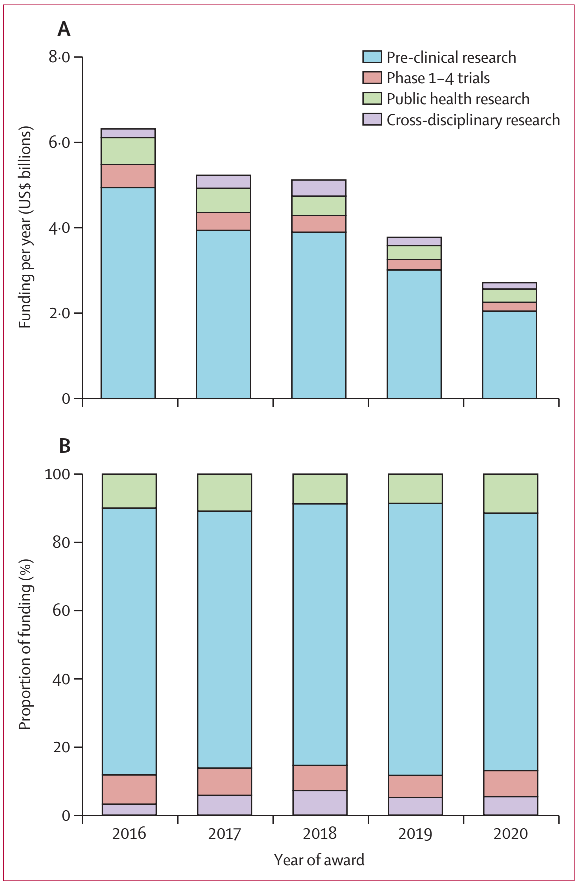

Figure: **Funding per year by type of science (A) and proportion of funding per year by type of science (B)**

A decline in cancer research investment was observed over the 2016–20 time period, most strikingly in 2020, with a 45% decrease from 2019. Whether this sharp decline reflects reallocation of research funding to the pandemic, a decrease in available funding (eg, due to fewer charitable donations), or is an augmentation of an underlying trend remains unclear. The longer-term impact of this decline remains to be seen. A bibliometric analysis of cancer research output in 2020 suggested that no decline was seen, although a shift in research emphasis to reflect the impact of COVID-19 on patients with cancer was noted.[9] Given the time lag from funding to publication, it is too early to take into account the effect of this drop in funding on outputs, particularly considering that publication metrics do not necessarily correlate with the amount of funding.[10]

Almost three quarters of funding awards were for pre-clinical research, not directly involving patients, and 29·2% of investment was into general cancer research (focused on understanding tumour biology). Although pre-clinical research will have inherent value in improving our knowledge and understanding of cancer, there might be lengthy delays translating this to patient benefit, with time lags up to 17 years cited.[11] For

	Investment per burden metric ($US)			Ranking			
	Funding per DALY	Funding per mortality	Funding per YLD	DALY ranking	Mortality ranking	YLD ranking	Combined ranking score
Bladder	43·97	844·44	710·89	5	7	11	23
Brain	134·48	4729·36	8999·98	1	1	1	3
Breast	122·40	3603·21	1822·48	2	2	3	7
Cervical	35·93	1147·14	1329·27	6	4	6	16
Cholangiocarcinoma	9·57	208·25	715·57	17	16	10	43
Colorectal	49·16	1099·48	1120·60	4	5	7	16
Haematological	61·84	170·70	1569·72	3	17	4	24
Head and neck	31·38	299·59	1109·98	8	13	8	29
Liver	21·21	1093·84	2088·61	10	6	2	18
Lung	5·89	133·25	500·67	18	18	13	49
Ovarian	20·12	545·90	700·64	11	9	12	32
Pancreatic	14·53	317·70	1559·01	13	11	5	29
Prostate	30·40	541·79	294·19	9	10	16	35
Renal	12·81	314·35	346·17	14	12	15	41
Skin	35·45	208·39	398·95	7	15	14	36
Testicular	15·81	826·11	168·91	12	8	17	37
Thyroid	9·98	271·18	109·39	16	14	18	48
Upper gastrointestinal	11·08	3149·17	752·79	15	3	9	27

DALY=disability-adjusted life-years. YLD=years lived with disability.

Table 2: **Investment for selected cancer types compared with burden of disease, using 2019 DALYs, mortality, and YLD**

new agents, the failure rate for product development along the research pipeline is high, particularly in oncology drug development.[12] Given these findings, the direct benefit to patient care from most of the research and development portfolio described here is likely to be low, and only apparent after a substantial time lag.

It has been suggested by researchers that prevention and early detection are key to cancer control globally.[13] However, despite this, our analysis reveals that only a relatively small proportion of research investment is directed at cancer detection and diagnosis. Although these are undoubtedly challenging topics, there has been increasing interest in supporting research in these areas and dedicated funding streams ringfenced for these could allow for increased investment in such research.

The principal treatments for most solid tumours are surgery and radiotherapy. It was estimated in 2015 that more than 80% of new cancer cases worldwide require surgery, and up to 50% require radiotherapy.[14,15] Despite this, our analysis shows that only 1·4% of research investment was for surgical research, and 2·8% for radiotherapy research. This lack of investment is underlined by a bibliometric analysis confirming that surgical oncology research consistently lagged behind other treatment modalities, and further data confirms relative underinvestment in radiotherapy clinical trials.[5,16] By contrast, almost 20% of investment was for drug treatment research, the majority pre-clinical. Although immuno-oncology is a rapidly growing field, the amount of funding (12·1% of total) is perhaps disproportionate.

A narrow focus on pre-clinical and medicinal research means that there is a need to broaden the scope of global cancer research spending to include modalities underserved by current funding strategies. There is also a disconnect between the level of research investment in drugs and the degree of access to such treatments in large parts of the world—whether due to lack of infrastructure, availability of treatments, or ability to pay. There might thus be greater patient benefit to be derived from the redistribution of funding to research at a later stage in the clinical pathway, from diagnosis to treatment and survivorship. Furthermore, these findings underscore the need to prioritise surgical oncology and radiotherapy research; for example, with increased investment in radiobiological research to support the development of radiotherapy clinical studies. Additionally, consideration of alternative and innovative approaches, aside from randomised trials, to answering clinical questions might be of value in the future, such as supporting large-scale collection of real-world data or using single-arm prospective cohort studies.

Our findings demonstrate that research spending on specific tumour types is not reflective of disease prevalence globally. Breast cancer accounts for the highest proportion of new cancer cases globally (11·7% of cases and 6·9% of deaths),[1] and research investment appeared proportionate to the disease burden (11·2%). However, lung cancer, with 11·4% of cases and 18% of deaths globally, received only 5·3% of the investment. Conversely, although relatively uncommon, brain cancers received the highest investment per burden metric. This might reflect that brain cancers are perceived as an area of unmet need due to poor prognosis. However, the high investment per burden metric might also be reflective of poor outcomes and short median survival, although this finding is not replicated in other poor prognosis cancers, implying that other factors might influence investment levels. By contrast, in breast cancer, for which median survival is longer than both lung and brain cancer, the high investment per burden metric might reflect higher research investment. Additionally, less than 10% of all research funding was for metastatic disease research. Although data are hard to obtain, it is likely that there are increasing numbers of patients living with metastatic disease, and in low-income and middle-income countries (LMICs), late clinical presentation means that many patients have metastatic disease at diagnosis. The investment in metastatic disease research thus appears disproportionately low. However, overall investment might be higher than noted here, as commercially funded studies will often take place in the setting of advanced disease, but such studies will not have been identified in this analysis.

When considering geographical distribution of funding, there are clear differences in patterns of funding and award size between countries. For example, the Japan Society for the Promotion of Science provides numerous awards, but these are typically ten times smaller than those from the US National Institutes for Health. This is a comparable finding to one from our previous infectious diseases analysis, which found that Japan provided the fourth highest number of awards but only 0·6% of total funding.[6]

An increasing proportion of cancer burden is falling on LMICs. By 2030, it has been estimated that approximately 75% of all deaths from cancer will occur in these settings.[17] However, cancer research is heavily weighted toward high-income countries, with only 0·5% of investment allocated to research addressing cancer in LMICs in this analysis. We also noted a relatively low investment in certain cancers with a higher prevalence in low-income and middle-income settings, such as oral cancers, cholangiocarcinoma, liver cancer, and upper gastrointestinal cancers. Furthermore, the majority of cancer biology research funding is awarded to institutions in high-income countries, and it has been shown that there might be differences in biological and molecular characteristics of cancer between regions, meaning that findings from high-income countries might not be globally generalisable.[18] Although publication outputs might be increasing in lower-income settings, this is not matched by the amount of funding received by different settings. Thus, creation of original research and accompanying research skills will continue to be lacking, despite increasing oncology burdens across LMICs.[19] There are a relatively small number of research centres receiving substantial international infrastructure funding located in, and directed by, lower-income settings. Establishing long-term infrastructure, combined with LMIC priority-setting exercises and funding streams, can perhaps begin to improve the equity of global research leadership. Our analysis underscores a need to set priorities and direct investment to cancer research in LMICs to support research relevant to these settings, build research capacity in these countries, and to impact cancer control globally.[20] These clear global inequities must be addressed by international stakeholders.

There are several limitations to this study. Firstly, it includes only public and philanthropic awards, and does not include commercial research funding, which inevitably will constitute a substantial proportion of the total investment. Data regarding such commercial funding are not disaggregated nor publicly available. In oncology, a drug development research analysis suggested that more than 50% of drug trials were industry sponsored, with trial numbers reflecting the incidence of cancers in high-income countries.[21] Furthermore, there is ongoing commercially funded research in other areas of oncology, including radiotherapy, diagnostics, and surgery, which was not captured in our analysis. Thus, while our inability to include commercial investment is likely to lead to an underestimate of the investment in clinical trials, metastatic disease, and pharmaceutical research, we believe that it is unlikely to substantially change our findings in terms of distribution of investment either in terms of cancer sites or globally. The true proportion of spend on cancer prevention and early detection, surgery, radiotherapy, and psychosocial aspects of cancer treatment is likely to be even lower than reported in this Article.

Some countries will be under-represented or not represented in this analysis—for example, Italy and South Korea—where there is likely to be some research funding available, but data are not easily accessible. Some European countries, such as Italy, might be heavily reliant on EU research funding, and therefore, although these countries produce relatively high research outputs, they are not shown in this analysis to have high levels of national funding for cancer research. WHO researchers collated the Health Research Funders database, which ranks organisations for their research and development spend. Our analysis includes data from 12 of the top 15 ranked funders. Outside the pharmaceutical sector, the overall total of other missing funding streams is unlikely to be large enough to change our findings substantially.

For more on the **Health Research Funders** see https://www.healthresearchfunders.org/health-research-funding-organizations/

There are missing data, notably from Cancer Research UK, an organisation that does not release data at the individual award level. Although some data are available from annual reports, there is insufficient granularity. Although this information allows categorisation of overall funding by cancer type, it is not possible to categorise Cancer Research UK awards by cross-cutting theme nor phase of research. For this reason, $1·2 billion of investment is not included in these components of the analysis. However, this funding will be largely invested in high-income countries (primarily the UK), and our subjective estimates suggest the vast majority ($0·97 billion) is likely to be awarded to pre-clinical research, in keeping with our findings. Most public and charitable funders do publish individual award data, and it has previously been suggested that the continued absence of detailed information from Cancer Research UK hinders effective priority-setting, and reduces the ability to minimise unnecessary duplication of research.[22]

Our analyses use data from the GBD study, which are modelled estimates and have been subject to criticism.[23] Additionally, the measurements alongside global burden of disease were restricted to areas where burden data could be easily matched up to our defined cancer sites, which did not include, for example, oesophageal cancer (included in the upper gastrointestinal cancer group).

The inclusion, exclusion, and classification of awards was carried out across our team of co-authors, but is subjective. All were provided with training and definitions for the categories used to minimise variation. About 10% of awards were cross-checked to validate the classification process (93·4% agreement with original classifications).

In conclusion, we believe that the findings of this analysis should be used to inform key stakeholders (eg, WHO and its agency the International Agency for Cancer Research, as well as research funding bodies and national governments). These data can inform assessment of portfolios of research and development, and short-term and medium-term priority-setting activities. Review of research funding priorities must consider factors such as incidence, prognosis, and public perception of the need for funding of different disease types and stages, alongside investment analyses. Any funding redistribution will require joint research priority setting across multidisciplinary stakeholders, including patients, to ensure that research is addressing key issues of concern to the cancer community. There are finite resources available for research and development investment across cancer and health. We must invest wisely.

Contributors
SAMcI, RIC, and MGH conceived the study. MGH obtained the raw data; all authors had access to this during the data analysis. All authors contributed to data analysis and award classification and met regularly to review data, and discuss analysis. MGH carried out final collation of results. SAMcI wrote the first draft of the manuscript. RA, RIC, EC and MGH contributed to editing and revision. SAMcI and MGH accessed and verified the underlying data in the study. All authors have read and approved the final manuscript.

Declaration of interests
SAMcI reports honoraria from MSD, Roche, and Becton, Dickinson & Company; is on advisory boards for Roche, Lilly, and MSD; reports conference travel and support from Roche, Lilly, and MSD; and institutional research funding from Novartis. RIC reports institutional research funding from Astra Zeneca and SECA. EC reports institutional research funding from Astra Zeneca and SECA; and honoraria from Roche, Astra Zeneca, Lilly, Novartis, Pfizer, and Daiichi-Sankyo; and conference travel and support from Roche and Novartis. RA reports institutional research funding from Novo Nordisk, Novartis, Roche, and Union for International Cancer Control, and honoraria from Merck, Hoffman-La Roche, and Novartis. AM reports payments from the British Medical Association as a committee member. All other authors declare no competing interests.

Data sharing
The data source is Dimensions.ai, a privately owned database. They do not permit open sharing of the full dataset. A sample dataset (up to 100 awards) to allow inspection and validation of the data and methodology can be provided on reasonable request to the corresponding author.

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