World J Surg (2015) 39:2126–2131
DOI 10.1007/s00268-015-3092-7

ORIGINAL SCIENTIFIC REPORT

Proposed Minimum Rates of Surgery to Support Desirable Health Outcomes: An Observational Study Based on Three Strategies

Micaela M. Esquivel[1] · George Molina[2,3] · Tarsicio Uribe-Leitz[1] · Stuart R. Lipsitz[2,4] · John Rose[5,6] · Stephen Bickler[5] · Atul A. Gawande[2] · Alex B. Haynes[2,3] · Thomas G. Weiser[1]

Published online: 13 May 2015
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Abstract

Background The global volume of surgery is estimated at 312.9 million operations annually, but rates of surgery vary dramatically. Identifying surgical rates associated with improved health outcomes would be useful for benchmarking and targeted health system strengthening.

Methods We identified rates of surgery associated with a life expectancy (LE) of 74–75 years, a maternal mortality ratio (MMR) of less than or equal to 100 per 100,000 live births, and the estimated need for surgery in the seven global burden of disease (GBD) super-regions based on the prevalence of surgical conditions. We compared our findings to surgical rates from Chile, China, Costa Rica, and Cuba ("4C"), countries with moderate resources but high health outcomes.

Results The median surgical rates associated with LE of 74–75 years ($N = 17$) and MMR below 100 ($N = 109$) are 4392 (IQR 2897–4873) and 5028 (IQR 4139–6778) operations per 100,000 people annually, respectively. The mean surgical rate estimated for the seven super-regions was 4723 (95 % CI 3967–5478) operations per 100,000 people annually. The "4C" countries had a mean surgical rate of 4344 (95 % CI 2620–6068) operations per 100,000 people annually. Thirteen of the twenty-one GBD regions, accounting for 78 % of the world's population, do not achieve rates of surgery at the lowest end of this range.

Conclusions We identified a narrow range of surgical rates associated with important health indicators. This target range can be used for benchmarking of surgical services, and as part of a policy aimed at strengthening health care systems and surgical capacity.

✉ Micaela M. Esquivel
mesquive@stanford.edu

1 Department of Surgery, Stanford University Medical Center, 300 Pasteur Drive, S067, H-3691, Stanford, CA 94305, USA

2 Ariadne Labs, Brigham and Women's Hospital and Harvard TH Chan School of Public Health, 401 Park Drive, Third Floor East, Boston, MA 02215, USA

3 Department of Surgery, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114, USA

4 Department of Surgery, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA

5 Division of Pediatric Surgery, Rady Children's Hospital, University of California San Diego, 4305 University Avenue, San Diego, CA 92105, USA

6 Center for Surgery and Public Health, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115, USA

Fig. 1 Relationship between observed surgical rates in 2012 and corresponding life expectancy for 194 WHO member countries. Adjusted R-square 0.5148. Adapted from Weiser et al.

Introduction

Recognition of the integral role of surgery in health delivery on a global basis has grown [1, 2]. The Disease Control Priorities Project (DCPP), a World Bank-funded effort to evaluate health interventions for low- and middle-income countries, identified surgery as a cost-effective strategy to reduce disease burden [3] and continues to estimate the effectiveness and importance of surgical services. Concurrently, The Lancet has convened a Commission on Global Surgery working to improve surgical delivery worldwide [4].

The global volume of surgery is estimated at 312.9 (95 % CI 266.2–359.5) million operations in 2012, but rates of surgery vary dramatically by country and region [5]. Less than 7 % of the global volume of surgery was performed in very low health expenditure countries which account for 37 % of the world's population, while 60 % of the surgical volume took place in the high-expenditure countries which account for 18 % of the world's population. Surgical rates ranged from under 100 to over 20,000 operations per 100,000 people annually [5], indicating tremendous variability in the provision of surgical services.

Benchmarking levels of service provisions has provided important guidance for policymakers at national and international levels. For instance, in 1985 maternal health advocates proposed a minimum cesarean delivery rate of 10 % based on limited though convincing perinatal mortality data. This provided a target for health system development which has improved maternal and perinatal outcomes [6–9].

A general lack of understanding of the relationship between surgical care and population health outcomes has limited the ability to set similar benchmarks for surgical capacity beyond those that exist for cesarean delivery. In order to establish a benchmark for surgical service provision, we used available data to estimate minimum rates of surgery associated with a variety of important health indicators including life expectancy (LE) and maternal mortality ratio, and estimated minimum surgical needs based on disease burden. We evaluated the validity of these rates by comparing them to known surgical rates from Chile, China, Costa Rica, and Cuba ("4C"), countries with moderate resources but high health outcomes.

Materials and methods

We used three strategies to identify minimum rates of surgery that are associated with positive health indicators. We first estimated rates of surgery per country for 2012 associated with LE of 74–75 years, obtained from the World Health Organization and the World Bank [10, 11]. We used previously reported country level surgical rate data for 2012 [5]. The mean LE by World Bank income group (high-, upper-middle-, lower-middle-, and low-income) showed a mean LE of 79.3 years for high-income countries, 73.8 years for upper-middle-income countries, 68.2 years for lower-middle-income countries, and 61.1 years for low-income counties. We chose a LE of 74–75 years of age as an optimistic yet reasonable goal and calculated the median surgical rate of countries that had a LE within this range.

For our second strategy, we estimated rates of surgery associated with a maternal mortality ratio (MMR) of less than or equal to 100 deaths per 100,000 live births using 2013 MMR data from the World Bank, with MMR defined as the number of women who die from pregnancy related causes while pregnant or up to 42 days postpartum per 100,000 live births [10]. We chose this MMR as our threshold based on the United Nations Millennium Development Goals of reducing the MMR by three quarters between 1990 and 2015. The MMR in 1990 was 380, thus a reduction of three quarters is an MMR of 95 by 2015 [12]. Once again, we used the previously reported country level surgical rate data for 2012 [5], and obtained the median surgical rate of countries that had an MMR of less than or equal to 100 deaths per 100,000 live births.

For our third strategy, we estimated the minimum need for surgery in the 7 global super-regions based on the prevalence of conditions from previous work by Rose et al. [13]. These prevalence data were obtained from the 2010 global burden of disease (GBD); the data were organized in 119 disease states in accordance with the World Health

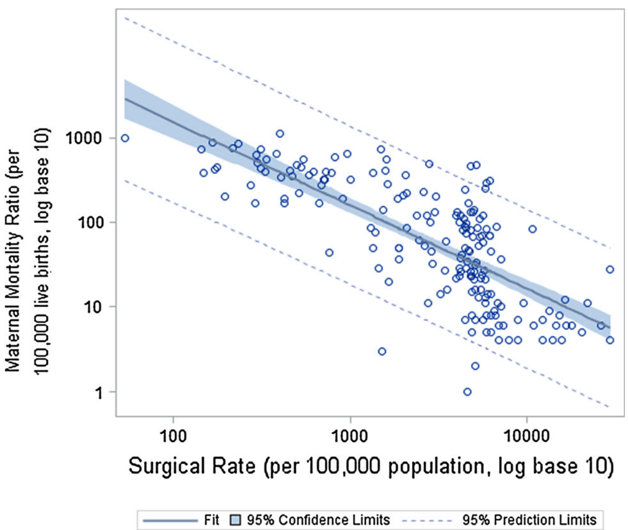

Fig. 2 Relationship between maternal mortality ratio and surgical rate in 2012 for 181 WHO member countries (13 of the 194 WHO member countries did not have maternal mortality ratio data). Adjusted R-square: 0.5556

Organization Global Health Estimate (GHE) [14]. These data represented 187 countries and were organized according to the 21 GBD epidemiologic regions. Predefined values for the incident need for surgery for each GHE disease states were used to calculate minimal need for surgery in each region based on the prevalence of each condition. A detailed description of these methods is described in a separate study [13]. We then aggregated these surgical need data to the seven global super-regions as used by GBD and weighted by population size [15]. We calculated the mean surgical need of the seven global super-regions for 2010.

We then compared our findings to the observed surgical rates of the "4C" countries (Chile, China, Costa Rica, Cuba) identified in The Lancet Global Health 2035 Commission Report [16]. The "4C" countries were used in the report as examples of countries that were classified as low-income or lower-middle-income in 1990 but that had reached high levels of health status by 2011. These four countries illustrated that a "scaling-up" of health sector interventions was possible, and produced better outcomes than economically similar countries and regions that had not done so [16]. We calculated the mean surgical rate for the 4C countries reported for 2012 as an external test of validity.

We used SAS version 9.3 for all statistical analyses.

Results

Based on the first strategy assessing surgical rates and LE, countries with reported LE of 74-75 years ($N = 17$) had a median surgical rate of 4392 (IQR 2897–4873) operations per 100,000 people annually. Figure 1 demonstrates the relationship between observed surgical rates per country and LE and shows that as surgical rates increase, there is a trend toward an increase in LE (adjusted R-square 0.5148). Based on our second strategy exploring the relationship between surgical rates and MMR, the median surgical rate for countries that had an MMR below 100 ($N = 109$) is 5028 (IQR 4139–6778) operations per 100,000 people annually. Figure 2 demonstrates the relationship between observed surgical rates per country and MMR and shows that as surgical rate increases, the MMR decreases (adjusted R-Square 0.5556). Based on the third strategy assessing minimum surgical need, the mean surgical rate estimated for the 7 super-regions based on the 21 GBD regions' prevalence data was 4723 (95 % CI 3967–5478) operations per 100,000 people annually. Estimated need of surgery for the 21 GBD regions and seven super-regions based on prevalence data from 2010 are shown in Table 1. The "4C" countries had a mean surgical rate of 4344 (95 % CI 2620–6068) operations per 100,000 people annually.

Based on 2012 surgical rate estimates, thirteen of the twenty-one GBD regions, accounting for 5.5 billion people (78 % of the world's population), do not achieve the lowest end of the surgical rate range (Table 2).

Discussion

Despite three diverse strategies, we identified a surprisingly narrow range of surgical rates associated with positive health indicators, including a LE of 74–75, a MMR of less than or equal to 100, and minimal surgical capacity to meet surgical disease prevalence. While there is no ideal strategy for identifying a minimum surgical rate threshold, LE and maternal mortality are reasonable outcome measures to choose, as they are desirable benchmarks for low- and middle-income countries working to improve their health systems. Using disease prevalence to estimate surgical need allows regions to consider and accommodate differences in their disease profiles when planning surgical service provision. The 4C countries also had a surgical rate similar to our three proposed strategies. This similarity helps validate our findings, as the 4C countries have experienced improved health outcomes and have exemplary maternal and neonatal health outcomes.

Using these three strategies along with our validation scheme, we identified that countries with a surgical rate ranging from 4344 to 5028 operations per 100,000 population annually have achieved desirable health outcomes. Although our study findings cannot infer a causal relationship between a minimum surgical rate and these positive health outcomes, it is likely that countries

Table 1 Estimated need of surgery for the 21 GBD regions and seven super-regions based on prevalence data from 2010, weighted by population

Epidemiological regions	Estimated total Surgical need in 2010		
	Surgical cases 2010 (in thousands)	Regions	Cases/100,000
Caribbean	2210	Latin America and Caribbean	3637
Central latin America	7821		
Tropical Latin America	7227		
Andean Latin America	20,178		
East Asia	57,821	Southeast Asia, East Asia, Oceania	4165
Southeast Asia	25,794		
Oceania	448		
North Africa and Middle East	19,875	North Africa and Middle East	4456
South Asia	72,920	South Asia	4520
Central Asia	3477	Central Europe, Eastern Europe, and Central Asia	5004
Eastern Europe	10,291		
Central Europe	6566		
Southern Latin America	2954	High-income	5069
Western Europe	22,323		
High-income North America	15,806		
Australasia	1209		
High-income Asia Pacific	9423		
Southern sub-Saharan Africa	3591	Sub-Saharan Africa	6208
Western sub-Saharan Africa	21,836		
Central sub-Saharan Africa	6039		
Eastern sub-Saharan Africa	21,859		

Adapted from Rose et al. [13]

providing these minimum levels of surgical care have strong health systems. Health systems that are able to support surgical provision to this degree are likely able to support other health interventions that improve its population's longevity. As such, surgical rates and capacity serve as a marker of the strength of a health system.

We chose a LE target of 74–75, which is 13–14 years above the mean LE of low-income countries and approximately 5 years below the mean LE of high-income countries. Countries with a LE of 74–75 had a median surgical rate of approximately 4400 operations per 100,000 people annually. Since this might appear arbitrary, we calculated the median surgical rates for LE of 73–74 years and 75–76 years, which resulted in similar rates of 4584 and 4694 operations per 100,000 people annually, respectively. However, the magnitude of the effect and the direction of the relationship (more longevity leading to more need for surgery, or vice versa) are complicated, and simply increasing surgical rates without attending to other fundamental weaknesses plaguing health systems are unlikely to meaningfully improve life expectancy [11].

There are certain limitations with each strategy. The reported global volume of surgery was based on operations in the operating theater, but standardization was not uniform across countries. Country-specific volumes may vary based on how such operations and procedures are recorded. This study is an ecological analysis, and therefore causal inferences between the relationship of surgical rates and LE and MMR cannot be made [17]. We did not adjust for other confounders, such as GDP or health expenditure, as these are collinear with surgical rates. Nor do we do not account for variation in surgical rates within each country and region, and therefore cannot assess the impact this may have on health outcomes. For example, there are likely differences in surgical rates in urban areas compared to rural areas of countries that are not accounted for in our study. Our assessment of surgical rates associated with surgical disease prevalence is likely an underestimate of the actual surgical need. Because of methodological considerations, many surgical conditions were not included in the analysis assessing surgical need based on disease prevalence [14]. Additionally, resource limited settings may have a higher burden of surgical conditions than might otherwise be expected, as neglected infections require surgical intervention more frequently than they might if addressed in a timely fashion. Despite these limitations, our

Table 2 Estimated volume of surgery that occurred in 2012 and estimated surgical rates based on population for each of the 21 GBD regions (regions in italics are those that do not meet lowest surgical rate of proposed range)

Epidemiological regions	Population 2012 (in thousands)	Observed surgical activity 2012	
		Surgical cases (in thousands)	Cases/100,000
Eastern sub-Saharan Africa	383,758	2281	*595*
South Asia	1628,583	12,734	*782*
Western sub-Saharan Africa	356,692	4033	*1131*
Central sub-Saharan Africa	97,757	1288	*1317*
Southeast Asia	625,871	13,632	*2178*
Oceania	9441	232	*2455*
East Asia	1375,458	39,627	*2881*
Central Asia	84,907	2504	*2949*
North Africa and Middle East	456,078	16,127	*3536*
Caribbean	38,686	1405	*3631*
Central Europe	114,643	4604	*4016*
Central Latin America	242,422	9854	*4065*
Andean Latin America	55,976	2353	*4204*
Subtotal (% total)	5470,272 (78 %)	110,674 (35 %)	
Southern sub-Saharan Africa	73,545	3653	4967
Eastern Europe	208,142	11,259	5409
Southern Latin America	61,947	3434	5543
Tropical Latin America	205,343	12,467	6071
Australasia	27,157	2755	10,145
High-income Asia Pacific	183,291	20,626	11,253
Western Europe	422,605	53,368	12,628
High-income North America	348,628	94,631	27,144
Total (% total)	7000,930 (100 %)	312,867 (100 %)	

Adapted from Weiser et al. [5]

study highlights important relationships between surgical rates and positive health indicators. As such, surgical rates and surgical capacity serve as a marker of the strength of a health system.

This target range of 4400–5000 operations per 100,000 people annually can be used as a benchmark goal that informs policy aimed at strengthening health care systems and surgical capacity. Maternal health advocates have used benchmarking and have shown the importance of cesarean availability to improve maternal outcomes. To our knowledge this has not been done for surgery, and we hope our findings can support surgical advocacy in the global health arena.

These findings support the argument that minimum rates of surgery are associated with desirable health indicators. Three-fourths of the world's population, accounting for 5.5 billion people, live in countries that do not meet the lowest surgical rate of our proposed range. Surgery plays an important role in global health and health service delivery, and many countries require increased surgical infrastructure to strengthen overall health systems and health outcomes.

Conflict of interest None.

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