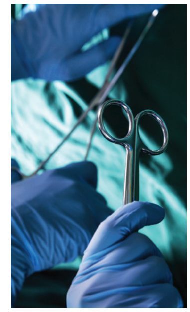

Chapter 21

# Benefit-Cost Analysis for Selected Surgical Interventions in Low- and Middle-Income Countries

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## INTRODUCTION

Since surgery was first included in the second edition of *Disease Control Priorities* (DCP2, 2006), research examining the cost-effectiveness of surgical interventions in low- and middle-income countries (LMICs) has expanded substantially (see chapter 18). A growing body of evidence suggests that surgical platforms can be cost-effective in these countries, according to the criteria established by the World Health Organization (WHO) (Grimes and others 2013).

In parallel, a nascent field of study within global health economics has attempted to expand the application of benefit-cost analysis (BCA) to global health interventions in these countries. In contrast with cost-effectiveness analysis, BCA seeks to estimate the net economic benefit of an intervention in monetary terms. The nature of BCA allows researchers to investigate the potential economic return of an investment in global health; it also allows ministries of health and finance to meaningfully compare health care projects to investments in other governmental sectors, such as education and transportation, which are routinely valued with BCA. The use of BCA in global health has recently become more visible; for example, Jamison, Jha, and Bloom (2008) and Jamison and others (2012) prominently feature BCA in their challenge papers for the 2008 and 2012 Copenhagen Consensus (CC).

Within the surgical cost-effectiveness literature, cleft lip and palate (CLP) has been the subject of at least three cost-effectiveness studies in LMICs; all suggest that CLP can be repaired in LMICs in a cost-effective manner (Corlew 2010; Magee, Vander Burg, and Hatcher 2010; Poenaru 2013). A more thorough review of CLP can be found in chapters 8 and 13 of this volume. The role of cesarean delivery in the context of obstructed labor, and its associated cost and benefit, has been previously studied by the authors (Alkire and others 2012a) and is presented here with updated results. This chapter presents two distinct BCAs:

- An approach for performing BCA using CLP repair as a model surgical intervention using primary data from a subspecialty hospital dedicated to CLP in India
- A BCA based on secondary data that model the benefit and cost of cesarean delivery for treatment of obstructed labor in 47 LMICs.

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## BENEFIT-COST ANALYSIS AND GLOBAL HEALTH

The use of BCA to assess global health interventions builds on the economic concept of full income, which reframes how a country's economic performance is measured (Becker, Philipson, and Soares 2003). This approach assumes that gross domestic product (GDP) per capita does not completely capture a country's economic welfare. In addition to the value of goods and services provided during a year, the full income of a country accounts for changes in life expectancy (LE) by valuing additional years of life in monetary terms (Becker, Philipson, and Soares 2003). Changes in LE are valued using the value of a statistical life (VSL) concept, which attempts to measure individuals' willingness to pay for small risk reductions in mortality, and from that it extrapolates what society would be willing to pay to prevent one statistical death; this latter number is termed the value of a statistical life (Hammitt 2007). As an example, if an individual would be willing to pay US$7 to decrease the risk of mortality by 1 in 1 million, then this individual's VSL would be US$7,000,000.

Broadly, economists rely on two different methods to measure VSL: revealed preference studies and stated preference studies. Revealed preference studies rely on behavioral data, such as wage differentials of professions with different mortality risk profiles, to estimate the additional income that workers are willing to accept to be exposed to increased on-the-job mortality risk; stated preference studies use surveys to ask what one is willing to pay for small mortality or morbidity risk reductions. It is striking that among the various approaches to estimating VSL, studies in the United States—where the majority of VSL estimates in the literature have taken place—consistently find VSLs within the same order of magnitude (Viscusi and Aldy 2003). Nomenclature has unfortunately plagued VSL studies because critics tend to argue that, especially when used in LMICs, the notion of differing *values* of life is unethical and morally suspect. The key to resolving this dilemma is to emphasize that VSL does not claim that the value of one's life is equivalent to his or her VSL. VSL studies do, however, suggest that individuals may value reductions in mortality risk differently based on age, income, and other demographic variables (Aldy and Viscusi 2008).

Returning to the concept of full income, Jamison and others argue that when economic performance is measured in full-income terms, a more complete assessment of economic welfare is obtained. Looking to the AIDS epidemic in Sub-Saharan Africa in the 1990s, the Commission on Macroeconomics and Health noted that although GDP per capita remained relatively constant during this period, full income fell and is likely to more closely approximate the economic performance of these countries during this devastating era (WHO 2001). Further discussion of full income and its potential to portray a more complete economic picture than GDP per capita alone can be found in Jamison and others (2012) and in Jamison and others (2013).

If full income can provide a more complete picture of economic performance, then valuing changes in morbidity and mortality according to economic welfare is a valuable exercise in itself. The analysis becomes more powerful, however, if we pair potential economic benefits with economic cost. BCA has long been used by the World Bank to assess development projects (World Bank 2010) and is commonplace in governmental assessments of transportation or environmental projects (Robinson 2007). Applying BCA specifically to global health interventions can allow analysts to demonstrate the potential economic return on investment to governments, nongovernmental organizations (NGOs), and donors; it can also allow stakeholders to compare health care projects with projects in other sectors, such as transportation or education. With these concepts in mind, Jamison and others (2012) perform a BCA for scaling up a number of interventions in LMICs and find benefit-cost (BC) ratios that range from 10:1 for essential surgical services to 35:1 for malaria treatment.

The BCA in this chapter builds on the CC analysis, but it differs in a number of important ways. As in the CC, we also value disability-adjusted life years (DALYs) averted using the VSL methodology. This process involves converting the VSL into its annualized equivalent, the value of a statistical life year (VSLY). The economic benefit of an intervention, then, is as follows:

$$\text{Economic Benefit} = \text{DALYs Averted} \times \text{VSLY}.$$

An important distinction between our analysis and the CC is that the CC chose to value the VSLY equally across LMICs (at US$1,000 or US$5,000). The approach used in this chapter differs because the seminal review of VSL concludes that VSLY strongly correlates with income (Viscusi and Aldy 2003). To be more useful to the governments and NGOs in countries where the studied disease process occurs, our estimates of VSLY are country specific. We also adjust the VSLY for age because economic data suggest that it peaks at roughly two-thirds of LE (Aldy and Viscusi 2008). To maintain consistency, our procedure for adjusting VSLY for age uses the same functional form for age weighting as in the DALY literature.

## BENEFIT-COST ANALYSIS OF A CLEFT LIP AND PALATE SURGICAL SUBSPECIALTY HOSPITAL IN INDIA

### Cleft Lip and Palate Overview

The incidence of CLP varies by ethnicity and geography. Current estimates range from one in 300 live births to one in 1,500 live births, placing CLP among the most common congenital anomalies (Canfield and others 2006; Poenaru 2013; Vanderas 1987).

Although the pathogenesis of CLP is complex and the subject of ongoing study, current data suggest a complex interplay of environment and genetics (Flint and Cummings 2010). Untreated CLP results in a number of potentially life-altering sequelae, including feeding difficulties, social stigmatization, and speech and hearing developmental delays (Corlew 2010). The primary treatment modality is surgery of the lip, palate, or both within a broader multidisciplinary approach that includes nutrition counseling, speech therapy, audiology, otolaryngology, dentistry, orthodontics, maxillofacial surgery, and possibly nasal surgery. Given that surgery can prevent the majority of the burden of disability, CLP has lent itself well to concentrated efforts such as mission trips and surgical specialty hospitals and is the focus of multiple prominent NGOs (Hughes and others 2012).

CLP has been included in estimates of the global burden of disease (GBD) since its inception. Although earlier GBD studies only considered CLP's contribution to morbidity, the most current iteration by the WHO, the Global Health Estimates (GHE), assumes a mortality risk associated with the burden, with an estimated 4,992 deaths in 2011 (WHO 2013). The most current GHE data for CLP, including the DALY mortality rate by World Bank region, are shown in table 21.1. It is important to note that the estimates for CLP are heavily skewed to LMICs. For example, although South Asia and Sub-Saharan Africa make up roughly 36 percent of the global population in 2011, 62 percent of total CLP DALYs and close to 75 percent of CLP mortality occurred in these two regions (WHO 2013). Of particular relevance to LMICs is the surgical backlog of CLP cases, defined as the total number of patients eligible for CLP repair who have not received it. Poenaru (2013) places the global estimate of the CLP surgical backlog between 420,000 and 2,100,000 cases, with the majority of the backlog in Southeast Asia and Sub-Saharan Africa.

**Table 21.1** Disability-Adjusted Life Years per 100,000 and Deaths per 10,000,000, Secondary to Cleft Lip and Palate, by World Bank Region, 2011

| World Bank region | DALYs per 100,000 | Deaths per 10,000,000 |
|---|---|---|
| High-income countries | 1.90 | 0.30 |
| East Asia and Pacific | 7.99 | 4.2 |
| Europe and Central Asia | 6.73 | 3.2 |
| Latin America and the Caribbean | 6.23 | 3.1 |
| Middle East and North Africa | 8.20 | 2.2 |
| South Asia | 17.85 | 15.0 |
| Sub-Saharan Africa | 16.37 | 14.3 |

*Source:* WHO 2013.

Clearly, LMICs continue to have substantial unmet need for CLP repair.

A number of studies have examined the cost-effectiveness of CLP repair in LMICs. Magee, Vander Burg, and Hatcher (2010) estimate the cost per DALY for nine one-week mission trips to LMICs, which included Kenya and Vietnam, to range from US$7 to US$96 per nondiscounted, non–age-weighted DALY averted. Poenaru (2013) examines the cost-effectiveness of the extensive Smile Train network; using the organization's reimbursement to hospitals as a proxy for cost, he estimates a cost per discounted, age-weighted DALY averted of US$134. Finally, Corlew (2010) finds a cost per discounted, age-weighted DALY of US$70 at a Nepalese hospital staffed primarily by local physicians. Although each study uses a different methodology to estimate cost, and DALYs were not calculated under uniform assumptions (namely, discounting and age-weighting), these estimates fall well within the WHO guidelines for what can be considered a cost-effective intervention (WHO 2002).

Finally, CLP has been the subject of at least two studies that attempt to capture the potential economic benefit of surgical repair. Both Corlew (2010) and Alkire and others (2011) value DALYs averted with a VSLY approach. Each study also values DALYs using the human capital approach, which assumes that people are analogous to machines and that lost years of life are equivalent to lost years of productivity. With this method, gross national income (GNI) per capita is used as a proxy for productivity, and DALYs are valued at a country's GNI per capita. Corlew values the DALYs averted in treated patients in Nepal and finds that with a human capital approach, cleft lip and cleft palate repair result in an economic benefit per patient of US$2,500 and US$7,000, respectively. Using a VSLY approach, the value of cleft lip and cleft palate repair is US$57,000 and US$150,000, respectively (Corlew 2010). Alkire and others (2011) ask what the potential economic benefit to Sub-Saharan Africa would be if all new cases of CLP in one year were surgically repaired. With the human capital approach, the potential ranges from US$252 million to US$441 million; with VSL, the potential economic benefit of the same CLP repair ranges from US$5.4 billion to US$9.7 billion (Alkire and others 2011). Although these figures are significant, it is difficult to draw meaningful conclusions without the context of cost.

### Benefit-Cost Analysis of Cleft Lip and Palate Repair

Using cost and patient data supplied by Operation Smile and a model that converts DALYs averted to economic benefit, we estimated the cost and benefit of delivering cleft care in a surgical specialty hospital in Guwahati, India, for one year. Operation Smile is a not-for-profit NGO that focuses on CLP in LMICs; from its inception in 1982 through 2010, it has cared for more than 120,000 children (Magee, Vander Burg, and Hatcher 2010). Although Operation Smile's delivery platform has historically been short-term international missions, recent efforts have focused on establishing subspecialty hospitals within LMICs.

The Operation Smile Guwahati Comprehensive Cleft Care Center (GCCCC) was founded in 2011 with the goal of providing sustainable, high-quality subspecialized surgical care to the Indian state of Assam. Operation Smile chose Guwahati after performing a needs-based assessment and noting a substantial backlog of untreated cleft patients; GCCCC estimates that Assam has up to 1,000 new cleft cases a year and a backlog of 20,000 to 30,000 untreated cases. Furthermore, the vast majority of Assam's 31 million citizens live in rural settings without access to cleft care for reasons both geographic and financial; the average income is roughly US$2 per day.

GCCCC is funded by a combination of government, private business, and NGO resources. In addition to providing primary surgical CLP repair using a full-time staff composed of more than 90 percent local medical professionals, it offers patients additional services such as dentistry, otolaryngology, speech pathology, and nutrition (Campbell 2014). These services are typically offered at cleft centers in high-income countries (HICs), but they are often missing from cleft care delivered in LMICs, especially when the mission model is employed. GCCCC has a team that educates and recruits patients; it has already visited every district within the state (Campbell 2014).

### Methods

The basic approach for modeling the economic impact of an intervention is discussed in depth by Corlew (2013), and the model for valuing DALYs used in this chapter is discussed in more detail in the appendix in Alkire and others (2012b). Given that BCA attempts to measure economic costs and benefits, it is necessary to make adjustments to the financial cost of caring for patients that was provided by Operation Smile. This final cost includes accounting for the opportunity cost to patients' families. To derive economic benefit, we did not use a human capital approach; VSL is the approach favored by economists because it is more firmly rooted in actual human behavior and more accurately approximates the value associated with health risk reduction (Belli and others 2001).

The cost data for surgical care at GCCCC for fiscal year 2012 (April 2012–March 2013) submitted by Operation Smile included the following:

- Operating overhead, including administrative costs such as printing, housekeeping and maintenance, and medical record keeping
- Depreciation of hospital building and equipment, which were costed using standard accounting methodology
- Training, including American Heart Association costs and continuing medical education expenses
- Staff expenses (salary, travel, and food)
- Patient food and travel
- Medicine
- Laboratory testing.

Water and electricity are supplied at no cost to GCCCC by the government of Assam. To capture these costs, we used publicly available data on the average tariff for electricity and water and WHO-CHOICE assumptions to estimate the cost of these resources to society (Indian Power Market 2012; Ministry of Urban Development of India and Asian Development Bank 2008; WHO-CHOICE 2014). In addition to the cost of the center, we attempted to account for opportunity cost to the families of patients using GNI per capita to value days lost secondary to preoperative, perioperative, and postoperative care. Finally, a cost per patient was obtained by dividing the total cost by the total surgical cases for fiscal year 2012; to obtain the cost of primary CLP repair, the total number of primary CLP repairs was multiplied by the cost per patient.

To maintain consistency and facilitate comparison with economic benefits, we converted cost to U.S. dollar estimates using the purchasing-power-parity (PPP) conversion factor for India in 2012 (World Bank 2013).[1] The PPP method compares the relative price levels of a fixed basket of goods between countries to establish a currency conversion rate, such that the price of the basket of goods is the same in both countries when stated in the reference currency. Market exchange rates are dependent upon the supply of and demand for a currency and reflect the price of money. The PPP approach results in a better, and typically more stable, cross-country comparator of the cost of goods. It is worth noting that this approach results in cost estimates that are roughly twice those obtained by using market exchange rates.

**Calculating DALYs.** The DALY is a health metric that attempts to quantitatively capture the morbidity and mortality secondary to a disease process in a population. One DALY is equivalent to the loss of one healthy year of life from either early death or disability. Disability weights (with 0 = perfect health and 1.0 = death) are used to calculate years lost to disability (YLD). A number of disability weights are available for accounting for CLP morbidity. The original GBD study provided disability weights for treated and untreated CLP (Murray and Lopez 1996), which implies residual morbidity and is most consistent with the reality of CLP; surgery can address a substantial portion of morbidity, but ongoing challenges remain with middle ear disease, speech, and other morbidities. Although there are disability weights for isolated CL and isolated CP, there are no disability weights for combined CLP. We therefore assigned the CP disability weight to patients who underwent repair of combined CLP.

DALYs averted for a surgical intervention rely on estimates of (1) the likelihood (0.0 to 1.0) of disability or mortality without surgery and (2) the likelihood (0.0 to 1.0) of disability or mortality to be averted by surgery (Bickler and others 2010; Gosselin, Maldonado, and Elder 2010; McCord 2003). For the purposes of this analysis, we assumed that CL and CP carry a value of 1.0 for likelihood of disability without surgery, and that CL on its own has a value of 0.9 for disability to be averted by surgery. For CP, we assumed the likelihood of disability to be averted by surgery to be 0.7. These numbers imply that surgery is successful at averting disability in 90 percent of CL cases and 70 percent of CP cases. These rates are largely consistent with the approach taken by Poenaru (2013) and acknowledge that secondary surgery is necessary in some cases of CLP. Our study attempts to estimate the number of DALYs averted secondary to surgical intervention for primary CLP. Although the newest iteration of the GBD study does consider mortality secondary to CLP (Vos and others 2012), we chose not to consider reduction in mortality because the evidence base for mortality rates secondary to CLP is still being established. Furthermore, we did not include DALYs averted from revision cleft surgery. These assumptions allow us to equate a broader concept (the left-hand side of the following expression) to the quantity we calculated (the right-hand side):

DALYs averted (Primary CLP repair) =
YLD averted (Primary CLP repair).

**Discounting and Age Weighting.** DALYs can be calculated under different assumptions; the two most important ones pertain to discounting and age weights. The most current iteration of the GBD study has abandoned these assumptions; however, to perform BCA that aligns with empirical economic evidence, we include these assumptions in this chapter. Discounting the value of future DALYs to their present value is common practice and improves the economic comparability of DALYs that occur at different times. All of our DALY estimates are therefore discounted. We used a 3 percent discount rate, which has been used both in studies by the architects of the DALY concept (Murray and Acharya 1997) and in studies by experts on valuing mortality risk reductions (Aldy and Viscusi 2008). The stated justification for age weighting in the DALY literature is that the social value of a year of healthy life is greater for young adults than for children or older adults. An age-weighting parameter, $\beta$, determines the age at which the DALY function peaks, with the peak occurring at $1/\beta$. The most common value of $\beta$ in the DALY literature is 0.04, which implies a peak at age 25. However, we used an alternative, country-specific age-weighting parameter, denoted by $\tilde{\beta}$, which is more consistent with empirical evidence on valuation of health risks (see further discussion of $\tilde{\beta}$ below).

The inclusion of discounting and age weighting results in a complex DALY formula (Murray and Acharya 1997):

$$\text{DALYs} = \int_a^L \{[K \times DW \times Cxe^{-\beta x} e^{-r(x-a)}] + [DW \times (1-K) e^{-r(x-a)}]\} \text{dx} \qquad (21.1)$$

in which $a$ = age of onset of disease, $L$ = country-specific life-expectancy if calculating years of life lost (YLL) or the age at onset of a disease plus the duration of disease if calculating YLDs, $K$ = an age-weighting modulation constant (0 = no age weights, 1 = full age weights), $DW$ = disability weight (1 for death), $C$ = age-weighting correction constant, $x$ = age integrated over the duration of disease (YLD) or years of life lost (YLL), $r$ = discount rate (3 percent in this study), and $\beta$ = age-weighting constant (Lopez and others 2006).

To specify which type of DALY is being considered, we rely on the notation DALYs [r, K, β]. To facilitate comparison with previous studies with regard to cost-utility analysis, we estimated DALYs averted with no age weighting or discounting (DALYs [0,0,0]) and DALYs averted with standard GBD age weighting and discounting (DALYs [3, 1, 0.04]).

For the special case of calculating DALYs to be valued using a VSLY approach, the formula is as follows:

$$\text{DALYs } [3,1,\tilde{\beta}] = \int_a^L \{[DW \times \tilde{C}xe^{-\tilde{\beta}x} e^{-r(x-a)}]\} \text{dx} \quad (21.2)$$

Compared with equation (21.1), the integral includes just one term because $K = 1$ (age weighting is turned on because VSLY varies with age [Aldy and Viscusi 2008]), which causes the second term to equal zero. The other key differences are the presence of $\tilde{\beta}$ and $\tilde{C}$, where the tilde indicates that country-specific age-weighting parameters and correction constants were used. Evidence indicates that VSLY peaks at about two-thirds of LE (Aldy and Viscusi 2008), so we modified the age-weighting factor in the DALY formula such that it peaks at two-thirds the LE. Therefore, DALYs [3,1,$\tilde{\beta}$] are discounted at 3 percent and are age weighted such that the maximum weight occurs at two-thirds of LE. Because (1/β) = age at which the age-weighting factor peaks, to calculate a country-specific β, we used the following expression to determine $\tilde{\beta}$:

$$\tilde{\beta} = 1/[(2/3) \times \text{LE}]. \quad (21.3)$$

The value of C is also country-specific because it varies with β according to table 5.2 in the GBD study (Lopez and others 2006). We fit a cubic polynomial to the values in that table and used it to predict $\tilde{C}$ for a given value of $\tilde{\beta}$.

**Converting DALYs Averted to Economic Benefit.** To value DALYs using the VSLY approach, we first estimated the VSL using the following formula (Viscusi and Aldy 2003):

$$\text{VSL (Unknown)} = \text{VSL (U.S.)} \times \left[\frac{\text{GNIp.c.(Unknown)}}{\text{GNIp.c.(U.S.)}}\right]^{\text{IE-VSL}} \quad (21.4)$$

in which VSL (Unknown) = VSL in a country where VSL studies have not been performed, VSL (U.S.) = VSL in the United States (US$7.4 million in 2006 dollars, updated to reference year),[2] GNI p.c. (Unknown) = GNI per capita in the desired study year, GNI p.c. (U.S.) = GNI per capita in the United States in the desired study year, and IE-VSL = the income elasticity of VSL.

The key variable in this transfer method is the income elasticity of VSL (IE-VSL), which determines the sensitivity of VSL to income. As IE-VSL increases, the estimated VSL in the lower-income country decreases. Although values of 0.55 to 1.0 are most often used in transferring estimates of VSL, recent evidence suggests that higher values are more appropriate for transfers to low-income countries (Hammitt and Robinson 2011). We used GNI per capita estimates based on the PPP method (Viscusi and Aldy 2003), and an IE-VSL of 1.0 and 1.5. It is worth noting that formal analyses of VSL have been performed in India (Shanmugam 1996) with a minimum VSL estimate of US$1.2 million in 2000 U.S. dollars (Viscusi and Aldy 2003). Other studies have found similar values (Madheswaran 2007; Shanmugam and Madheswaran 2011). These studies, however, have been largely performed in urban settings, and it is difficult to compare these VSL data with a poor region such as Assam.

To calculate the potential economic benefit of an intervention that averts a given number of DALYs [3,1,$\tilde{\beta}$], we multiplied DALYs [3,1,$\tilde{\beta}$] by the value of a statistical life year. $\text{VSLY}_x$, the value of a statistical life year at age x, is given by the following expression:

$$\text{VSLY}_x = V \times \tilde{C}x\text{e}^{-\tilde{\beta}x} \quad (21.5)$$

in which $V$ = age-neutral (constant) value of a statistical life year (literally, a parameter that converts a single DALY unweighted for age to a monetary value), and $\tilde{C}x\text{e}^{-\tilde{\beta}x}$ is the age-weighting factor found in the original DALY formula modified to peak at 2/3 of LE. We discuss the calculation of $V$ in the following section. Using the DALY age-weighting factor creates internal consistency with the age weighting of DALYs and the VSLY.

The formula for estimating the economic benefit of an intervention to the individual receiving it can therefore be written as

$$\text{Economic Benefit} = \int_a^L \{[DW \times \text{VSLY}_x \times e^{-r(x-a)}]\} \text{dx}. \quad (21.6)$$

Substituting the equation for $\text{VSLY}_x$ into this results in the following:

$$\text{Economic Benefit} = \int_a^L \{[DW \times V \times \tilde{C}xe^{-\tilde{\beta}x} \times e^{-r(x-a)}]\} \text{dx}. \quad (21.7)$$

If the constant $V$ is moved out of the integral, the formula can be rewritten as follows:

$$\text{Economic Benefit} = V\int_a^L \{[DW\times\tilde{C}xe^{-\tilde{\beta}x}\times e^{-r(x-a)}]\}\,\mathrm{d}x, \tag{21.8}$$

which by equation (21.2) reduces to

$$\text{Economic Benefit} = V\times \text{DALYs }(3,1,\tilde{\beta}) \tag{21.9}$$

The DALY formula already contains the age-weighting factor ($\tilde{C}xe^{-\tilde{\beta}x}$), so we need only multiply DALYs $[3,1,\tilde{\beta}]$ by $V$, not $VSLY_x$, which would result in double age weighting. Assuming one has already calculated DALYs $[3,1,\tilde{\beta}]$, the only variable left to define is $V$, the age-neutral value of a statistical life year. To solve for $V$, set $DW = 1$ and $a = 0$, which indicates that the disability is equivalent to death at birth. By definition, the economic benefit in this case is the VSL, and $L$ = life expectancy (LE). Therefore, $V$ is defined by the following expression:

$$\text{VSL} = \int_0^{LE} V\times\tilde{C}xe^{-\tilde{\beta}x}e^{-r(x-a)}\,\mathrm{d}x. \tag{21.10}$$

We move the constants outside of the integral:

$$\text{VSL} = V\times\tilde{C}\int_0^{LE} xe^{-\tilde{\beta}x}e^{-r(x-a)}\,\mathrm{d}x. \tag{21.11}$$

We solve for $V$ and integrate:

$$V = \frac{\text{VSL}}{\tilde{C}}\times\frac{(\tilde{\beta}+r)^2}{1-e^{-(\tilde{\beta}+r)LE}[1+LE(\tilde{\beta}+r)]}. \tag{21.12}$$

As described, multiplying $V$ by DALYs $(3,1,\tilde{\beta})$ yields the economic value of averting these DALYs.

## Results

During the 2012 fiscal year (April 2012 through March 2013), GCCCC treated 1,498 patients with primary surgical repair for cleft lip, cleft palate, or CLP, resulting in an estimated 9,600 DALYs [0,0,0] averted. The present value of the total economic benefit is sensitive to the assumed income elasticity of demand; using the most conservative (lower bound of VSL) parameters, the estimated economic benefit was US$32 million (in 2012 U.S. dollars). Assuming a total economic cost of US$2.75 million, this resulted in a cost per DALY [0,0,0] averted of US$285 and a benefit-cost ratio (BCR) of 12. Estimates using a range of DALY and IE-VSL assumptions are presented in table 21.2.

**Table 21.2** Economic Cost, Benefit, and DALYs Averted at the Guwahati Comprehensive Cleft Care Center for Fiscal Year 2012

| | Outcome |
|---|---|
| Total cost[a] | US$2,745,000 |
| DALYs averted[b] | |
| DALYs [0,0,0] | 9,600 |
| DALYs [3,1,0.04] | 5,400 |
| Cost per DALY averted | |
| DALYs [0,0,0] | $285 |
| DALYs [3,1,0.04] | $508 |
| Estimated economic benefit[c] | |
| IE-VSL = 1.5 | US$32,000,000 |
| IE-VSL = 1.0 | US$116,000,000 |
| Benefit-cost ratio[c] | |
| IE-VSL = 1.5 | 12 |
| IE-VSL = 1.0 | 42 |

*Note:* Where dollar figures are used, they are 2012 U.S. dollars. DALY = disability-adjusted life year. IE-VSL = income elasticity of value of a statistical life.
a. Cost includes fixed and variable costs, along with opportunity cost to the families of patients; includes only primary cleft lip, cleft palate, and cleft lip and palate repair.
b. Non–age weighted, nondiscounted disability-adjusted life years (DALYs) are represented with the notation DALY [0,0,0], while discounted, age-weighted DALYs are represented with the notation DALYs [3,1,0.04].
c. Estimates of economic benefit and consequently benefit-cost ratio rely on valuing DALYs in monetary terms. A special form of the DALY was devised to account for the fact that the VSL varies with age.

## Discussion and Recommendations

This chapter derives a BCR for CLP repair in a subspecialty surgical hospital in Guwahati, India, and finds a BCR of between 12 and 42, using the more conservative estimates of economic benefit. These findings suggest that investment in CLP repair in a referral center similar to GCCCC is a good economic proposition, with a net positive return on investment. Our cost per DALY averted depends on assumptions regarding age weighting and discounting and ranges from US$285 to US$508. The WHO has provided guidelines for determining an intervention's cost-effectiveness by comparing the cost per DALY averted to GDP per capita, with a cost per DALY averted of less than GDP per capita considered to be highly cost-effective. Although our estimates fall well within that range (WHO 2002), they are greater than previous estimates for CLP repair in the literature. The initial investment in infrastructure and equipment required at GCCCC, the broad range of services offered to CLP patients compared with short-term international missions, and inclusion of the opportunity cost of lost productivity likely explain the observed difference in estimates of cost per DALY averted.

**A Model for Delivery of Surgical Care.** By performing almost 1,500 primary CLP surgeries in fiscal year 2012, GCCCC has demonstrated that it can begin to address the substantial backlog of 20,000 to 30,000 cases while also addressing the 1,000 new cases each year. Moreover, GCCCC demonstrates a number of important principles for developing sustainable surgical care. In contrast to many short-term missions, GCCCC provides additional services to cleft patients, including otolaryngology, speech therapy, dentistry, and nutrition counseling. Furthermore, the large majority of medical care staff consists of local providers, which facilitates ongoing onsite training and enhances the sustainability of the center. The unique public-private partnership established among NGOs, private business, and the local government—the major funder of GCCCC—has been essential to developing and sustaining this model (Campbell 2014).

In addition to providing care, it is essential that medical organizations track and report their health-related outcomes. Operation Smile has an established track record of publishing outcome data (McQueen and others 2009), and GCCCC has made it clear that reporting and acting on outcome data are important to the center. A review of the more than 8,000 surgical procedures performed revealed no deaths; furthermore, no surgical procedures have required a blood transfusion (two units of blood are always available). Regarding cleft palate–specific outcomes, GCCCC reports a 3.9 percent palatal fistula rate for more than 700 primary repairs, which compares favorably with published data from HICs (Campbell 2014; Cohen and others 1991; Deshpande and others forthcoming). Cleft lip–specific outcomes data for more than 1,800 cases seen in follow-up suggest a total complication rate of 4 percent, largely made up of dehiscence and infection, and a revision rate of only 0.4 percent. In sum, GCCCC demonstrates that high-quality, sustainable, locally supported surgical care can be provided to an underserved population in an LMIC such as India. It further indicates that this care can be provided in a highly cost-effective and economically favorable fashion.

**Advantages of Benefit-Cost Analysis.** BCA facilitates comparison with investments not only in other medical procedures but also in government programs and development projects. For the 2012 CC, BCRs were calculated for a number of development projects, including investments in global health, education, and agriculture.

- Our BCR of between 12 and 42 is similar to the BCR of 10 for essential surgical services, as estimated by Jamison and others (2012).
- BCRs have also been estimated for reducing the prevalence of stunting through a package of interventions that targeted malnutrition in India, and they range between 44 and 138.6 (Hoddinott, Rosegrant, and Torero 2012).
- Estimate of BCRs for retrofitting schools in India to better withstand earthquakes range from 0.04 to 5.6 (Kunreuther and Michel-Kerjan 2012).

It is difficult to directly compare a project that is aimed at a single disease process, such as cleft repair, to projects that have broader goals, such as investing in nutrition; we present these data, however, as an example of how BCA can be used to compare investment across health sectors. A BCA for essential surgical services in LMICs would lend itself better to these broader comparisons.

The economic valuation of benefits in BCA also allows for a more intuitive discussion with stakeholders who are less academically oriented. For example, the cost per DALY averted of an intervention carries meaning to global health academicians and is necessary for cost-effectiveness analysis, but donors and other stakeholders are not always well-versed in the theory of DALYs. The ability to say that an intervention will return $X for every $1 dollar spent has meaning to all potential audiences, especially those who are making decisions about allocation of funds.

The Bellagio Essential Surgery Group, which comprised physicians, economists, and policy makers and sought to improve access to surgical care in Sub-Saharan Africa, made a number of recommendations regarding essential research questions. Among these recommendations were estimating the burden of surgical disease at the country level, assessing the ability to access surgical care in terms of surgical capacity and patient financial resources, and addressing the quality and effectiveness of surgery at first-level hospitals (Luboga and others 2009). In addition to these necessary efforts, estimates of the economic cost and benefit of surgical intervention are essential to developing the evidence base. Kruk and others (2010) estimate current surgical expenditure at first-level hospitals in three Sub-Saharan hospitals and find that only 7 percent to 14 percent of the total operating cost was allocated to surgery; in addition, they find that the majority of surgical care was delivered by midlevel providers. Quantifying current levels of expenditure on surgical care allows policy makers to make crucial funding decisions; as the burden of surgical disease is further delineated, these types of data will prove essential as decisions are made about how to scale up surgical care delivery. By exploring estimates of economic benefit in addition to cost, policy makers can better understand both current and potential returns on investments in global surgery.

### Study Limitations

BCA as performed in this chapter has a number of limitations. One is that we have assumed that the counterfactual in our scenario is the absence of CLP services. This assumption may be an oversimplification of the issue and would drive up our BC ratios if patients receiving CLP care at GCCCC could have received comprehensive cleft care elsewhere. It is a reasonable assumption to make, however, given that the estimated surgical backlog of CLP in India ranges from 233,000 to 544,000 cases (Poenaru 2013) and that GCCCC on its own will require 40 years to 60 years to address the backlog in Assam at the current rate of CLP repair. Furthermore, our results are generalizable only to cleft referral centers with similar characteristics to GCCCC; we are unable to draw conclusions for mission-based models based on these data.

The current analysis focuses on an admittedly narrow subspecialty of surgical care, and estimating the benefits and costs of increasing surgical capacity in LMICs would undoubtedly be a useful contribution to the global surgical evidence base. We recognize that there is uncertainty when deriving economic benefit with a VSL methodology, but we have used the most conservative estimate of VSL. At the recommendation of Hammitt and Robinson (2011), we use an IE-VSL of 1.5 to transfer estimates of VSL from the United States to poor states in LMICs such as Assam, India. If the more commonly used IE-VSL value of 1.0 were used, then our estimates of benefit would increase dramatically. It could be argued that our approach to costing the price per surgery is less rigorous than a micro-costing approach. We are reassured, however, that our cost per surgery falls within the range found by a recent review of surgical cost in India (Chatterjee and Laxminarayan 2013). Our estimate suggests a price of roughly 40,000 rupees per surgery, which compares well with Chatterjee and Laxminarayan's study (2013), which found a range of cost for cesarean delivery (2,500 rupees to 41,000 rupees), hernia repair (5,200 rupees), endoscopic sinus surgery (53,000 rupees), and coronary artery bypass grafting (177,000 rupees).

The DALY age-weighting formula, although adjusted in this study to be more consistent with the VSL literature with regard to age when VSLY peaks, implies VSL curves that peak too early when compared with studies in the VSL literature (Aldy and Viscusi 2008). Consequently, our study may overestimate the VSL of children. The VSL of children is the subject of research; however, the available evidence suggests that the VSL is at least that of an adult, if not higher (Hammitt and Haninger 2010; Roman and others 2012).

Finally, a number of assumptions were used to estimate DALYs averted from cleft surgery. Although we attempted to be consistent with previous methods outlined in the surgical literature (Bickler and others 2010; McCord 2003), the nature of assumptions employed imparts a degree of uncertainty in our results that must be acknowledged.

### Future Research

This study examines a specific platform for delivery of surgical care—the surgical specialty hospital. As the global surgery community continues to consider the pros and cons of the various platforms, further economic analyses should be geared toward understanding the benefit and cost of the mission-based model of surgical care. An extensive debate regarding the pros, cons, and possibilities for improvement has taken place in the literature (Dupuis 2004; Farmer and Kim 2008; Meier 2010), yet a robust evidence base with objective outcome and economic data is lacking. A recently published study directly compares the mission-based model to the referral-center model (Rossell-Perry and others 2013). Using outcomes data from CLP operations performed by a single cleft surgeon in Peru in different settings (referral versus mission based), Rossell-Perry and others found a statistically significant difference in palatal fistula, postoperative hemorrhage, and wound dehiscence, with all occurring more frequently in the mission-based model. Although one cannot draw significant conclusions from one study based in one setting, this study should compel further comparative research that includes economic analyses in addition to outcome data.

### Conclusions on Cleft Lip and Palate Repair

In summary, we find that investment in a surgical subspecialty center dedicated to CLP repair can be a good economic proposition, and that it is possible to deliver high-quality, sustainable surgical care to underserved populations in LMICs. More broadly, we emphasize that BCA serves as a useful tool for evaluating the potential economic return on investments in global health, allows for the evaluation and discussion of projects both within and outside of global health academia, and facilitates comparisons of investment in health with projects in other governmental sectors. For these reasons, BCA should be applied more broadly in global health analysis, and this chapter demonstrates one manner in which this could be accomplished.

## BENEFIT-COST ANALYSIS OF CESAREAN DELIVERY FOR OBSTRUCTED LABOR

### Overview

Our second analysis illustrates a higher level (that is, a cross-country) application of the methods presented in the section on cleft lip and palate. Obstructed labor, defined by the WHO as labor in which "the presenting part of the fetus cannot progress into the birth canal, despite strong uterine contractions" (Dolea and AbouZahr 2003, 1), is among the most common causes of maternal death in LMICs (Khan and others 2006). Obstructed labor also results in significant morbidity, including obstetric fistula (Dolea and AbouZahr 2003), which is an abnormal communication between the rectum and vagina (rectovaginal fistula) or the bladder and vagina (vesicovaginal fistula). Beyond the substantial risks to physical health, victims of obstetric fistula are known to suffer from poor mental and social health because they are often banned from their homes and turned away from their communities (Wall 2006; WHO 2005).

The current morbidity and mortality posed by obstructed labor need not be so high, as evidenced by the fact that maternal death and fistula secondary to obstructed labor are rarely seen in HICs (Adler and others 2013; Lozano and others 2012). The sequelae of obstructed labor can be prevented by operative delivery of the fetus, which is most commonly via cesarean delivery (Dolea and AbouZahr 2003; Hofmeyr 2004; Neilson 2003). Timely diagnosis and treatment of obstructed labor with cesarean delivery requires access to emergency obstetric systems, which is unfortunately unavailable to most mothers in LMICs (Paxton and others 2006; Pearson and Shoo 2005). Good evidence suggests that access to emergency obstetric services correlates strongly with decreased maternal mortality (Islam, Hossain, and Haque 2005; Jamisse 2004; Kayongo and others 2006).

The past two decades have seen increased investments in global maternal health, with a consequent 34 percent reduction in maternal mortality rates since 1990 (Lozano and others 2011; WHO and others 2010). Although funding for maternal health in LMICs has increased, the distribution of the funding may not be appropriately aligned. Countries with the highest maternal mortality ratios do not receive a commensurate level of funding, and international aid organizations and governments continue to confront insufficient resources to address maternal health adequately (Pitt and others 2010).

Although the decision-making process behind allocation of financial resources by governments and NGOs is complex, economic evaluations, including BCA, can play an important role. This section evaluates the impact of treating obstructed labor with cesarean delivery across multiple regions, specifically examining countries that the WHO identifies as providing an insufficient number of cesarean deliveries to meet current demand (Gibbons and others 2010). We determine country-specific estimates of both the cost per DALY averted and the BCR for providing cesarean delivery in the context of obstructed labor. The DALYs averted refer only to the mother's experience from neglected obstructed labor, not that of her child.

A more comprehensive discussion of the epidemiology and treatment of obstructed labor and obstetric fistula is provided in chapters 5 and 6 in this volume, respectively, and in *Reproductive, Maternal, Newborn, and Child Health* in this series.

### Methods

For the estimations and calculations in this section, *obstructed labor* refers to cases that are neglected or left untreated. The section of this chapter on cleft lip and palate provides a complete discussion of DALYs, VSL, and how DALYs are valued using the VSL approach.

**Estimating the Incidence and Sequelae of Obstructed Labor and Obstetric Fistula.** The relevant population for this chapter is the estimated number of women who incurred obstructed labor in 2010 in 47 countries noted by the WHO as providing an insufficient number of cesarean deliveries (Gibbons and others 2010).

- To estimate the number of cases of obstructed labor, we used a modeling approach based on a recently performed review of the literature that estimates the global incidence of all cases of obstructed labor, including neglected and treated cases (Adler, Ronsmans, and Filippi forthcoming). Based on these data, we then estimated the incidence of neglected obstructed labor in a country using the estimated proportion of births in a health facility as a proxy for timely treatment of obstructed labor (UNICEF 2013); this modeling approach is based on methodology previously used by the GBD study (Dolea and AbouZahr 2003).

- To estimate the incidence of obstetric fistula and mortality secondary to obstructed labor, we relied on a recent meta-analysis that estimates the incidence of fistula in South Asia and Sub-Saharan Africa (Adler and others 2013). It is worth noting that the prevalence and incidence reported in Adler and others (2013) is lower than previous estimates (Wall 2006), likely because of a more rigorous selection criteria for study inclusion. For mortality estimates, we relied on estimates of mortality rates for South Asia and Sub-Saharan Africa from the GBD 2010 study (Lozano and others 2012). For these two regions, the total number of cases of neglected obstructed labor was estimated, and then cases of maternal death and obstetric fistula secondary to obstructed labor in these regions were divided by all cases of neglected obstructed labor to produce two ratios: maternal deaths per 1,000 cases of neglected obstructed labor and obstetric fistula per 1,000 cases of neglected obstructed labor. Given that maternal death and obstetric fistula should not occur if obstructed labor is treated appropriately—these sequelae are almost never seen in HICs—we calculated the country-specific incidence of these sequelae based on the estimated rate of neglected obstructed labor in a country.

We assume that if left untreated, obstetric fistula is a permanent sequela once present in survivors of obstructed labor. Probabilistic sensitivity analysis was employed for the following variables using Monte Carlo simulation: incidence of all cases of obstructed labor and fistula based on Adler's reviews (Adler and others 2013), and incidence of maternal mortality secondary to neglected obstructed labor based on GBD 2010 (Lozano and others 2012).

We apportioned the incidence of obstructed labor and its sequelae of maternal death and obstetric fistula according to seven maternal age groups: 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49. This was accomplished by (1) calculating the total number of births in each of these age groups for every included country in 2010; (2) dividing the number of births in each age group by total births to calculate the relative proportion each age group contributes to total births; (3) calculating the total number of cases of obstructed labor and its sequelae for all women ages 15–49 years; and (4) multiplying the age-specific proportions from (2) by the total number of cases of obstructed labor or its sequelae from (3). An important limitation of this approach is that it does not account for the relationship between parity and obstructed labor: younger women are thought to have increased rates of obstructed labor because they are more likely to be nulliparous.

**Establishing the Cost of a Cesarean Delivery.** As part of a background report for the 2010 *World Health Report*, the WHO estimated the unit cost of a cesarean delivery for countries that were identified as providing an insufficient quantity to meet demand (Gibbons and others 2010). The inputs for estimating cost included "initiation of labor at referral level, diagnosis of obstructed labor and referral, Caesarean delivery associated devices and medicines, operative facility time, medical human resources time, management of shock including hysterectomy and blood transfusion (assumed for 1% of CS performed), postoperative hospital stay for stabilization…program administration, training, and the corresponding office space, electricity and other services, as well as a variety of standard consumables and equipment" (Gibbons and others 2010, 6).

It is important to note that that study did not include cost associated with vaginal birth, such as clean cord practices and the presence of a birth attendant. To account for this omission, we identified studies that estimated the cost of a vaginal delivery in a health facility in countries in South Asia and Sub-Saharan Africa (Bhat and others 2009; Iyengar and others 2009; Levin and others 2003; Newlands and others 2008; Orach, Dubourg, and De Brouwere 2007; Quayyum and others 2010; Sarowar and others 2010). We established a range of values for the proportion of vaginal delivery cost to the WHO cesarean delivery cost, and we used this to adjust the WHO country-specific estimated cost of cesarean section to more appropriate values. We employed probabilistic sensitivity analysis over a range of vaginal delivery to cesarean delivery cost proportions using Monte Carlo simulation.

**Estimating Disability-Adjusted Life Years.** Not all cesarean deliveries are meant to address obstructed labor, and not all cases of obstructed labor are treated with cesarean delivery. We estimated that 80 percent of obstructed labor cases require cesarean delivery; the remaining 20 percent can be addressed with instrumental vaginal delivery. These latter cases are excluded from our analysis.

We estimated the number of DALYs that could be averted in the 47 countries included in the WHO cost study if 80 percent of the obstructed labor cases were prevented in a timely fashion with a cesarean delivery. Because cesarean delivery is assigned a disability weight by the GBD study and carries a risk of mortality (Souza and others 2010), we first calculated the gross number of DALYs that would be averted by preventing 80 percent of obstructed labor cases, and then subtracted the number of DALYs that would be incurred secondary to cesarean deliveries to arrive at the net DALYs averted.

This study used disability weights from the GBD study (Lopez and others 2006) to estimate DALYs secondary to cesarean delivery and obstetric fistula.

**Estimating the Cost per Disability-Adjusted Life Year Averted and the Benefit-Cost Ratio.** To estimate the total cost of providing the necessary number of cesarean deliveries to prevent the sequelae of obstructed labor, we multiplied the country-specific unit cost of a cesarean delivery by the number of cesarean deliveries required to treat 80 percent of the cases in that country. Once the total country-specific cost was calculated, we divided this cost by the total number of DALYs [0,0,0] that cesarean delivery for obstructed labor was estimated to avert. To calculate the BCA, we divided the country-specific economic benefit of treating obstructed labor by the total cost of providing the cesarean deliveries required to do so; the estimated benefit was based on valuing DALYs [3,1,$\tilde{\beta}$] averted with the VSL approach. This section uses an IE-VSL of 1.5 to transfer VSL estimates.

## Results

Table 21.3 presents the estimated number of cesarean deliveries necessary to treat 80 percent of obstructed labor in each country, along with the number of cases of obstetric fistula and maternal death that would be

**Table 21.3** Estimated Number of Cesarean Deliveries Required to Prevent 80 Percent of Obstructed Labor, with the Total Number of Preventable Obstetric Fistulas and Maternal Mortality, 2010

| Country | Caesarean deliveries[a] | Preventable obstetric fistulas | Preventable maternal mortality[b] |
|---|---|---|---|
| Algeria | 812 (441–1,400) | 6 (2–12) | 9 (8–11) |
| Bangladesh | 46,429 (25,247–80,086) | 362 (100–671) | 533 (460–609) |
| Benin | 958 (521–1,653) | 7 (2–14) | 11 (9–13) |
| Burkina Faso | 4,492 (2,443–7,748) | 35 (10–65) | 52 (44–59) |
| Cambodia | 3,524 (1,916–6,078) | 27 (8–51) | 40 (35–46) |
| Cameroon | 6,274 (3,412–10,823) | 49 (13–91) | 72 (62–82) |
| Central African Republic | 1,466 (797–2,528) | 11 (3–21) | 17 (15–19) |
| Chad | 9,479 (5,154–16,351) | 74 (20–137) | 109 (94–124) |
| Comoros | 270 (147–466) | 2 (1–4) | 3 (3–4) |
| Congo, Dem. Rep. | 13,855 (7,534–23,900) | 108 (30–200) | 159 (137–182) |
| Côte d'Ivoire | 5,728 (3,115–9,880) | 45 (12–83) | 66 (57–75) |
| Eritrea | 3,306 (1,798–5,702) | 26 (7–48) | 38 (33–43) |
| Ethiopia | 56,534 (3,0742–97,518) | 441 (121–817) | 649 (560–742) |
| Gabon | 154 (84–265) | 1 (0–2) | 2 (2–2) |
| Ghana | 5,195 (2,825–8,961) | 41 (11–75) | 60 (51–68) |
| Guinea | 5,093 (2,769–8,785) | 40 (11–74) | 58 (50–67) |
| Haiti | 4,109 (2,234–7,087) | 32 (9–59) | 47 (41–54) |
| India | 276,385 (150,291–476,747) | 2,157 (592–3,993) | 3173 (2,737–36,28) |
| Indonesia | 43,246 (23,516–74,597) | 337 (93–625) | 496 (428–568) |
| Kenya | 17,442 (9,485–30,087) | 136 (37–252) | 200 (173–229) |
| Lesotho | 471 (256–812) | 4 (1–7) | 5 (5–6) |
| Liberia | 1,877 (1,021–3,237) | 15 (4–27) | 22 (19–25) |
| Madagascar | 9,754 (5,304–16,824) | 76 (21–141) | 112 (97–128) |
| Malawi | 33,04 (1,797–5,699) | 26 (7–48) | 38 (33–43) |
| Mali | 7,165 (3,896–12,359) | 56 (15–104) | 82 (71–94) |
| Mauritania | 1,315 (715–2,268) | 10 (3–19) | 15 (13–17) |

*table continues next page*

**Table 21.3** Estimated Number of Cesarean Deliveries Required to Prevent 80 Percent of Obstructed Labor, with the Total Number of Preventable Obstetric Fistulas and Maternal Mortality, 2010 (continued)

| Country | Caesarean deliveries[a] | Preventable obstetric fistulas | Preventable maternal mortality[b] |
|---|---|---|---|
| Mongolia | 18 (10–31) | 0.1 (0–0.3) | 0.2 (0.2–0.3) |
| Morocco | 3,426 (1,863–5,910) | 27 (7–49) | 39 (34–45) |
| Mozambique | 8,194 (4,455–14,134) | 64 (18–118) | 94 (81–108) |
| Nepal | 8,879 (4,828–15,315) | 69 (19–128) | 102 (88–117) |
| Niger | 12,832 (6,978–22,134) | 100 (28–185) | 147 (127–168) |
| Nigeria | 85,159 (46,307–146,894) | 665 (183–1,230) | 978 (843–1,118) |
| Oman | 17 (9–30) | 0.1 (0–0.25) | 0.2 (0.2–0.2) |
| Pakistan | 57,141 (31,072–98,565) | 446 (122–825) | 656 (566–750) |
| Philippines | 26,402 (14,357–45,542) | 206 (57–381) | 303 (261–347) |
| Rwanda | 2,557 (1,391–4,411) | 20 (5–37) | 29 (25–34) |
| Senegal | 2,685 (1,460–4,632) | 21 (6–39) | 31 (27–35) |
| Sierra Leone | 2,233 (1,214–3,852) | 17 (5–32) | 26 (22–29) |
| Sudan | 20,044 (10,900–34,575) | 156 (43–290) | 230 (199–263) |
| Swaziland | 148 (81–256) | 1 (0–2) | 2 (1–2) |
| Tanzania | 18,198 (9,896–31,391) | 142 (39–263) | 209 (180–239) |
| Togo | 1,574 (856–2,715) | 12 (3–23) | 18 (16–21) |
| Tunisia | 394 (214–680) | 3 (1–6) | 5 (4–5) |
| Uganda | 13,035 (7,088–22,485) | 102 (28–188) | 150 (129–171) |
| Vietnam | 2,255 (1,226–3,889) | 18 (5–33) | 26 (22–30) |
| Yemen, Rep. | 11,957 (6,502–20,624) | 93 (26–173) | 137 (118–157) |
| Zambia | 5,844 (3,178–10,080) | 46 (13–84) | 67 (58–77) |
| Total | **811,629** | **6,334** | **9,318** |

*Note:* Table reports mean, with 95 percent uncertainty interval in parentheses.
a. Necessary to prevent 80 percent of obstructed labor.
b. Adjusted for mortality secondary to cesarean delivery.

prevented by providing cesarean delivery for obstructed labor. Maternal mortality is adjusted to account for mortality secondary to cesarean delivery. For the 47 countries, an estimated 815,000 cesarean deliveries would have prevented 6,300 cases of obstetric fistula and 9,400 maternal deaths. Table 21.4 presents the total cost of providing the necessary number of cesarean deliveries to prevent all cases of obstructed labor for the included countries in 2010. For each country, the total cost of providing cesarean deliveries for obstructed labor was then divided by the potential nondiscounted, non-age-weighted DALYs (notated as [0,0,0]) averted if all cases of obstructed labor were treated to create a cost per DALY averted. The average cost per DALY averted varied by country, ranging from US$243 to US$1,192 per DALY averted. The median cost per DALY averted was US$416.

Table 21.4 also presents the country-specific gross economic benefit of preventing obstructed labor. The mean total benefit across countries was estimated to be US$1.4 billion in 2010 dollars. The last column of table 21.4 shows BCRs for providing cesarean deliveries in each country, calculated by dividing the estimated economic benefit by the total cost of providing cesarean deliveries. The BCR ranges from 0.3 for the Democratic Republic of Congo to 75.5 for Gabon, with a median value of 4.0.

## Discussion and Recommendations

**Valuing Maternal Health Care.** The analysis in this section elucidates the cost and benefit of treating neglected obstructed labor with cesarean delivery across a number of disparate regions. We estimate that cesarean delivery for obstructed labor, depending on the country, costs US$243–US$1192 per DALY [0,0,0], with a median cost of US$416 per DALY for the 47 countries included in

**Table 21.4** Total Cost of Treating Obstructed Labor with Cesarean Delivery, Cost per DALY Averted, Gross Economic Benefit, and Benefit-Cost Ratio, US$, 2010

| Country | Total cost (thousands)[a] | Cost/DALY averted[b] | Gross economic benefit (thousands)[c] | Benefit-cost ratio[d] |
|---|---|---|---|---|
| Algeria | 245 (130–440) | 463 (214–924) | 7293 (5,400–9,300) | 33.6 (14.2–64) |
| Bangladesh | 7,590 (3,890–13,620) | 243 (112–484) | 45,702 (34,100–58,300) | 6.8 (2.9–13) |
| Benin | 207 (110–370) | 349 (161–696) | 677 (500–900) | 3.7 (1.6–7) |
| Burkina Faso | 1,012 (520–1,820) | 386 (178–770) | 2,752 (2,100–3,500) | 3.1 (1.3–5.9) |
| Cambodia | 812 (420–1460) | 364 (168–726) | 4,221 (3,100–5,400) | 5.9 (2.5–11.2) |
| Cameroon | 1,325 (680–2,380) | 363 (167–724) | 7,759 (5,800–9,900) | 6.6 (2.8–12.6) |
| Central African Republic | 356 (180–640) | 551 (253–1103) | 361 (300–500) | 1.1 (0.5–2.2) |
| Chad | 1,967 (1,010–3,530) | 350 (161–698) | 5,647 (4,200–7,200) | 3.2 (1.4–6.2) |
| Comoros | 61 (30–110) | 407 (188–813) | 118 (100–200) | 2.5 (1–4.7) |
| Congo, Dem. Rep. | 4,415 (2,260–7,920) | 581 (267–1159) | 1,106 (800–1400) | 0.3 (0.1–0.5) |
| Côte d'Ivoire | 1,314 (670–2,360) | 395 (182–789) | 5,773 (43,00–7,400) | 5 (2.1–9.5) |
| Eritrea | 978 (500–1,760) | 547 (252–1092) | 435 (300–600) | 0.5 (0.2–1) |
| Ethiopia | 14,214 (7,290–25,510) | 452 (208–902) | 21,257 (15,800–27,200) | 1.7 (0.7–3.2) |
| Gabon | 80 (40–140) | 901 (415–1798) | 2,665 (2,000–3,400) | 37.4 (15.8–71.4) |
| Ghana | 1,410 (720–2,530) | 454 (209–905) | 4,322 (3,200–5,500) | 3.5 (1.5–6.6) |
| Guinea | 1,249 (640–2,240) | 416 (192–830) | 1,749 (1,300–2,200) | 1.6 (0.7–3) |
| Haiti | 1,009 (520–1,810) | 667 (305–1338) | 1,570 (1,200–2,000) | 1.8 (0.7–3.4) |
| India | 49,033 (25,150–88,000) | 279 (129–557) | 716,631 (534,700–914,300) | 16.5 (7–31.5) |
| Indonesia | 10,777 (5,530–19,340) | 395 (182–787) | 150,723 (112,400–192,300) | 15.8 (6.7–30.1) |
| Kenya | 3,973 (2,040–7,130) | 371 (171–741) | 14,498 (10,800–18,500) | 4.1 (1.7–7.9) |
| Lesotho | 150 (80–270) | 685 (314–1,369) | 527 (400–700) | 4 (1.7–7.6) |
| Liberia | 509 (260–910) | 482 (222–962) | 232 (200–300) | 0.5 (0.2–1) |
| Madagascar | 2,198 (1,130–3,950) | 381 (175–760) | 3,464 (2,600–4,400) | 1.8 (0.8–3.4) |
| Malawi | 752 (390–1,350) | 452 (208–903) | 949 (700–1,200) | 1.4 (0.6–2.7) |
| Mali | 1,528 (780–2,740) | 378 (174–754) | 3,484 (2,600–4,500) | 2.6 (1.1–4.9) |
| Mauritania | 337 (170–600) | 439 (202–875) | 1,814 (1,400–2,300) | 6.1 (2.6–11.6) |
| Mongolia | 6 (0–10) | 552 (254–1,101) | 58 (0–100) | 9.7 (4.1–18.5) |
| Morocco | 867 (440–1,560) | 391 (180–780) | 13,974 (10,400–17,800) | 18.2 (7.7–34.7) |
| Mozambique | 1,900 (970–3,410) | 452 (208–902) | 2,587 (1,900–3,300) | 1.5 (0.6–2.9) |
| Nepal | 1,684 (860–3,020) | 283 (130–563) | 5,765 (4,300–7,400) | 3.9 (1.6–7.4) |
| Niger | 2,923 (1,500–5,250) | 386 (178–770) | 2,359 (1,800–3,000) | 0.9 (0.4–1.7) |
| Nigeria | 20,988 (10,770–37,670) | 422 (194–842) | 106,203 (79,100–135,600) | 5.7 (2.4–10.9) |
| Oman | 14 (10–30) | 1,192 (550–2,376) | 941 (700–1200) | 75.7 (32–144.4) |
| Pakistan | 17,413 (8,930–31,250) | 489 (225–976) | 107,143 (79,900–136,700) | 7 (2.9–13.3) |
| Philippines | 6,315 (3,240–11,330) | 365 (168–728) | 85,589 (63,900–109,200) | 15.3 (6.5–29.2) |
| Rwanda | 577 (300–1040) | 379 (175–756) | 1,278 (1,000–1,600) | 2.5 (1.1–4.8) |
| Senegal | 557 (290–1,000) | 343 (158–684) | 2,664 (2,000–3,400) | 5.4 (2.3–10.3) |
| Sierra Leone | 525 (270–940) | 416 (191–829) | 978 (700–1,200) | 2.1 (0.9–4) |

*table continues next page*

**Table 21.4** Total Cost of Treating Obstructed Labor with Cesarean Delivery, Cost per DALY Averted, Gross Economic Benefit, and Benefit-Cost Ratio, US$, 2010 (continued)

| Country | Total cost (thousands)[a] | Cost/DALY averted[b] | Gross economic benefit (thousands)[c] | Benefit-cost ratio[d] |
|---|---|---|---|---|
| Sudan | 5,750 (2,950–10,320) | 437 (202–872) | 20,130 (15,000–25,700) | 4 (1.7–7.5) |
| Swaziland | 52 (30–90) | 796 (365–1,592) | 571 (400–700) | 12.5 (5.2–23.9) |
| Tanzania | 4,281 (2,200–7,680) | 406 (187–810) | 12,029 (9,000–15,400) | 3.2 (1.3–6.1) |
| Togo | 316 (160–570) | 340 (157–679) | 473 (400–600) | 1.7 (0.7–3.2) |
| Tunisia | 220 (110–400) | 831 (383–1,657) | 4,457 (3,300–5,700) | 22.8 (9.6–43.6) |
| Uganda | 3,381 (1,730–6,070) | 455 (209–907) | 6,301 (4,700–8,000) | 2.1 (0.9–4) |
| Vietnam | 587 (300–1,050) | 357 (165–710) | 5,172 (3,900–6,600) | 9.9 (4.2–19) |
| Yemen, Rep. | 3,105 (1,590–5,570) | 446 (206–891) | 19,918 (14,800–25,400) | 7.2 (3.1–13.8) |
| Zambia | 1,583 (810–2,840) | 518 (238–1,034) | 3,627 (2,700–4,600) | 2.6 (1.1–4.9) |
| Median | n.a. | 416 | n.a. | 4.0 |

*Note:* n.a = not applicable. Table reports mean, with 95 percent uncertainty interval in parentheses.
a. Total cost to treat 80 percent of cases of neglected obstructed labor with cesarean delivery.
b. The cost per DALY averted using [0,0,0] assumptions. See text for explanation.
c. Estimated by valuing DALYs [3,1,$\tilde{\beta}$] with value of a statistical life year.
d. Benefit-cost ratio calculated by dividing gross economic benefit by total cost.

this study. These estimates compare favorably with the costs reported in chapter 18 of this volume, which summarizes the global surgery cost-effectiveness literature. Using WHO guidelines (WHO 2002), cesarean delivery for obstructed labor is highly cost-effective in the vast majority of countries, and cost-effective in all included countries.

The BCRs in table 21.4, however, convey the main message of this section: the BCR is greater than 1 for nearly every country examined. The exceptions are the Democratic Republic of Congo, Eritrea, Liberia, and Niger, most of which have relatively high costs per DALY averted. These results suggest that devoting appropriate financial resources to cesarean delivery can combat the catastrophic health consequences to mothers in an economically favorable fashion. Indeed, the median BCR for the 47 countries included in our study is 4:1, which represents an excellent return on investment. Our headline results are also our most conservative; we used the largest IE-VSL value (1.5) reported in the literature, which significantly reduces the estimated benefits (see the section of this chapter on cleft lip and palate for more detail regarding the IE-VSL). Even the four countries mentioned above would have BCRs greater than 1 if the more commonly used assumption of IE-VSL = 1 were used.

**Implications of Results.** Our results have potentially meaningful implications for all involved stakeholders within the continuum of maternal and newborn care. We first emphasize for potential donors and NGOs the relative cost-effectiveness of cesarean delivery for obstructed labor in comparison with the WHO's per capita income thresholds. We are not the first to suggest that surgical care can be cost-effective, but our results add to the burgeoning evidence base.

Our data further suggest that when prioritizing budgeting of different sectors, governments should recognize that investment in health care can achieve net-positive economic benefits, as indicated by BCRs greater than 1. Specifically, allocating appropriate levels of funding for providing the suggested minimum of emergency obstetric care, considered within the broader context of maternal health care, is a good economic proposition in the vast majority of countries investigated.

It is crucial to note that cesarean delivery is not a panacea. Indeed, the overuse of the procedure in many HICs, along with the associated cost, has been well documented (Gibbons and others 2010). This chapter assesses cesarean delivery in the context of obstructed labor, in which there is a well-defined role for operative delivery. The results of this chapter do not imply that cesarean delivery is always cost-effective; they do suggest, however, that when used appropriately, the economic benefits of the procedure can outweigh the cost.

We also emphasize that we are not advocating vertical programming aimed at providing cesarean delivery or emergency obstetric care in isolation; experience tells us that properly functioning health systems must be in place for mothers to receive appropriate, high-quality care (Maine 2007). The current focus on packages of interventions that are integrated into a functioning health system are envisioned such that women in need of an emergent cesarean delivery are aware of facilities available, are properly diagnosed, are transported to a referral hospital within a reasonable amount of time, and undergo safe cesarean delivery in a capable facility (Fournier 2009; Nyamtema, Urassa, and van Roosmalen 2011). In this broader context, our argument is that cesarean delivery—as part of a larger strategy—can address maternal mortality in an economically favorable fashion.

### Study Limitations

The analysis in this section has a number of important limitations. Our methodology rests on the overly simplified assumption that a lack of surgical capacity is the major driver of preventable morbidity and mortality. We may have overestimated the potential benefit of cesarean delivery given other barriers, such as a lack of timely diagnosis and poor transportation infrastructure, that are known to play a role in neglected obstructed labor (Chhabra, Gandhi, and Jaiswal 2000; WHO 2005). However, our calculated BCRs suggest that surgical intervention would still be beneficial even if the number of cesarean deliveries successfully performed were far fewer than the perfect rate we have assumed. At our median estimate of the BCR, surgical intervention would still break even if only 25 percent of the potentially preventable DALYs were actually averted.

A critique of the methods used for placing a dollar value on DALYs is presented elsewhere (Alkire and others 2011; Warf and others 2011). There is uncertainty regarding transfers of VSL estimates to low-income countries for which formal studies are lacking (Hammitt and Robinson 2011), but we have minimized the risk of overvaluing a DALY by using an IE-VSL of 1.5. In fact, our estimates of BCRs are possibly too conservative as a result of using the lower-bound estimate of IE-VSL for valuing DALYs. Most important, our analysis does not account for the benefit of reducing perinatal mortality and morbidity with improved access to cesarean delivery. The perinatal mortality rate as a result of neglected obstructed labor depends on the case series, but ranges from 38 percent to 92 percent (Hofmeyr 2004; Melah and others 2003; Neilson 2003). Finally, there is uncertainty regarding the true number of maternal deaths and fistula worldwide and the contribution that obstructed labor makes to that number; we have attempted to account for this uncertainty with probabilistic sensitivity analysis.

## CONCLUSIONS

A case could easily be made for addressing obstructed labor from a strictly humanitarian perspective, yet some continue to suggest that surgery is a luxury. This section demonstrates that investment in cesarean delivery is not only cost-effective; it can yield a net positive economic return within the context of a horizontally functioning health system. More broadly, the analyses used in this chapter can be applied to other interventions and are crucial for better-informed investments in global health care delivery.

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## NOTES

The World Bank classifies countries according to four income groupings. Income is measured using gross national income (GNI) per capita, in U.S. dollars, converted from local currency using the *World Bank Atlas* method. Classifications as of July 2014 are as follows:

- Low-income countries (LICs) = US$1,045 or less in 2013
- Middle-income countries (MICs) are subdivided:
  - Lower-middle-income = US$1,046 to US$4,125
  - Upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs)= US$12,746 or more

1. The World Bank: Open Data. http://data.worldbank.org/.
2. United States Environmental Protection Agency. "Frequently Asked Questions on Mortality Risk Valuation." http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/mortalityrisk valuation.html.

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