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Abstract

Background: The Solidarity Bridge Medical Program (SBMP) supplies surgical tools and instrumentation to the underserved populations of Bolivia, Latin America's poorest nation. Through collaborative work with in-country social workers and public hospital surgeons, patients that live in deep poverty and otherwise could not afford the cost of treatment are selected to receive necessary instrumentation as determined by licensed physicians.

Purpose: The purpose of this study was to examine the cost-utility of neurosurgical and pacemaker interventions for select populations in two major Bolivian cities, provided by SBMP.

Methods: From September 2010 to January 2011, approximately 36 pacemaker patients and 21 neurosurgery patients were interviewed both pre- and post-operatively. Included in the surveys were general demographic information as well as retrospective and prospective symptomatic data, self-assessment of overall health, and functional restrictions/limitations that affect patient health utility (or quality of life). Utility data for the neurosurgical program was derived from the standardized HUI-3, while utility data from the pacemaker program was modeled after the EQ-5D. Some modifications were necessary in both sets of collection due to cultural and situational barriers associated with the patient population. Cost information was collected from financial records of Solidarity Bridge as well as during patient surveys. Cost-utility results were analyzed to determine whether or not the program(s) is/are effective.

Results: With varying times of post-operative follow-up, patients in both programs, on average exhibited an increase in overall health classification and decrease in associated symptoms and functional limitations. Neurosurgery patients reported a mean increase of 4.45 on their overall health evaluation (scale from 1-10) from pre- to post-operatively, with 94% of patients exhibiting an overall increase in quality of life. The cost-utility of SBMP neurosurgical intervention at 2yrs assuming a 94% retention rate, 5yrs with 94% retention rate, and 5yrs with 50% retention rate was approximately $1,395/quality-adjusted life years (QALY), $2,664/QALY, and $11,112/QALY, respectively. The cost-utility under the same conditions for pacemaker implementation was $3,725/QALY, $2,193/QALY, and $9,155/QALY, respectively. Additionally, pacemaker patients reported an average increase of 4.57 on the same overall health evaluation, with 97.22% of them displaying an increase from their pre- to post-operative state.

Conclusion: In both the neurosurgery and pacemaker programs, there was a statistically significant increase in mean satisfaction and mean utility post-operatively ($p<.0001$). According to WHO threshold values for cost-effectiveness in Bolivia, the extrapolated values from both neurosurgery and pacemaker subgroups are considered highly cost-effective at 2- and 5-year intervals. If retention were lowered to 50% (from 94% observed in our subgroup), both programs would still be considered cost-effective at 2- and 5-year intervals. Further data collection and analysis with a larger cohort is necessary to improve strength and accuracy of these figures.

Introduction:

Solidarity Bridge (SB) is a non-profit organization that, among other things, provides a Medical Program that supports an ongoing partnership between American and Bolivian healthcare. This program provides medical supplies (mostly surgical) for underserved populations in addition to conducting mission trips for American medical personnel to travel and work hands-on in Bolivian hospitals alongside local medical teams. The two subfields of the SB Medical Program (SBMP) upon which this study is focused, include the Pacemaker Program (the largest subgroup of the Medical Program) and the Neurosurgery Program (Hinojosa, 2011).

Bolivia is a country of extreme poverty, possessing the lowest GDP in South America and the second lowest (behind that of Haiti) in the western hemisphere. According to data from the World Health Organization, only 26% of the population is covered by the health insurance system (World Health Organization, 2007). The purpose of the SB Pacemaker Program is to provide life-saving pacemakers to patients who require them but cannot afford their high costs. Likewise, the Neurosurgery Program provides surgical instrumentation for spine, head, and neck patients that require but cannot afford the necessary materials. Because medical resources are so scarce in Bolivia even with the assistance of SBMP, cost-utility and cost-effectiveness analysis of the programs that do exist can provide much help in guiding these resources towards their most efficient uses (Neumann, 2004).

This study was designed to examine the patient demographics, overall health outcomes, and general cost breakdown of each program. I utilized cost-utility and some cost-effectiveness analysis in an attempt to focus some debate and analysis upon the overall value of the program, as well as explain where and why some weaknesses to its overall effectiveness may be. Through rigorous fieldwork and established analytical techniques, I sought to determine whether SB intervention with pacemaker and neurosurgery instrumentation is indeed cost-effective.

Materials and Methods:

With approval from Northeastern University Human Subjects Research Protection, I traveled to Cochabamba and Santa Cruz, Bolivia for the Summer 2/Fall 2010 co-op period for data collection (I primarily stayed in Cochabamba, making three short trips to SC). Before this trip, I spend a Summer 1 semester at NU preparing for research with advisors from NU and University of Massachusetts Medical School (UMass Med). This preparation included literature searches and weekly reports on subjects pertaining to cost-utility and cost-effectiveness analysis, medical research in developing nations, the Bolivian health care system altogether, and other subjects that would prove useful in my completion of the actual field data collection (Craig R. Mitton 1999) (Jürgen Graf 2005) (Gillian D. Sanders 2005) (Laijun Song 2008) (Ganiats 1994) (Nicole Schwab 2004) (Robert Beaglehole 2008) (Sidney Chocron 1996).

While in Bolivia, I interviewed approximately 37 SB pacemaker recipients and 21 recipients of SB neurosurgical instrumentation from September, 2010 to January, 2011. Surgeries were performed at Hospital Viedma in Cochabamba, Bolivia along with Hospital Municipal San Juan de Dios, Hospital Universitario Japonés, and Hospital Oncologico in Santa Cruz, Bolivia. Patient ages ranged across a 60 year span from 19 to 79 yrs. and surgeries dated from Jan 2008 to the Dec 2010. The interviews covered

topics regarding demographic information, states of current and prior health, and overall cost incurred. In addition to questions derived from the analytic methods for determining health utility (HUI-3 & EQ-5D- these are described in more detail later), I asked patients about specific symptoms that are commonly seen in patients who receive each respective treatment for possible use as health markers. Two neurosurgeons from University of Massachusetts Medical School, Richard Moser, M.D., FACS, and Jared Ament, M.D., M.Sc. assisted greatly in developing and overseeing the project along with my Northeastern honors research advisor, Gail Begley, Ph.D. Dr. Moser provided me with easy access to communication and coordination within the Solidarity Bridge organization as he is an active U.S. board member, while Dr. Ament primarily advised in developing the interview forms for both programs. In addition to these contributors, Dr. Maria Avendaño who works as a SB-affiliated cardiologist in Cochabamba, provided further guidance for the overall (Spanish) translation, format, and content of our interviews with patients receiving pacemaker intervention. The goal of my fieldwork in Bolivia was to monitor the health of the patients, interviewing them pre- and post-operatively whenever possible. I collected retrospective data from patients that had already undergone surgery or for some reason could not be reached beforehand for prospective data collection.

In order to conduct the patient interviews, I took Spanish classes both before departing for the trip in addition to taking intensive immersion course for the first seven weeks of my stay in Bolivia at the Maryknoll Language Institute in Cochabamba (Ortega, 2011). Approximately 85% of Bolivia's population is of indigenous (Amerindian) or mestizo (mixed Amerindian and white) descent and while the country's national language is Spanish, some of its people speak only indigenous languages- predominantly Quechua and/or Aymara (Central Intelligence Agency, 2011). To account for this, a SB social worker fluent in Quechua and Spanish assisted me with any interviews that needed translation (all patients/interviewees fluently spoke either Spanish or Quechua).

To qualify for SB assistance, patients must first undergo an interview with a SB social worker to confirm financial need as well as obtain a licensed physician's referral that the SB equipment is necessary or highly recommended for further treatment. The social worker interview includes a visit to the patient's house and a series of questions for the patient and other family members or friends if possible. These interviews already included much of the demographic information used in this study such as family and socioeconomic data. The additional demographic information that we desired was supplemented into patient interviews over the five month period of data collection. During my stay in Bolivia, I worked with SB social workers to call patients from 2008-2010 who were going to receive or had already received SB instrumentation (and had listed phone numbers or contact information) and schedule an interview. The social workers and I would either ask if they could come in to the SB office for the interview or more often we simply traveled to visit patients at their homes for a follow-up interview. For those patients that could be reached by phone but lived too far for an in-person interview, I conducted an interview over the phone. If the patient was not capable of being interviewed for health reasons, the social workers and I would ask family members or friends listed as patient contacts to respond on the patients behalf.

Finally at the end of each interview, I asked patients to quantitatively describe their overall state of health from a scale of 1-10, with a 1 assigned as extremely poor health, near death, and a 10 being

perfect, symptom-free health. This was certainly a confusing question for many patients, and needed to be explained a few times over before receiving any response. I conducted simple pre- and post-operative comparison of these numbers to provide an idea of whether or not the patients felt that their overall health had improved or declined since SBMP intervention and by how much. I used these results as a comparison to determine whether or not they correlated with patterns from the standardized health utility figures.

Health Utility

I collected patient-utility data during interviews via a set of questions aimed towards defining specific health attributes as they applied to each patient's condition. Using the standardized Health Utilities Index-3 (HUI-3), I worked along with Dr. Ament to categorize patient responses into numerical figures representing their overall health-utility before and after surgery (David Feeny, 1995). The traditional HUI-3 uses eight separate categories to describe overall health state: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. Although not all of these categories represented the symptoms that were affecting our patients, they were scored according to how they applied to each individual patient. Symptoms that did not affect patients were scored as perfect health for that category; for example vision problems did not exist for any neurosurgery patients and was therefore scored as perfect vision before and after the intervention. In order to prepare interview responses for incorporation into analysis, patients were often provided with a list of choice answers to select which best described their situation.

The interviews for neurosurgery and pacemaker patients were quite similar, although a few of the questions regarding symptoms varied between them. After learning how to conduct the analysis on neurosurgery data with Dr. Ament, I was then able to translate these methods into analyzing the pacemaker program data in the same way. In addition to using the HUI-3 analysis format, for the pacemaker data I also included the EuroQol-5D Health Questionnaire (Rosalind Rabi, 2001) as an alternative analytical method. I included this method because it seemed to more accurately describe the symptomatic issues associated with patients requiring pacemakers and therefore could potentially describe their health states more accurately than the HUI-3. The EQ-5D evaluates five separate categories that together define the overall health state- mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each category is evaluated with a number from 1-3, where 1 represents a healthy/normal state for that category (for example in the pain/discomfort category, a 1 would signify that the patient does not experience any pain or discomfort), a 2 represents some problems in that category, and a 3 represents the most severe form of impairment in that category (for example a 3 in the mobility category would mean the patient cannot walk and is confined to bed). Comparison of results from this analytic technique with those from the HUI-3 should provide some supplemental knowledge as to whether or not they are both accurately describing the results from our patient cohort.

Dr. Ament and I compared pre-and post-operative health utility values derived from HUI-3 and EQ-5D measurements for each patient, providing overall health utility improvement figures (Andrew Garratt 2002). These utility improvements were assumed to remain constant throughout the patients'

lives as we do not have any data to suggest otherwise due to time and financial constraints. The base case scenario is assumed to be consistent with patient health states before surgery, as there is little other treatment offered to patients that cannot afford to undergo pacemaker implantation. Because SBMP only donates to patients that absolutely cannot afford the procedure, there is no reason for us to expect that their health condition would improve without SBMP surgical intervention.

Complications that were experienced by neurosurgery patients were generally due to further physical trauma such as falling or experiencing an accident, and these data were incorporated into the health-utility analysis if they either required further surgical treatment or provoked fatality. In cases that required further surgical treatment due to complications, health utility data were collected for the patient's condition before and after each surgical procedure. The only consistent complication experienced by pacemaker recipients that required further surgical treatment was battery replacement, as the pacemakers donated by SBMP normally require a new battery after approximately 3-5 years of use. Dr. Ament and I incorporated these complications (including patient mortality) into an expected value decision tree based upon their identity and cause and applied them to the retention figures. Complications that did not cause either further treatment or patient mortality were noted but not compensated for in how they affected health utility. These included all medical complications, regardless of whether or not they are typically associated with the patient's specific conditions. While many of these complications and their subsequent outcomes may not be causally related to the specific SBMP intervention, we considered those that existed among our cohort to be representative of the environment in which SBMP is operating. Thus in reporting the effectiveness of SBMP intervention, they should impact the cost and utility results accordingly.

Once Dr. Ament and I organized the figures for health-utility results, he recommended the following formula to me for extrapolation of Quality-Adjusted Life Years (QALYs) for each patient scenario at 1, 2, and 5-year intervals (Phillips 2009)(Marthe Gold 1996):

Equation 1:
$$QALY = \sum_{x=1}^{2} \frac{t^x u_2}{(1+d_q)^x} - \sum_{x=1}^{2} \frac{t^x u_1}{(1+d_q)^x}$$

x= time, u_1= post-operative utility value, u_2= pre-operative utility value, t= patient retention rate, d_q= discounting value

At each time interval in Equation 1 the u_1 summation value represents the base-case scenario, which is subtracted from the u_2 summation value to obtain the increase or decrease in QOL that surgical intervention provides (a positive value for Eq. 1 would represent an increase in QOL, whereas a negative value would signify that the patient's QOL has decreased after undergoing surgical intervention).

Dr. Ament conducted the QALY analysis for all spinal patients (not including some neurosurgery patients, such as those sustaining aneurysms) because of our time goal to submit the data to the American Association of Neurosurgery 2011 Annual Conference. In doing this however, Dr. Ament was able to teach me the analytical methods that I then used to analyze the entire neurosurgery data set (which was surprisingly similar to results from just the spinal cohort) as well as all of the data from the pacemaker program.

Discounting

Per recommendation from Dr. Ament, he and I both used a compounding discount (d_q) value of 3% per year for the utility and costs data extrapolation. This is a common d_q value in QOL studies that use similar methodology and lately has been used more frequently in cost-utility analysis than the other popular value of 5% (Marthe Gold 1996). Discounting in general addresses the fact that both outcomes and costs are generally valued not only by their overall effect or amount, but also by the time in which they are received. Any health outcomes that patients can experience *now* are valued slightly more than the same exact outcome one year from now, which is valued slightly greater than 2 years from now, and this continues compounding itself each year that it projects into the future. Likewise from a cost standpoint, society values money higher that is earned/spent in the present than money that can or will be earned/spent one year from now and so on (Johan L. Severens 2004).

Retention

For the retention rates (t), Dr. Ament and I performed our calculations with a value of 94% and again with a value of 50%. The 94% retention rate represents the percentage of patients we were able to contact that received SBMP neurosurgical intervention and were still alive (we spoke with the family members of patients that had passed away). So far, there had been no record of any patients who received pacemaker intervention that had passed away, however it is reasonable to assume that some still may have passed away but not reported it to SBMP.

While 94% retention accounts for patient deaths *reported* to SBMP, many patients have not been spoken for regarding their current health condition because they were not able to be contacted during the study. In an effort to be a bit more conservative, we lowered our hypothesized retention rates to just 50% of patients and recalculated QALYs for comparison. This method assumes that out of all of the patients that receive SBMP equipment (pacemakers or neurosurgical instrumentation) at any given time interval, 50% of them have either died or experienced some complication that causes them not to receive the typical benefits experienced by patients without complications. For pacemaker patients this could include requiring but not receiving a battery change or rhythm adjustment (although these procedures are provided by SBMP-affiliated clinics at a discounted price and occasionally without any charge if they patient cannot afford payment). We assume that while these patients do not experience the benefits of treatment, the cost of their treatment remains unaffected, increasing the average cost/QALY across the entire cohort.

Costs

I investigated all associated cost information during my time in Bolivia through examining SB financial records, speaking with SB employees including the founder and Director of SB, Juan Lorenzo-Hinojosa, as well as directly asking patients and hospital staff about their costs. Many costs were given to me in American dollars, but I converted those that were in Bolivianos to American dollars using the current exchange rate of 1USD:6.95 Bolivianos (Currency Converter 2011). To more accurately

represent what these costs mean to the people/organizations that are spending them, I then converted all costs to international dollars per recommendation by the WHO when conducting cost-effectiveness/utility analysis (T. Tan-Torres Edejer 2003). International dollars are an international currency unit developed to represent the purchasing power that $1USD has in the United States. This is different than simply converting to USD, because the conversion to international dollars accounts for the fact that $1 USD will likely be able to purchase either more or less in the United States than it would be in other countries. These values are obtained via multiplying currency units by the respective country's Purchasing Power Parity (PPP), which is widely defined as such that when the price of single homogeneous commodity or basket of homogeneous goods is converted into the home currency, the price is the same as in the home country (Su 2005). According to the most updated PPP of Bolivia, $1 USD can purchase more in Bolivia than it can in the United States. For our analysis, I multiplied any costs incurred by patients, hospitals, or organizations in Bolivia by Bolivia's 2005 PPP of 2.84 (this was the most updated figure given by WHO) (World Health Organization 2011). Costs incurred by U.S. sources however, such as donated surgical materials from U.S. organizations, were not multiplied by Bolivia's PPP because they represent money that was "spent" (not actually spent, but incurred via product donation) in the U.S. and should not be considered the same as a cost incurred in Bolivia or by a Bolivian organization (T. Tan-Torres Edejer 2003).

After determining both the cost and QALY figures for both programs at each time interval, Dr. Ament and I simply divided each cost by its respective incremental-QALY figure for 2- and 5- year intervals, both at 94% and 50% retention rates. These figures provide the extrapolated cost/QALY values under their given conditions and can be used as projections for how the program is functioning. To determine whether or not the results of these values are cost-effective, I referred to the WHO regional threshold values for cost-effectiveness (World Health Organization 2011). According to these data, Bolivia is categorized under the America D region based upon its economic status. The cost-effectiveness threshold values for all countries categorized into this region are as follows: interventions that cost less than $4,806/QALY are considered very cost-effective, those that cost between 4,806 and $13,823/QALY are considered cost-effective, and those that cost more than $13,823 are not cost-effective.

Results and Discussion

Pacemaker Demographics

Approximately 101 patients have undergone SBMP pacemaker intervention in Cochabamba and Santa Cruz, Bolivia in 2010, while over 1,000 have been donated since 2001 (Hinojosa 2011). Of those receiving donations in 2010, I was able to contact and survey 36 patients, 15 males and 21 females, throughout my time in Bolivia. Patient ages spanned across a 50-year range, from the youngest at 29 yrs. to the eldest of 79 yrs., with a mean age of ~58 yrs. On average, these patients lived with at least four other members in the same household, however just under half of the patients were employed at any time before or after surgery. When asked their highest level of education, roughly 27% of patients reported obtaining a high school diploma. Almost half of the patients have not finished basic primary school. The average combined family income (including any financial support provided by friends or

family members, i.e. spouses, children, parents, etc.) was roughly $2,337 USD; just under half of the estimated national per capita GDP of $4800 (Table 1) (Central Intelligence Agency 2011).

Neurosurgery Demographics

For the neurosurgery program, I conducted interviews with 21 patients who had undergone at least one SBMP neurosurgical intervention within the years 2008-2010. The average age of this cohort was significantly younger than that of the pacemaker cohort, with an average age of ~37yrs. More than 2/3 of the patients were male and just over half were unmarried (including the 4 patients living in concubine). The number of children for neurosurgical patients was also much lower with a mean of 1.6, however these patients on average lived with between 4 and 5 members in their home. Less than half of these patients reported receiving a high school diploma; however 3 patients were active students before they required SBMP intervention. While a much higher percentage of patients were actively employed before requiring SBMP intervention, the mean salary was lower than that of the pacemaker cohort, at just $1,689 per year (Table 1). As noted before however, this represents the total combined salary of the patient and any friends or family members who contribute with the patient's medical expenses.

Table 1: Patient Demographics

Category	Pacemaker Patients	Neurosurgery Patients
# of Patient Interviews	36	21
Mean Age	58.3	36.9
Sex	15= Male 21= Female	15= Male 6= Female
Marital Status	21= Married, 5= Divorced, 4= Widowed, 3= Single, 1= Separated, 2= Concubine (or Civil Union)	9= Single, 4= Married, 4= Concubine (Civil Union), 2= Separated
Average # of Children	4.2	1.6
Average # of People Living in Home (including patient)	5.0	4.4
Mean Highest Level of Education Reached (1= No formal schooling, 2= Less than primary school, 3= Completed primary school, 4= High School Diploma, 5= University/post-secondary education)	2.77	3.11
Employed? (Before any health issues that were treated with SBMP intervention)	17= Yes 17= No 2= Retired	13= Yes 5= No 3= Student
Annual Salary (includes salaries of all members who contribute to medical expenses- i.e. spouses, children, parents, siblings, etc.)	$2337.21 (USD)	$1,689

Pacemaker Costs and Health-Utility (QALYs)

Health utility values showed a consistent increase among pacemaker patients using both HUI-3 and EQ-5D methodology, from pre- to post-implantation (Table 2). Of the 36 patients evaluated, 34 (94.4%) exhibited an overall health utility increase according to the EQ-5D scale, 33 (91.7%) exhibited an overall health utility increase according to the HUI-3 scale, and 35 reported an increase when asked to rate their overall health from 1-10. The EQ-5D method, which uses a health utility scale ranging from 0-1 (0=dead, 1=alive with perfect health), displayed a mean utility difference from pre- to post-operative health utility of 0.650 in the 5.8 months after implantation (average time at which patients were interviewed). Similarly, using the HUI-3 method, the same cohort of patients under the same conditions displayed a mean difference from pre- to post-implantation of 0.513.

Table 2: Pacemaker Mean Health Utility Values Over 5.8-Month Average Time Interval

Health-Utility Analysis Technique	**Mean Pre-Operative Value**	**Mean Post-Operative Value**	**Mean Gain (Pre- to Post-Op)**
EQ-5D Utility Score	0.077	0.727	*0.650*
HUI-3 Utility Score	0.286	0.799	*0.513*
Self-Assigned Health Classification (0 = dead, 10 = perfect health)	3.17	7.74	*4.58*

The SBMP uses a systematic socioeconomic method of choosing only those patients that are in the lowest financial stratum of Bolivia to receive donated pacemakers. The Bolivian public health care system rarely covers the costs of a pacemaker for patients that require them, and therefore SBMP only elects those patients that both need pacemakers and have absolutely no means of obtaining them. Because this is the reality of the selected population, the costs and health gains associated with SBMP pacemaker intervention are compared with a quite pessimistic base-case scenario that includes zero cost and zero health gain from the pre-operative state. I have neither knowledge nor data pertaining to other possible treatments for Bolivian patients requiring pacemakers that cannot afford them and have been informed by multiple SBMP employees and patients that in such cases, they are simply sent back to their homes to be cared for by family and friends.

Table 3: Pacemaker Mean Health Utility Data by Category

EQ-5D Category (1=Best, 3=Worst)	**Mean Pre-Operative Value**	**Mean Post-Operative Value**	**Mean Improvement (Pre- to Post-Operative)**
Mobility	2.222	1.361	*-0.861*
Self-Care	2.111	1.056	*-1.056*
Usual Activities	2.583	1.694	*-0.889*
Pain/Discomfort	2.194	1.694	*-0.500*

Anxiety/Depression	2.083	1.194	*-0.889*

The costs associated with SBMP pacemaker intervention include the cost of the pacemaker, cost of surgery (surgery room and payment to surgeons and nurses), hospital stay, time lost at work, follow-up appointments, and the patient fee paid to SBMP**.** The total mean discounted cost for the first year among all 36 patients that were interviewed totaled $4,203. Discounting the continuing costs such as follow-up appointments at 3% per year, the average total cost at 2- and 5-year intervals were $4,224 and $4,286, respectively. The 5-year value, could variably change depending on whether or not the patient requires a battery replacement surgery. Incorporating the costs of the battery replacement under the assumption that by year 5 all patients will require such a surgery, the total projected cost five years after implantation rises to $5,460. According to SBMP social workers and cardiologist, Dr. Maria Avendaño, five years is around the average time at which most patients do require a battery replacement.

The mean discounted incremental QALY gain across all 36 patients, assuming a 94% retention rate, at 2- and 5-year intervals following pacemaker implantations were calculated to be 1.134 and 2.490, respectively. Incorporating costs to these values, the average discounted incremental costs per QALY gain ($/QALY) are $3,725/QALY and $1,721/QALY, respectively. However, assuming that during the 5-year interval the patient needs a battery replacement surgery, the average $/QALY would climb to $2,193/QALY.

In an effort to provide a more conservative estimation of the SBMP, Dr. Ament and I repeated the same $/QALY analysis, only this time assuming that only 50% of patients receiving treatment were retained in the program due to mortality, loss to follow-up, or other conditional factors causing patients not to receive the expected health benefit. Assuming this revised retention rate with the same 3% discounting factor, the average $/QALY at 2- and 5-year intervals would instead be $9,017/QALY and $7,186/QALY, respectively. If the 5-year figure again includes costs associated with a battery change along with the 50% retention rate, it instead rises to $9,154/QALY.

Patient interviews also included questions regarding extra symptomatic information, as recommended by Dr. Avendaño. Of the 94.44% of patients that pre-operatively reported exhibiting fatigue with little physical effort, 29.41% responded post-operatively that it no longer occurred, 55.88% reported that the fatigue improved, and only 2.94% reported that it worsened and/or stayed the same. When asked if they experienced shortness of breath during their usual daily activities, 69.44% of patients pre-operatively responded yes. Of these 69.44%, 72% of them reported no longer having these episodes post-operatively and 28% reported that they still occur but have improved (none responded that they stayed the same or had worsened). Pre-operatively, 72.22% of patients responded feeling heart palpitations in their chest. Of these 72.22%, 53.85% reported complete disappearance post-operatively and 34.62% reported a reduced frequency and severity of palpitations (none responded that they were the same or had worsened). Finally, patients were also asked if they experienced swelling in their feet or in any of their other body parts and 63.89% of them responded yes. Of that 63.89%, with any pre-operative swelling, 86.96% reported the swelling to have been completely eradicated, 8.69% reported that it stayed the same, and 4.35% reported that it improved.

Table 4: Extrapolated Pacemaker Cost-Effectiveness Results (based upon EQ-5D figures)

	1 year	2 years	5 years	5 yrs, w/ Battery Replacement
Total Avg. Discounted Cost (USD)	$4,202.59	$4,224.29	$4,285.68	$5,459.94
Avg. QALY Gain, 94% Retention	0.593	1.134	2.490	2.490
Avg. QALY Gain, 50% Retention	0.315	0.469	0.596	0.596
Cost/QALY Gain, 94% Retention	*$7,087.60*	*$3,724.83*	*$1,721.18*	*$2,192.77*
Cost/QALY Gain, 50% Retention	*$13,324.68*	*$9,016.53*	*$7,185.63*	*$9,154.48*

Neurosurgery Costs and Health-Utility (QALYs)

Health utility values were shown to increase in all neurosurgery patients that were interviewed from pre- to post-implantation according to the Health Utilities Index-3 (HUI-3) and self-evaluated overall health (Table 5). Of the 21 patients evaluated, 20 (95.2%) exhibited an overall health utility gain while only one patient exhibited a loss. The HUI-3, which uses a health utility scale ranging from 0-1 (0.00 = dead, 1.00 = perfect health), displayed a mean utility difference from pre- to post-operative health utility of 0.514 in the 7.4 months after implantation (average time post-surgery at which patients were interviewed).

Table 5: Neurosurgery Mean Health Utility Values Over 7.4-Month Average Time Interval

Health-Utility Analysis Technique	Mean Pre-Operative Value	Mean Post-Operative Value	Mean Gain (Pre- to Post-Op)
HUI-3 Utility Score (0.00 = dead, 1.00 = perfect health)	0.128	0.642	*0.514*
Self-Assigned Health Classification (0 = dead, 10 = perfect health)	2.619	7.05	*4.43*

As is the case for much health care treatment, the Bolivian public health care system is rarely able to provide coverage for the costs of neurosurgical instrumentation, especially since it is such specialized treatment. Therefore like the pacemaker program, SBMP only elects patients who require instrumentation and have absolutely no means of affording it. Again, the assumed base-case scenario includes zero cost and zero health gain from the pre-operative state. Dr. Ament and I used these

assumptions as measurements against the costs and health gains associated with SBMP neurosurgical intervention. Patients who cannot afford such specialized medical treatment would be extremely unlikely to receive it if it without SBMP-assistance.

Table 6: Neurosurgery Mean Health Utility Data by Category

HUI-3 Category	Mean Pre-Operative Value	Mean Post-Operative Value	Mean Improvement (Pre- to Post-Operative)
Ambulation, 1-6 (1= Normal, 6=Unable to walk)	4.857	2.857	*-2*
Emotion, 1-5 (1= Happy & interested in life, 5= So unhappy that life is not worthwhile)	3.714	1.762	*-1.952*
Pain, 1-5 (1= Free of Pain and discomfort, 5= Severe pain that prevents most activities)	3.952	2.524	*-1.429*

*The other 5 categories received perfect scores throughout the intervention as none of the patients exhibited their symptoms before or after surgery.

The costs associated with SBMP neurosurgical intervention include the costs of the equipment being implanted, cost of surgery (surgery room and payment to surgeons and nurses), hospital stay, time lost at work, follow-up appointments, and the patient fee paid to SBMP. When we discount the continuing costs such as follow-up appointments or treatment at 3% per year, the average total costs at 2- and 5-year intervals were $1,251 and $1,597, respectively.

The mean discounted incremental QALY gains across all 21 patients following neurosurgical intervention, according to the observed 94% retention rate at 2- and 5-year intervals were 0.897 and 1.969, respectively. Incorporating costs to these 2- and 5-year values, the average discounted incremental costs per QALY gain ($/QALY) are $1,395/QALY and $2,664/QALY, respectively. If we lower the retention rates (assuming the observed figure does not accurately represent the total population served by SBMP) to just 50% and recalculate the expected $/QALY, the projected values would climb to $2,664/QALY and $11,160/QALY, respectively.

Table 7: Extrapolated Pacemaker Cost-Effectiveness Results (based upon HUI-3 figures)

	2 years	5 years
Total Avg. Discounted Cost (USD)	$1,251	$5,245
Avg. QALY Gain, 94% Retention	0.897	1.969
Avg. QALY Gain, 50% Retention	0.370	0.472
Cost/QALY Gain, 94% Retention	*$1,395*	$2,664

Cost/QALY Gain, 50% Retention	*$3,377*	$11,112

Discussion/Analysis

The World Health Organization (WHO) assigns country-specific cost-effectiveness threshold values to categorize health programs into three categories: highly cost-effective, cost-effective, or not cost-effective (World Health Organization 2011). These values are given in international dollars and based upon gross domestic product (GDP), as recommended by the Commission of Macroeconomics and Health. All countries are regionalized according to their location and economic status with Bolivia falling into the American D country region. According to the values assigned to that group, all extrapolated values from this study are considered either cost-effective or highly cost-effective. For the pacemaker program, both the 2- and 5-year projections are considered highly cost-effective when the retention rate was 94%, regardless of whether or not the patient needs a battery change at five years. The same projections with 50% retention would be considered cost-effective. For the neurosurgery program, both the 2- and 5-year projections are also considered highly cost-effective when the retention rate was 94%. The 2-year projection at 50% retention is also considered highly cost-effective, whereas the 5-year projection at 50% retention would be considered cost-effective for Bolivia.

If we assume that the health utility data from the patient sub-group in this study accurately represents the health progression of the entire SB program, then minimum retention rates of 79% and 39% for the pacemaker and neurosurgery programs, respectively, would have to be maintained for the program to be considered highly cost-effective at the 2-year time interval. Under the same assumption, the programs would only need to maintain retention rates of 36% and 17%, respectively, for them to be considered cost-effective at their 2-year time intervals. For the 5-year time interval, assuming that none of the patients require a battery change in the pacemaker program, the pacemaker and neurosurgery programs would have to maintain 62% and 76% retention rates to remain highly cost-effective and only a 34% and 45% retention rates to remain cost-effective, respectively. However, assuming that all of the pacemaker patients do require a battery change within the 5-year post-operative period, then the program would have to retain a retention rate of at least 69% to remain highly cost-effective and 40% to remain cost-effective.

Because this type of study was the first for the SBMP, it was difficult to determine which methods would maximize effectiveness in determining the health utility of the observed cohort. During the first few weeks of time spend in Bolivia, I worked alongside physicians, medical staff, social workers, and hospital patients to develop and translate effective methods of obtaining the desired utility data. This took a bit of trial and error due to the lack of experience and literature support that exists on this specific type of study and cohort population. Various techniques were considered during this preparation work, as the goal was to choose an analytical method that sufficiently encompassed all or most aspects of patient health within both specialties, without compromising the integrity of our data by overcomplicating the interviews and confusing patients.

Typically in cost-utility or cost-effectiveness studies, measuring preferences for health outcomes is a popular way to determine how patients value different health states to provide an idea of what

improvements would most benefit them. In general, this involves offering patients two theoretical descriptions of how the rest of their life could proceed and the patients are then asked to decide which outcome they would prefer. The standard gamble and time trade-off (TTO) are two classical methods of measuring preference that are widely used (Michael F. Drummond, 1997).

The standard gamble (J. von Neumann, 1944) generally works by offering two alternatives, the first with two possible outcomes: a probability "p" that the patient receives treatment and either returns to perfect health and lives an additional "t" number of years or a probability "1-p" that they die immediately upon receiving treatment. The second alternative gives a definite outcome of receiving treatment and living "t" number of years under chronic health state "i" until death. The probability "p" is then varied until the patient feels indifferent between the two alternatives, giving a preference value of taking the risk "p" to gain health state "i" for a time "t."

The TTO (G.W. Torrance, 1972) is similar to the standard gamble, again offering the patient two alternatives: the first is that they remain in health state "i" for a time "t" until death and the second is that they are completely healthy for a time $x < t$ until death. The value "x" is varied until the patient is indifferent between the two alternatives, giving the required preference score for the given state "i."

While both of these methods have been used extensively in similar studies, they can be very time-consuming as well as confusing for the patient to accurately respond (Michael F. Drummond, 1997). For these reasons, pre-scored multi-attribute health status classification systems have recently grown in popularity as alternative methods. Three main systems that have existed far throughout the last decade include the Quality of Well-Being (QWB), Health Utilities Index (HUI), and EuroQol (EQ-5D). We opted to utilize the latter two for our particular study (per suggestion by Dr. Ament).

I collected all health utility data in this study as primary data from the patients' own responses and evaluations, except a few occasions during which the patient could not speak for themself and a close family member instead provided their responses. The uncertainty of the data is due to both the few numbers of patients that were interviewed, as well as the broad range of follow-up time with which interviews were conducted. It would be preferable to follow a larger cohort of patients, tracking their health conditions at regular intervals to explore possible trends of improvement and decline that may exist among patients with similar health issues. However the inherent limitations of conducting a medical program in an area with sub-optimal accessibility to communication and follow-up structure prevent some of the features that would be expected in a similar study in a more developed country.

Spending five months with SBMP-social workers provided me with much time to investigate which areas of SBMP were functionally effective vs. those that could use improvement. This being the first time an effectiveness study was conducted for the group, it allowed the social workers and I to cross a new frontier for the organization. As previously stated, this study was the first of its kind and not much literature currently exists examining the cost-effectiveness of health programs in Bolivia. Some patients were hesitant to be interviewed or meet with a SBMP employee, which is possibly due to the lack of familiarity with these types of studies in Bolivia, leading to confusion as to why they were being contacted by the organization that had provided them treatment. In addition to the lack of

familiarity with this type of study, there was some difficulty reaching patients for interviews simply because of geographic and/or communication barriers that exist in a developing nation such as Bolivia. While most patients had been able to leave a phone number for either themselves or a close contact, many of these numbers were no longer in use. The patients with whom I was able to communicate and conduct interviews were quite expressive of their gratitude for the help that they had received. It was apparent to the patients that if they had not received SBMP assistance, they were very unlikely to have received the necessary treatment for their condition.

Currently for the SBMP, follow-up visits are provided and encouraged for the patients via informing them of the benefits they will receive from seeing a medical doctor as well as simply staying in touch with the program. Patients are warned that it could be detrimental to the effectiveness of the treatment and their overall health if they do not undergo routine visits as recommended by medical doctors, however there is no real risk of a third-party consequence if patients do not maintain follow-up (outside of the patients and their families). After witnessing the extreme gratitude that patients and their families exhibited towards SBMP workers and to myself, I presume that there would be a great improvement in follow-up numbers if patients were informed of this study before or sometime around the time of receiving initial intervention. If more patients had knowledge of an SBMP follow-up interview to track their health and improve the program, they may be more likely to contact SBMP or at least make themselves more readily available to provide updates on their progression following treatment. Simply notifying patients before treatment would be an easily implementable task that could potentially provide much improvement to follow-up numbers and overall data strength at little-to-no cost for the patients or SBMP.

While the data collected in this study suggests effective performance of the SBMP, continuance of the study would certainly improve the strength of the data by increasing the cohort size and time variable. It could provide many new patients for the analysis as well as secondary follow-up interviews with patients who have already taken part in the study. The five months that I spent in Bolivia began with approximately two months of language classes, along with much work with the SBMP medical staff and social workers before we were ready to actually conduct patient interviews. That said, there exists a huge pool of patients that have received and/or will receive SBMP-intervention with whom attempts at communication have not yet been made. This is especially true of those patients in Santa Cruz, as the vast majority of my time was spent in Cochabamba due to time and travel restraints. The little time that was spent in Santa Cruz was largely focused on increasing interview numbers with neurosurgery patients because of the low number of patients that I was able to contact and interview in Cochabamba. The only three pacemaker patients that I even attempted to contact from Santa Cruz were three patients that happened to come in on a day that I was in the office for a routine follow-up visit with the cardiologist. If it is possible to increase efforts in contacting patients, especially those who have received intervention in Santa Cruz, both the data in this study and the potential for maintaining some effectiveness analysis of the organization would almost certainly improve tremendously.

In conclusion, this study exhibits very promising extrapolated figures reflecting the work done by the SBMP's neurosurgery and pacemaker programs in Cochabamba and Santa Cruz, Bolivia. While the data suggest that the SBMP is likely to be cost-effective throughout a 5-year span, more work is

necessary in order to strengthen our data before we can confidently say whether or not the program actually is cost-effective. Further in-depth research could indeed cross the frontier of determining cost-effectiveness of SBMP, and possibly many other NGO-funded medical programs.

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