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The Global Burden of Surgical Disease

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Abstract
Purpose of review This review explores ongoing efforts to document the global burden of surgical disease. The chapter recaps the theoretical basis for surgical disease burden measurement. It then focuses on the indirect and direct epidemiology of surgical disease throughout the world, with a particular focus on global and low- and middle-income country (LMIC) work.
Recent findings This review will focus on the results of peer-reviewed publications concerning surgical burden epidemiology from the last 5 years. It will demonstrate the multiple attempts to define which surgical conditions should be treated to meet high unmet needs for surgical care. It will also describe the results of modeling, field epidemiology, and alternate methods for assessing global, regional, and country burdens of surgical disease.
Summary Many people in the LMICs live without access to sufficient surgical care. Research from the past 5 years has begun to define this unmet need.

Keywords Burden of surgical disease · Low- and middle-income countries · Disability-adjusted life years · Surgical epidemiology · Surgical disease modeling · Surgical conditions

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Introduction

Prior to 2011, very little epidemiology had been conducted to define the baseline global burden of surgically treatable disease. In the past 5 years, this neglected epidemiology has undergone a renaissance, with increasingly sophisticated estimates for the global-, regional-, and country-specific population burdens of surgically treatable conditions. The economic and political will to provide treatment for those living with and often dying from surgical conditions demands accurate data [1]. Here, we attempt to review this new literature.

Theoretical Considerations

The Global Burden of Disease Study—sponsored by the World Health Organization, the World Bank, multiple academic institutions, and the Bill and Melinda Gates Foundation—began in 1990 with estimates for the prevalence of 289 disease states and 1160 disease sequelae. This was expanded in 2013 to include 301 disease states and 2337 sequelae. The purpose of this effort was to quantify disease burden for prioritizing policy and research agendas. These data were extracted from health system records, household surveys, and other data sources from all countries in the world. The investigators calculated years lost to disability (YLDs) and disability-adjusted life years (DALYs) lost for each of the conditions. YLDs and DALYs were based on disability weights (DWs) assigned by public surveying in five disparate countries [2]. This work has been used extensively for global health policy development, funding allocation, and technology development. Unfortunately, the methodology of the Global Burden of Disease (GBD) project did not consider all possible surgical conditions, or group those that it did consider into a discrete category. This has led to surgical conditions and treatments being subsumed within other disease categories

such as infectious disease, chronic health conditions, and traumatic injuries within the analysis.

Accurate estimations hinge upon defining what is a surgical condition and what comprises surgical treatment. These require explicit definition, given the historical neglect of surgical diseases within global epidemiology and public health development efforts.

Because of this gap within the GBD Study with regard to surgical diseases, a definition of surgical conditions and treatments similar to below was proposed by Bickler in 2010 and buttressed by a theoretical framework for the met, unmet, and unmeetable surgical disease burden.

> A surgical condition can be understood as any health state that would benefit from any form of surgical treatment - not just operative treatment. Surgical treatment then comprises the personnel, care, procedures, and systems that provide this care [3••].

In this definition, the total burden of surgical conditions is the disability and premature death that would exist in a population without any surgical care. The met need is that which has been attended to with surgical care, the unmet need is that which could be attended to with greater surgical care, and the unmeetable need is that amount of surgical disease that would be uncorrectable even with the best surgical care. The metrics used to create the theoretical basis for a surgical disease burden were years of life lost (YLLs), YLDs, and DALYs gained or lost given the presence or absence of surgical treatment. By positioning the surgical disease burden within the GBD's global public health language of DALYs, YLDs, and YLLs, Bickler's work sought to speak the language of global policymakers and development agencies. Subsequent work, also by Bickler for the World Bank's Disease Control Priorities Project, applied the core equations of the GBD Study to surgical conditions [4].

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD}$$

where the YLL is defined as the sum of all years lost prematurely and YLD is the sum of all prevalent conditions multiplied by their DW.

For health system evaluation, planning, and financing considerations in the developing world, the unmet need for surgical treatment carries great importance. This is the treatment gap that development programs could theoretically target. Parallel work has sought to further refine the idea of the met, unmet, and unmeetable need for surgical care with the inclusion of incident and prevalent surgical disease (Fig. 1). In similar papers in 2012 and 2014, Ozgediz and Poenaru argued that there were significant delays in the surgical care delivered to many patients. By looking at these delays—the time between when a surgical disease is incident and when it becomes prevalent—for cases such as cleft lip and cleft palate, they arrived at the idea of the backlog or delayed unmet need [5, 6]. Assuming that in low-income countries access to timely surgical care is very limited for many conditions, delay may constitute significantly to the unmet need.

Modeling of Surgical Disease Burden

Very few low- and middle-income countries (LMICs) currently have the capacity to collect, monitor, and disseminate the data necessary to clearly understand their local burden of surgical disease [7, 8•]. In the seminal study from 2008 by Weiser, 75% of WHO member states were unable to provide full, country-wide surgical data [9]. In the setting of prior incomplete data, many have attempted to extrapolate and build models from the GBD project data, LMIC facility surveys, high-income country data sources, and other global databases for surgical conditions and treatments.

Which Surgical Conditions to Treat?

In deciding which operative procedures may be necessary for global surgical expansion, many have proposed minimum sets of procedures (Table 1). Previously, these have been proposed without data and often as solely of *expert opinion* [13]. In an evolution away from expert opinion, the revised Disease Control Priorities Project of 2015 identified 44 surgical procedures that would avert about 1.5 million deaths a year, and estimated 6–7% of all avertable deaths in low-income and middle-income countries. This was done by examining data from the GBD project following expert consensus and analyzing these procedures for DALY burden [10]. Data from the World Health Organization Emergency and Essential Surgical Care Global database found that cesarean delivery, laparotomy, and treatment of open fracture were predictors of the ability to perform all obstetric, general, basic, emergency, and orthopedic procedures. These were termed "bellwether procedures" by the authors [11].

Although these procedures may be recommended as components of a minimum package, data from LMICs suggest there is a large gap between the ideal package of interventions and what is actually provided. In Ghana, a facility assessment of 155 centers found that 95 (77.2%) did not have the capability in 2014 to perform all three bellwether procedures [14]. This result may suggest that huge gaps exist between what would ideally be provided as a minimum set and what truly does exist in LMIC's surgical facilities. In a developed country analysis which may define the *meetable need* for emergency surgical care, Scott et al. defined seven operative emergency general surgery procedures which accounted for 80.0% of procedures, 80.3% of deaths, 78.9% of complications, and 80.2% of inpatient costs in the USA (partial colectomy, small

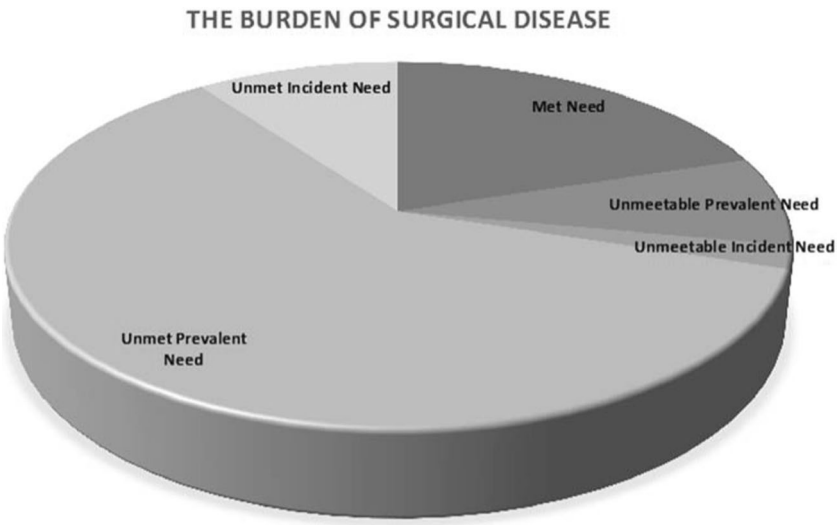

Fig. 1 The burden of surgical disease, with theoretical relative volumes of met, unmet, and unmeetable surgical disease (adapted from [5, 6])

bowel resection, cholecystectomy, operative management of peptic ulcer disease, lysis of peritoneal adhesions, appendectomy, and laparotomy) [12]. It is very likely that these seven high frequency procedures in the USA would be much less available in an LMIC setting. Also, there are many factors that contribute to variations in surgical need. These factors may vary by location, population, income, and access to care. Peritoneal adhesion (intra-abdominal scaring usually from prior surgery) is one example of a condition that significantly contributes to the burden of surgical disease in the developed world but is uncommon in LMICs where the pool of patients that had prior surgery is much lower.

Table 1 Which surgical conditions to treat?

Reference	Method	Conditions	Procedures
Mock et al. [10]	GDB-based DALY analysis following expert consensus	Dental Obstetric, gynecological, and family planning Injury Congenital Visual impairment Nontraumatic orthopedic	44 procedures, with location from community facilities, primary health centers, first-level hospitals, referral hospitals
O'Neill et al. [11]	WHO essential surgical care Global database analysis following expert consensus	Obstetric General Basic Emergency Orthopedic	"Bellwether procedures" Cesarean delivery Laparotomy Open fracture treatment
Scott et al. [12]	US national inpatient sample analysis	All emergency general surgical conditions that could be treated with the high frequency procedures found	Partial colectomy Small bowel resection Cholecystectomy Management of peptic ulcer disease Lysis of adhesions Appendectomy Laparotomy

How Much Surgery Is Required?

By performing comparisons with high-income countries, it may be possible to extrapolate what would be the potentially *meetable* need for surgical procedures (Table 2). Some have attempted to use modeling to estimate the current levels of and future needs for surgical treatment in LMICs. Initial estimates suggested that 234.2 (95% CI 187.2–281.2) million major surgical procedures are undertaken every year worldwide [9]. The poorest countries in this analysis had remarkably less major surgery per 100,000 population than richer countries [295 (SE 53) procedures per 100,000 population per year for those spending <$100 versus 11,110 (SE 1300; $p < 0{\cdot}0001$) per 100,000 population for those spending >$1000 per person on healthcare]. In similar work, given a theoretical rate of 5000 operations per 100,000 population, it was found that 5.5 billion people did not live in areas with this surgical rate in 2012, and if given current rates of growth, the poorest regions of the world will not meet that rate by 2035 [16]. This is disturbing, given that Weiser also found a dose–response relationship between life expectancy and surgical rates up to 1533 operations per 100,000 people [19]. This data would seem to show that sufficient surgical treatment may be integral to population health and that its absence is both a marker of and cause for ill health and death in LMICs.

Using the 2010 GBD categories, Rose et al. estimated that 10 million major inpatient operations were performed in the USA in 28.6% of all hospital admissions [15]. From this finding and with data from the GBD, the authors calculated that 321.5 million surgical procedures were globally necessary, with regional rates of needed surgery much higher than currently delivered [25•].

Table 2 Modeling how much surgery is required

Type	Reference	Burden conclusions
Total number of surgeries	Weiser et al. [9]	234,200,000 surgical procedures *performed* each year, globally
	Rose et al. [15]	321,500,000 surgical procedures *necessary* each year, globally
Rate of surgeries	Uribe-Leitz [16]	5.5 billion in areas below 5000 operations/100,000 people per year
	Esquivel et al. [17, 18]	Life expectancy goals met at 4392 to 5028 operations/100,000 people per year
	Weiser et al. [19]	Life expectancy gains up to 1533 operations/100,000 people per year
	Beard et al. [20]	Ideal hernia surgical rate of 357/100,000 people per year
DALY analysis	Stewart et al. [21]	11 surgical conditions; 20 M YLLs and 25 M DALYs lost
	Higashi et al. [22–24]	Obstetric conditions: 21.1 M DALYs avertable with full surgical care
		Digestive conditions: 4.8 M DALYs avertable with full surgical care
		Traumatic conditions: 52.3 M DALYs avertable with full surgical care

In Ghana and Tanzania, Beard et al. used parallel estimations based on the US NHANES prospective cohort. They mapped this data onto Ghanaian and Tanzanian demographic data and found the prevalence of inguinal hernia of 3.15–5.36% in adults and 7–12.09% in adult men [20, 26]. They found a lower incidence rate of inguinal hernia lower than that in the USA (explained by younger population) and calculated an ideal hernia surgical rate of 420 and 357/100,000 population, which was higher than the US's measured rate. This is due to the overall higher prevalence of inguinal hernia, felt to be due to higher burden of physical labor (such as smallholder farming).

Others have modeled the surgical rates associated with improved health outcomes. Esquivel et al. compared rates of surgery in high life expectancy populations and low maternal mortality populations with the estimated need for surgery in the seven GBD regions. They found the need for 4392 (IQR 2897–4873) and 5028 (IQR 4139–6778) operations per 100,000 persons to achieve the life expectancy and maternal mortality goals. The authors concluded that 78% of the world's population—mostly living in LMICs—do not have sufficient rates of surgery. This highlights surgical care provision gaps for the poorest populations and provides a policy point for surgical care strengthening in these regions [17, 18].

Several investigators have attempted to determine surgical disease burden in terms of YLLs and DALYs. Compiling studies on emergency surgical conditions and data from the Global Burden of Disease Study 2010, some have calculated 20 million years of life lost and 25 million disability-adjusted life years from 11 emergency general surgical conditions [21]. Using the data derived from the 2010 GBD project and as part of the World Bank's Disease Control Priorities Project, Higashi et al. attempted to estimate the avertable burden of several groups of conditions. In the first case, the maternal health surgical conditions are maternal hemorrhage, obstructed labor, obstetric fistula, abortion, and neonatal encephalopathy. Of 56.6 million DALYs lost, 21.1 million DALYs (37%) would be avertable by full coverage of quality obstetric surgery in LMICs [22]. In the second case, these authors examined four digestive diseases: appendicitis, intestinal obstruction, inguinal and femoral hernia, and gallbladder and bile duct diseases. They found that 4.8 million DALYs or 65% of burden related to the selected digestive diseases are avertable and that the LMICs had the greatest avertable burden in absolute DALYs (1.7 million) and avertable proportion [23]. In the third case, they examined traumatic injury and concluded that 21% of the injury burden in LMICs was potentially avertable by basic surgical care (52.3 million DALYs). Again, the poorest regions had the largest proportion of avertable burden and total avertable burden (Sub-Saharan Africa and South Asia, respectively) [24].

Direct Measurement of Surgical Disease Burden

Field Epidemiology

The Surgeons OverSeas Assessment of Surgical Need (SOSAS) survey was first used to perform a household survey in Sierra Leone in 2012 (Table 3). In each selected household, two members underwent a verbal head-to-toe examination. The investigators found that 25% of respondents reported a surgical condition needing attention. 12.6% had traumatic musculoskeletal problems, with 63.9% of those needing care for their condition which they were unable to receive. Through a death survey, they found that 25% of deaths in the preceding year may have been averted by surgical care [27••]. One interesting finding of this work was that 36.1%

Table 3 Field epidemiology

Reference	Location	Burden conclusions
Groen et al. [27••]	Sierra Leone	25% prevalence of surgical conditions on questionnaire
Wong et al. [28]		63.9% of these conditions without care (unmet need)
Stewart et al. [29]	Nepal	20% of deaths potentially avertable/palliated with surgical care (unmet need)
Gupta et al. [30]		20% of burn victims had surgical need (unmet need)
Petroze et al. [31, 32]	Rwanda	14.8% prevalence of surgical conditions on questionnaire
Linden et al. [33]		12% prevalence of surgical conditions on questionnaire and exam (select conditions)
Wu et al. [34]	Kenya	6.3% prevalence of congenital malformations
		DALYs lost of 54–120/1000 children

of elderly deaths recorded in the survey reported a surgical condition in the week prior [28].

In Nepal, the same SOSAS methodology was used and extrapolated that nationwide, 1.25 million patients greater than 50 years old have a surgically treatable condition. They found that one in five deaths could potentially be averted or palliated with surgical care [29]. By sampling 2695 individuals in parallel work in Nepal, 20% of patients with burns had unmet surgical need following the burn [30].

In Rwanda, several similar household surveys have been conducted. A SOSAS-type verbal questionnaire of 3175 individuals found that 14.8% (95% CI 13.3–16.5%) had an operative condition during the previous 12 months, 6.4% (95% CI 5.6–7.3%) had a current operative condition, and 6.3% (95% CI 5.4–7.4%) of Rwandan children have a potentially treatable surgical condition [31, 32]. The most recent—with physical exam—was conducted amongst 2135 persons. Multiple surgical conditions were surveyed, and prevalence was calculated. Overall prevalence of any surgical condition was 12% (95% CI 9.2–14.9). The large majority were injuries or wounds (55%) and hernias or hydroceles (40%) [33].

Household survey work in Kenya geared to identifying congenital malformations found a 6.3% prevalence of malformations. The authors used the GBD disability weights and this prevalence data to calculate that these conditions accounted for 54–120 DALYs per 1000 children [34].

Alternate Measurement of Surgical Disease Burden

Qualitative Methods

Qualitative methods have also been used to examine the perception of unmet need for surgical care. Dare et al. performed three country-wide case studies in Papua New Guinea, Uganda, and Sierra Leone. In semi-structured interviews with stakeholders in the provision of surgical care in each country, they found a wide variation in the level of priority for surgical care between countries [35]. Shrime et al. performed another provider survey and found that 30% of the global burden of disease could be surgical by expanding the definition of included patients that would not require operation, but any surgical care [36].

Cost-Effectiveness Analyses

A direct application of surgical disease burden assessments is in cost-effectiveness analysis. This type of analysis has the potential to translate burden calculations from abstract YLDs and DALYS into dollars lost due to surgical conditions or saved through surgical treatment. For example, in an econometric modeling paper, Meara and colleagues performed calculations using value of lost output (VLO) and value of lost welfare (VLW) approaches. These analyses were used to estimate the financial impact of surgical disease globally. They estimated the 15-year cost of all global surgical diseases (between 2015 and 2030) to be US$20.7 trillion. Losses were greater in low- and middle-income countries [37]. In field epidemiology work, three African hospitals were surveyed for all patients undergoing emergency laparotomy, elective and emergency inguinal hernia repair, elective and emergency cesarean section, amputation, fracture manipulation, or fracture fixation. DALYs saved for each patient were calculated, along with cost for care. This showed that each DALY saved cost between $4.36 and $225.89 per procedure [38]. This is likely much lower than for the same procedures in the developed world. In similar work on cleft lip and palate surgical missions in the developing world, each DALY averted the cost $247.42 [39].

Conclusion

This brief review of selected literature from the past 5 years attempts to show the increasing depth and breadth of our understanding of the global burden of surgical disease. Investigators have responded to calls for more data with modeling strategies based on previously collected information

and, in many cases, performed direct field data acquisition to answer the basic question: What is the unmet burden of surgical disease? Recent publications point to core procedures as those most important for burden analysis: from the Disease Control Priorities Project's proposal of 44 procedures based on GBD estimates, to the 3 very select bellwether procedures proposed in the review of WHO data, to methods that examine a high-income country's 7 most frequent emergency surgical procedures. Modeling has been used to examine both the amount and rate of surgical procedures performed, with DALYs lost and avertable calculated in these models. It is safe to suggest that each year, millions of necessary surgical procedures go undone in LMICs and that provision of these surgeries could avert millions of YLLs and DALYs lost. Also, field epidemiology from LMICs in the past 5 years has confirmed rates of prevalent and untreated surgical illness as high as 25 and 63%, respectively. As the global health and development community becomes more fully aware of this new data, it is hoped that funding and treatment will follow. The unmet burden of surgical conditions differentially impacts people in low- and middle-income countries. The work detailed above is in service to their human right to health through better access to surgical treatment.

Compliance with Ethical Standards

Conflict of Interest Drs. Bendix and Havens declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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