



# Estimating the Global Demand and Delivery of Cancer Surgery

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## Abstract

**Background** Cancer is a leading cause of death and disability globally. While surgery remains a vital part of cancer management, access to surgical care remains inconsistent. Our objective was to estimate the global need for cancer-related surgery and to identify disparities in the surgeon workforce.

**Methods** The World Health Organization International Agency for Research on Cancer and the Global Cancer Observatory were queried for estimates on national incidences of 35 different malignancies. The proportion of patients requiring surgery for each of these cancers was extrapolated from the United States Surveillance, Epidemiology and End-Result database. The number of people requiring cancer surgery in each country was calculated and compared with the surgical workforce. Estimates were presented as choropleth maps. Associations were tested with country development indicators.

**Results** An estimated 9,464,214 (95% CI 4,364,196–14,564,230) patients required cancer-related surgical care in 2018. An overall 1.24 people needed cancer surgery per 1000 population. This was related to income status ( $p < 0.01$ ) and Human Development Index ( $r = 0.86$ ,  $p < 0.001$ ), with the largest need being in high-income countries. The number of people requiring cancer surgery per surgeon (CP–S ratio) ranged from 7.3 in the European region to 80 in the African regions. The CP–S ratio was 10 times higher for low- versus high-income countries ( $p < 0.001$ ) and was inversely related to healthcare expenditure ( $r = -0.59$ ,  $p < 0.001$ ).

**Conclusions** An estimated 9.5 million people required cancer surgery globally. Low- and middle-income countries experience a severe and acute shortage of surgeons to provide for the cancer surgery needs of the population.

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## Introduction

Cancer is the second leading cause of death worldwide, accounting for 9.6 million deaths in 2018 alone [1, 2]. Its incidence is on the rise and is estimated to increase from 12.7 million new cases in 2008 to 22.2 million new cases by 2030 [3]. While various treatment modalities exist, surgery remains an essential component of cancer therapy. While surgery can be used as a diagnostic, therapeutic, or palliative option, in many instances it is considered to be curative. It is estimated that between 62 and 80% of cancer patients require some form of surgical treatment [4, 5]. However, access to surgical care for cancer patients remains disparate among different countries around the globe [6]. Currently, the economic burden of surgical treatment for cancer is greatest in high-income countries (HICs) as compared to low- and middle-income countries (LMICs) [4]. However, as populations continue to age and health systems become more sophisticated enabling the detection of earlier stage cancers, the burden of surgical treatment in LMICs is expected to rise [4].

In order to make informed policy decisions and appropriate resources adequately, a better understanding of the global burden of cancer surgery is needed. In a recent analysis, Sullivan et al. estimated that in 2015, there were approximately 15.2 million new cancer cases, of which 80% required surgery. However, less than one-fourth of these patients receive safe and timely surgical care [5]. Improving access to safe, timely, and effective surgical care can save millions of lives each year. In order to accomplish this, research and advocacy toward strengthening healthcare systems and optimizing the global surgical workforce are imperative. The aim of this study was to estimate the global need for cancer-related surgery and to assess relative disparities in the surgeon workforce.

## Methods

We collected information on 194 countries using publicly available data sources. Data regarding each country's demographics, cancer incidence, economic status, and health profile were collected as outlined below. Population cancer incidence for the year 2018 was acquired from the World Health Organization (WHO) International Agency for Research factsheets on Cancer and Global Cancer Observatory [7]. We chose the 35 malignancies whose incidences are best reported among WHO records and for which the data were readily available. It is important to understand that cancer incidence estimates are dependent upon detection ability and the presence of national registries among other factors; therefore, these analyses likely underestimate the need for cancer surgery in LMICs.

WHO Cancer Country Profiles were used to obtain information about the presence of a national cancer policy or action plan, as well as the presence, coverage, and scope of any cancer registry [8]. Country population estimates for the year 2018 and economic data were used to classify countries by income status (high, upper middle, lower middle, low) [9]. Each country's health expenditure per capita was obtained from the World Bank [10]. The Human Development Index (HDI) and HDI classification were obtained from the United Nations Development Programme, Human Development Reports 2015 [11]. The number of surgeons in each country was obtained from a prior report by Holmer et al. [12] on the global surgical workforce. Data used for this manuscript are in aggregate, derived from publicly available sources with no identifiable information. The analysis was therefore exempt from ethical review.

To calculate the annual global number of patients requiring cancer-related surgery, we followed a three-step process. First, we obtained an estimate of the proportion of patients with a specific cancer that will require surgery. Then, we multiplied this proportion by the annual incidence of that particular cancer in each country to determine the number of people requiring cancer surgery per malignancy per country. We repeated this process for all 35 selected malignancies and summed the numbers to arrive at the estimated global annual number of people requiring cancer surgery.

To estimate the proportion of patients requiring surgery for a particular cancer diagnosis, we used data from the United States Surveillance, Epidemiology and End-Result program (SEER) [13]. This database includes epidemiological and survival data that is representative of all diagnosed cancer patients in the USA. Using data for the year 2013, the database was queried for the fraction of patients with a new diagnosis of one of the 35 malignancies that required surgery of any kind (diagnostic, therapeutic, palliative, or curative).

The WHO-estimated incidence of each malignancy in a given country was then multiplied by the SEER-derived proportion of corresponding cancer cases that required surgery to arrive at an estimate for the number of patients that required surgery for that malignancy in a particular country. These numbers were added for all 35 malignancies (eTable 1) to obtain the estimated need for cancer-related surgery in that country. For analytical and presentation purposes, this sum was then divided by the population and multiplied by 1000 to calculate a Cancer Surgery Index (CSI). The CSI represented the annual number of people requiring cancer surgery per 1000 population. The entire calculation was repeated for each country with available data. Worldwide CSIs were then depicted as a choropleth map using eSpatial software [14].

CSI was categorized by tertiles into three groups: high, medium, and low, and tested for associations with country-specific factors, including income status and development index using the Chi-square test. CSI was also represented as a continuous variable to test for association with per capita healthcare expenditures using scatter plots and the Spearman correlation coefficient. As both of these variables were skewed, each was log-transformed prior to inferential analysis.

To estimate the relative disparity in resources available to perform cancer surgery in each country, we determined the ratio between the number of people requiring cancer-related surgery and the number of available surgeons per 100,000 population. The ratio of number of people requiring cancer surgery per surgeon was depicted as a choropleth map. This ratio was labeled as the CP–S ratio (cancer patient-to-surgeon ratio). The CP–S ratio of each country was similarly grouped by tertile into high, medium, and low categories and tested for associations with the country's income status and development indicators. A high CP–S ratio indicates a high number of patients with requiring cancer-related surgery per surgeon, that is, a higher CP–S ratio in a country is indicative of decreased access to surgical care for cancer patients. CP–S ratio was also represented as a continuous variable to test for association with per capita healthcare expenditures and Human Development Index using scatter plots and the Spearman correlation coefficient.

All *p* values were two-sided. Analytic standard errors were calculated for estimates. Data were analyzed using STATA version 13 (StataCorp College Station, TX). Choropleth maps were made using eSpatial [14].

## Results

Incidence data from 19 countries were not available (Seychelles, Togo, Antigua and Barbuda, Dominica, Grenada, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Andorra, Monaco, San Marino, Cook Islands, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, Niue, Palau, Tonga, Tuvalu), and therefore, data from 175 countries were analyzed.

An estimated 9,464,213 (95% CI 4,364,196–14,564,230) people required at least one cancer-related operation in the year 2018. The highest need was for breast cancer ( $N = 1,846,824$ , 95% CI 983,434–2,710,213) followed by colon cancer ( $N = 888,011$ , 95% CI 356,622, 1,419,400). eTable 1 lists the total number of patients requiring at least one operation for all the 35 selected malignancies.

The CSI varied significantly by country (Fig. 1). The median CSI per country was 0.76 (interquartile range, IQR 0.39–2.22) and ranged from minimum of 0.12 in Gambia to

a maximum of 4.19 people per 1000 population in Hungary. By WHO geographic regions, the highest median CSI was for the European region (3.1 per 1000 population) (Table 1). The number of people requiring cancer surgery and the CSI for each country is presented in eTable 2. CSI varied almost linearly with country income status, the median CSI was 3.27 (2.37–3.51) per 1000 population for HICs, 1.12 (0.77–1.55) for upper-middle-income, 0.48 (0.37–0.68) for lower-middle-income, and 0.33 (0.28–0.39) for low-income countries (LICs) ( $p < 0.001$ ). CSI was significantly and positively related to the country's human development index ( $r = 0.86$ ,  $p < 0.001$ ) and per capita expenditure on healthcare ( $r = 0.78$ ,  $p < 0.001$ ).

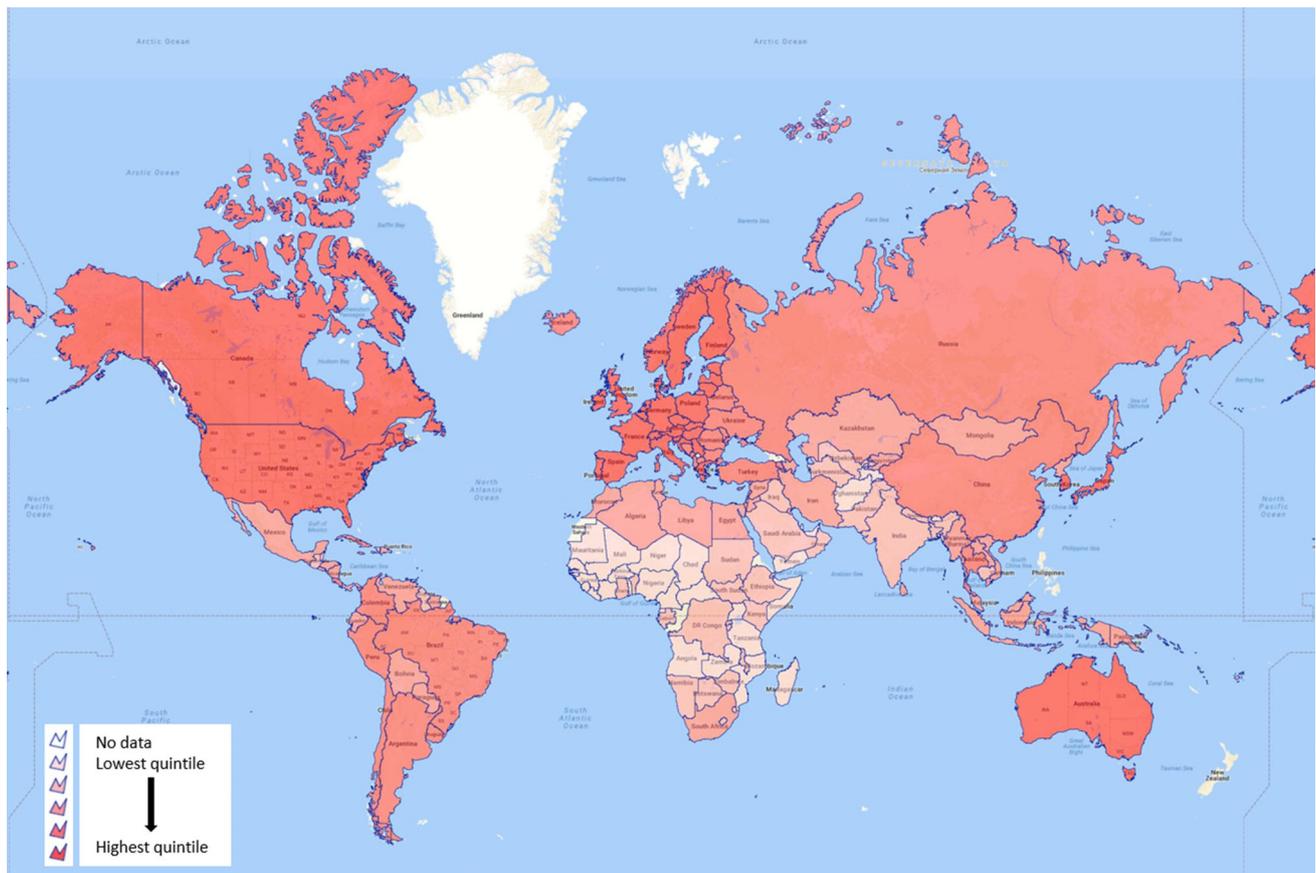
Information on the number of surgeons per population was available for 136 out of the 175 countries. The global median ratio of number of patients requiring cancer-related surgery to number of available surgeons (CP–S ratio) was estimated to be 16.62 (IQR 7.11–42.57). This CP–S ratio varied widely between countries (Fig. 2), with a minimum of 1.62 in Kyrgyzstan to a maximum of 351.0 in Somalia. For countries in the African region, annually, there were approximately 80 patients in need of cancer-related surgery per surgeon per year compared with an average of 7 in Europe and 9 in the Americas (Table 1). Each country's CP–S ratio can be found in eTable2.

The CP–S ratio was significantly and *inversely* associated with a country's income classification ( $p < 0.001$ ), Human Development Index ( $r = -0.59$ ,  $p < 0.001$ ), and per capita expenditure on health care ( $r = -0.60$ ,  $p < 0.001$ ) Table 2 and Fig. 3. A tenfold difference was observed in the median CP–S ratio between HICs (median 9.3, IQR 5.6–15.3) and LICs (median 94.1, IQR 50.5–152.8).

## Discussion

Our results indicate that an estimated 9.5 million patients required at least one cancer operation in the year 2018 alone. Of the estimated need for cancer-related surgery, about 80% of operations occurred in high- and upper-middle-income countries where cancer incidence is reported to be higher. While LMICs had a lower burden of cancer-related surgery, they also had relatively fewer resources to address this need. The number of patients requiring cancer-related surgery per available surgeon was 10 times higher in LICs compared to HICs. Our results indicate a severe shortage of surgeons to address the cancer-related surgical needs in countries with lower-income status, lower development index, and lower per capita healthcare expenditure.

While our analysis provides reasonable estimates based upon available data, it is very likely that the burden of



**Fig. 1** Cancer Surgery Index (number of people requiring cancer surgery per 1000 population) by country (in quintiles)

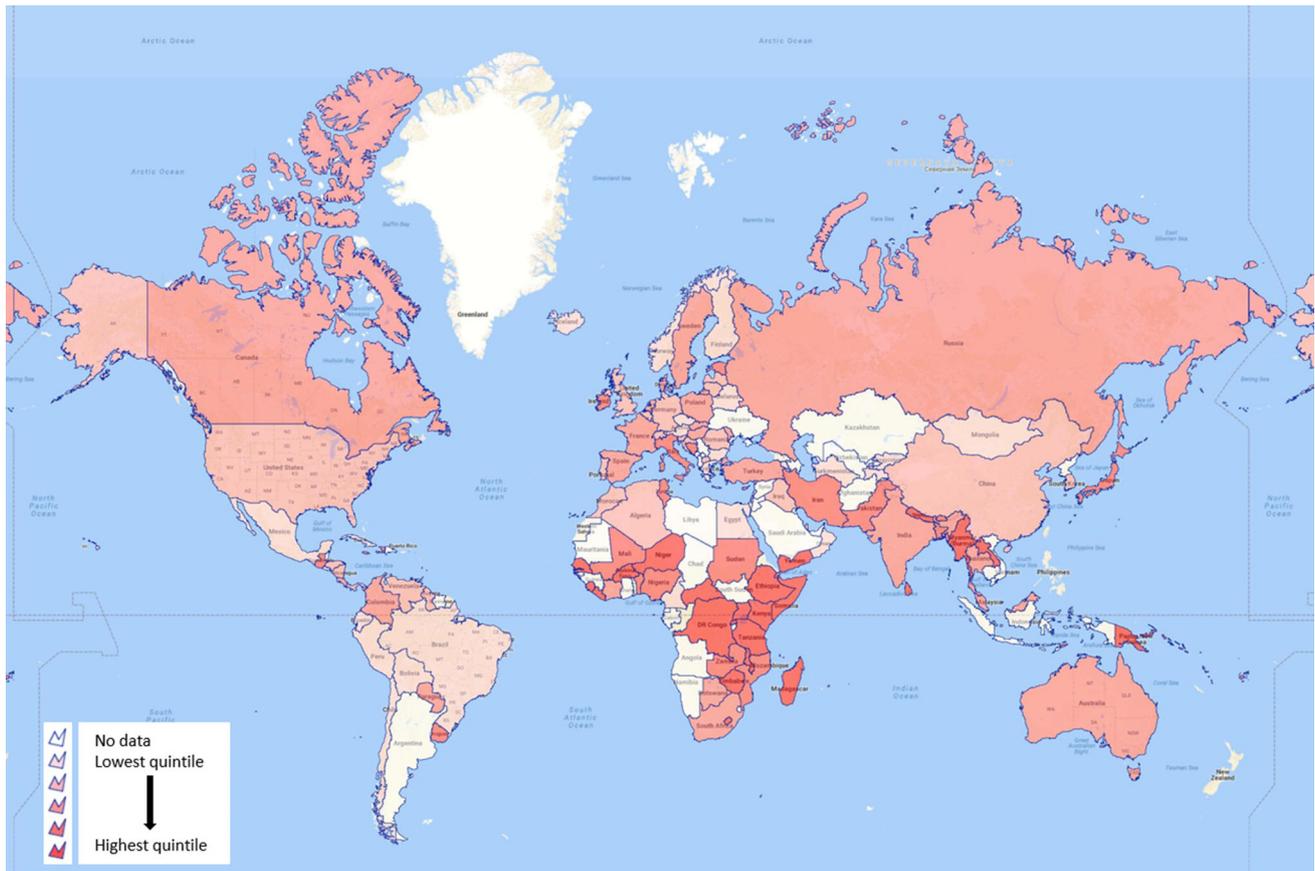
**Table 1** Variation in the need for cancer surgery and available resources by WHO regions

WHO region	Number of countries	Total population (billions)	CSI median (IQR)	CP-S ratio median (IQR)
African	45	1.07	0.34 (0.29–0.39)	80.00 (28.6–129.5)
Americas	30	1.01	1.08 (0.85–1.44)	9.05 (4.23–17.06)
South-East Asian	11	1.99	0.49 (0.42–0.71)	40.94 (24.85–66.12)
European	50	0.92	3.09 (2.12–3.51)	7.32 (4.82–13.3)
Eastern Mediterranean	21	0.69	0.47 (0.35–0.67)	15.75 (3.06–40.14)
Western Pacific	18	1.91	0.91 (0.67–2.50)	22.27 (11.72–53.10)
All	175	7.59	0.76 (0.39–2.22)	16.62 (7.11–42.57)

CSI Cancer Surgery Index—number of patients in need of cancer surgery per 1000 population, CP-S cancer patient-to-surgeon ratio—number of patients in need of cancer surgery per surgeon, IQR interquartile range

cancer surgery is severely underestimated in LMICs. The reported incidence of cancer is depended upon the presence of population-level cancer registries, which in turn are related to a country's development indicator [15]. As LMICs evolve their healthcare infrastructure, improvements in access to healthcare, diagnostic technology, and surveillance programs will inevitably unmask a higher incidence of cancer and corresponding need for cancer-

related surgery. Sullivan et al. [5] with the Lancet oncology commission published a seminal paper on global cancer surgery. The authors estimated a 59% increase in the need for cancer surgery between 2015 and 2030 in low human development category countries. They further estimated that in the year 2030, 17.3 million cancer patients will need surgery, of which 10 million will be in LMICs.



**Fig. 2** Number of people in need of cancer surgery per surgeon in each country (in quintiles)

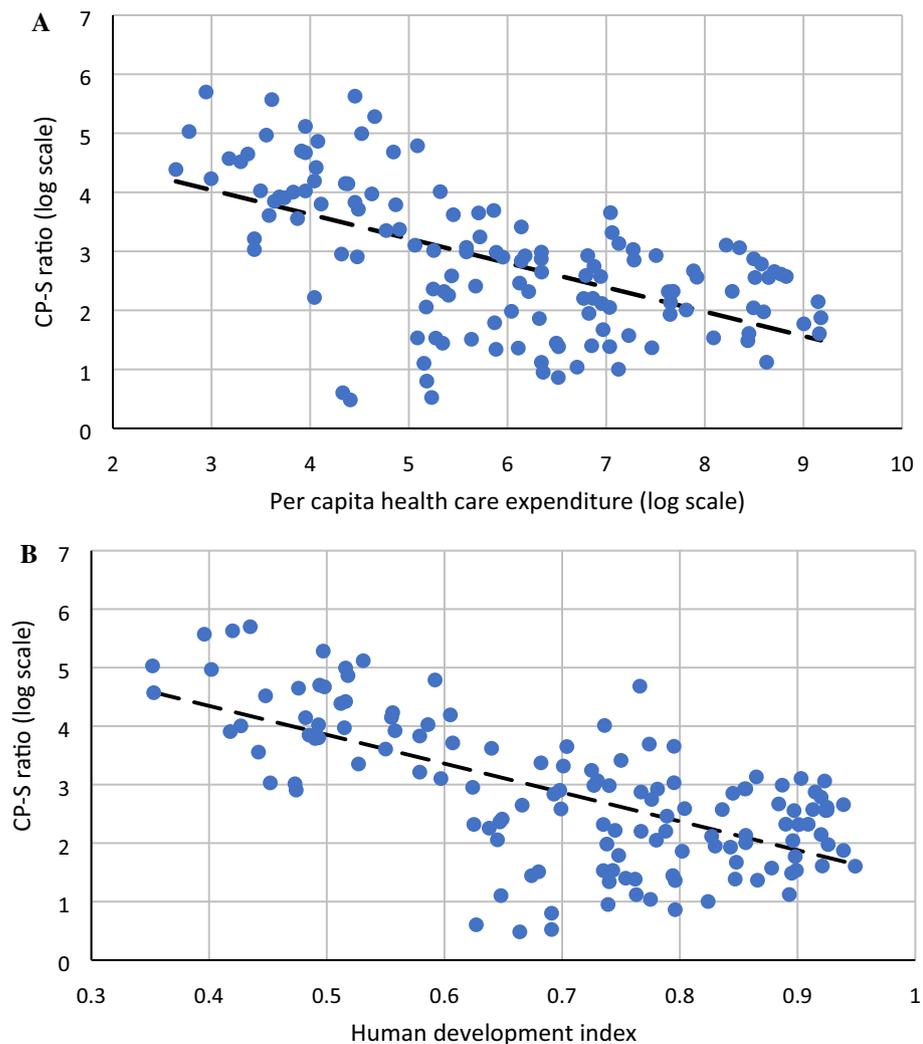
**Table 2** Bivariable analysis of factors associated with the CP–S ratio (number of people that require cancer surgery per surgeon)

Variable	Categories	CP–S tertile, number of countries (%)			p value
		Low	Medium	High <sup>a</sup>	
Region	Africa	2 (6.5)	5 (16.1)	24 (77.4)	<0.001
	Americas	13 (52.0)	9 (36.0)	3 (12.0)	
	South-East Asia	0 (0)	3 (33.3)	6 (66.7)	
	Europe	24 (57.1)	17 (40.5)	1 (2.4)	
	Eastern Mediterranean	5 (35.7)	4 (28.6)	5 (35.7)	
	Western Pacific	2 (13.3)	7 (46.7)	6 (40.0)	
	South America	0 (0)	0 (0)	0 (0)	
HDI class	Very high	21 (48.8)	22 (51.2)	0	<0.001
	High	17 (50.0)	10 (29.4)	7 (20.6)	
	Medium	8 (26.7)	11 (36.7)	11 (36.7)	
	Low	0 (0)	2 (7.1)	26 (92.9)	
Income classification	High	22 (50.0)	21 (47.7)	1 (2.3)	<0.001
	Upper middle	15 (45.5)	14 (42.4)	4 (12.1)	
	Lower middle	9 (24.3)	9 (24.3)	19 (51.4)	
	Low	0 (0)	1 (4.5)	21 (94.5)	
Per capita expenditure on health care (Spearman correlation coefficient = −20.58)				<0.001	
HDI (continuous variable) (Spearman correlation coefficient = −0.60)				<0.001	

CP–S cancer patient-to-surgeon ratio, is categorized into low, medium, and high groups by tertiles, HDI Human Development Index

<sup>a</sup>A high CP–S ratio corresponds to high burden of cancer surgery relative to resource availability

**Fig. 3** Scatter plot depicting the relationship of the CP–S ratio with per capita expenditure on health (a) and Human Development Index (b)



Unfortunately, surgical care has not been prioritized in most LMICs and less than 5% of the population have access to timely surgical care [16]. We found a similar resource disparity based on country income status. While HICs had a higher burden of cancer surgery, they also had a higher number of surgeons to address this need. LMICs suffer a dearth of surgical workforce [12], and therefore, access to cancer surgery is also limited. For example, in Somalia the CP–S ratio was calculated to be 350. This means that every surgeon in Somalia needs to perform one cancer operation almost every day of the year to meet the annual cancer surgery need of the country. This is an insurmountable burden with the given resources. Our results help to identify the countries that are least able to provide access to cancer surgery. These data can be used to focus resources and training programs to these with the greatest need.

The inability to provide appropriate cancer care bears immense and severe economic consequences [5, 17]. Countries are expected to lose to between 0.5 and 1% of their annual GDP by 2030 from surgical cancers [5]. Investing in improving infrastructure and medical training, such that patients diagnosed with cancer receive safe, affordable, and timely surgical care, is a highly cost-effective strategy [18]. Our study also highlights the importance of the availability of basic cancer registry data. In order to ensure adequate resource allocation for the care of cancer patients worldwide, policy makers rely on accurate estimates of cancer incidence. The WHO recently called for the development of population-based cancer registries, upon which effective cancer control policies can be made [19, 20]. Cancer registries are not always costly to maintain and have been accomplished by some LICs [20–22]. However, cost alone is not sufficient. LMICs suffer a

dearth of several kinds of skilled personnel, and the ability to access pathology services, for example, is also severely limited [23]. As a result, many tumors being treated with palliative approaches never make it to hospital-/pathology-based cancer registries.

To improve access to cancer surgery in LMICs, a multipronged approach is required. The essential first step is to understand the true burden of the problem with increased efforts toward primary data collection and reporting of cancer epidemiology. Simultaneously addressing the workforce shortage through education, training, partnerships, telementoring, and task-shifting programs would provide beneficial. Additionally, efforts in advocacy and public policy are essential for scaling up efforts and making governments realize the importance of investing in national cancer control programs.

There are a few limitations to our analysis. First, as mentioned earlier, our methodology depends upon national reports of cancer incidence. In LMICs, these incidences are likely underestimated and the true burden of cancer-related surgery is much higher than reported. Second, we used the number of available surgeons as a surrogate for required resources. The actual number of surgeons capable of performing the needed cancer surgeries would be a smaller subset of all available surgeons, as about half of cancer-related surgeries require a site-specific specialist [5]. However, even though the actual numeric value of the ratio of patients to surgeons holds less meaning, the difference in ratios provides important insights into the relative resources available between countries. Additionally, we used data from the SEER database of the United States to estimate the proportion of people with a new cancer diagnosis that required cancer-related surgery. Clinical practices vary between countries, and this proportion may differ depending on which HICs data are used. However, it is unlikely that this difference would impact the conclusions of our study.

## Conclusions

At least 9.5 million people around the world are estimated to require cancer-related surgery annually. Global variation exists in the need for cancer-related surgery and is associated with a country's income status, healthcare expenditure, and availability of cancer data. We highlight a significant relative resource deficit in LMICs compared to HICs. While LMICs have a lower burden of cancer-related surgery, they suffer from having an even lower surgical workforce to address these needs. There is an urgent and dire need for systematic improvements in low- and middle-income countries to allow for adequate and timely access to cancer surgery.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflicts of interest.

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