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ORIGINAL SCIENTIFIC REPORT

Measuring the Burden of Surgical Disease Averted by Emergency and Essential Surgical Care in a District Hospital in Papua New Guinea

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Abstract

Background Timely access to emergency and essential surgical care (EESC) and anaesthesia in low- and middle-income countries (LMICs) prevents premature death, minimises lifelong disability and reduces their economic impact on families and communities. Papua New Guinea is one of the poorest countries in the Pacific region, and provides much of its surgical care at a district hospital level. We aimed to evaluate the surgical capacity of a district hospital in PNG and estimate the effectiveness of surgical interventions provided.

Methods We performed a prospective study to calculate the number of DALYs averted for 465 patients treated with surgical care over a 3-month period (Sep–Nov 2013) in Alotau Hospital, Milne Bay Province, PNG (pop 210,000). Data were also collected on infrastructure, workforce, interventions provided and equipment available using the World Health Organization's Integrated Management of Emergency and Essential Surgical Care Toolkit, a survey to assess EESC and surgical capacity. We also performed a retrospective one-year audit of surgical, obstetric and anaesthetic care to provide context with regards to annual disease burden treated and surgical activity.

Results EESC was provided by 11 Surgeons/Anaesthetists/Obstetricians (SAO) providers, equating to 5.7 per 100,000 population (including 4 nurse anaesthetists). They performed 783/100,000 procedures annually. Over the 3-month prospective study period, 4954 DALYs were averted by 465 surgical interventions, 52 % of which were elective. This equates to 18,330 DALYs averted annually or, approximately 18 % of the published but estimated disease burden in the Province in the 2013 Global Burden of Disease Study. The overall peri-operative mortality rate was 1.29 %, with 0.41 % for elective procedures and 2.25 % for emergencies.

Conclusions Much of the burden of surgical disease in Papua New Guinea presenting to Alotau General Hospital serving Milne Bay Province can be effectively treated by a small team providing emergency and essential surgical care. This is despite a relatively low surgical volume and limited numbers of trained surgical anaesthesia obstetric providers, and likely underservicing. The ability of surgical care to avert disease in Papua New Guinea highlights its importance to public health in LMICs.

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Introduction

There is a growing awareness of the need for emergency and essential surgical care (EESC) in low- and middle-income countries (LMICs). This requires timely access to safe surgery and anaesthesia when needed. Surgery received only a chapter in the World Bank's 2nd edition of Disease Control Priorities in Developing Countries, whilst the 3rd edition, published in 2015, devoted an entire volume to essential surgery and anaesthesia [1]. Despite this growing interest in EESC in LMICs, the achievements of surgical care have usually not been presented in a format that has yet convinced those planning or financing health systems. Surgery has even been described as the "neglected stepchild of public health" [2], though in reality it may be the quiet achiever whose ability to deliver value for money is only now being appreciated.

The Lancet Commission on Global Surgery, published in April 2015 [3], noted that despite significant advances in global health in the last 25 years, progress with EESC, including anaesthesia, has stagnated or regressed in many countries. Lack of access to safe, affordable and timely surgical and anaesthesia care affects five billion people, particularly in LMICs, where one-third of the world's population receives only some 6 % of the world's surgical procedures [3–5].

Surgical conditions account for a significant portion of the global disease burden. Injuries account for an estimated 11 % of all disability-adjusted life years (DALYs) lost globally, and non-communicable diseases contribute 55 % of global DALYs, many of which would require surgery [6]. To date, surgical conditions, including injuries, malignancies, congenital anomalies, obstetric complications, cataracts glaucoma and perinatal conditions account for an estimated 15 % of all DALYs lost worldwide, with the number suspected to be much higher when other common yet unmeasured surgical conditions are included [1]. Access to safe and timely surgery with the provision of anaesthesia in LMICs could help prevent many deaths, correct deformity and minimise life-long disability [7]. The World Health Assembly resolution 68.15 recognises the contribution of surgery to the health system and calls for EESC to be strengthened as a component of universal health coverage [8].

A number of studies have shown that a variety of different surgical care models can be delivered cost effectively in LMICs, including emergency obstetric care (cost/DALY averted range US$18-3420.000) [9, 10], cataract surgery (cost/DALY averted range US US$5.06–$106.00) [11–13], male circumcision (cost/DALY averted range US$7.38–$319.29) [14, 15], cleft lip and palate repair (cost/DALY range US$15.44–$96.04) [16, 17], elective hernia repair (cost/DALY averted range US$7.38–$319.29) [18, 19], as well as short term orthopaedic relief missions (cost/DALY averted range US$343–$362) [20–23]. To date, only a few studies have evaluated the cost-effectiveness of an entire surgical facility or ward with a cost/DALY averted range of US$10.93–$77.40 per DALY averted [19–25]. Although limitations exist in the ability to make meaningful comparisons of current literature on cost-effectiveness of surgery, nevertheless it has been shown that the provision of surgical care, through a variety of different delivery models, can be implemented at similar costs to other important public health interventions, such as oral rehydration therapy (US$1,062.00 per DALY averted), breast feeding promotion (US$930.00 per DALY averted) and highly active anti-retroviral therapy for HIV (US$922.00 per DALY averted) [1, 3, 17].

This study was the first of its type to be conducted in Papua New Guinea, and was undertaken at Alotau General Hospital, a district hospital in PNG and the main referral centre for Milne Bay Province, with an estimated population of 210,000. The study aimed to evaluate the surgical capacity, and estimate the disease burden averted in a district hospital.

Methods

The Setting: Alotau, Milne Bay Province, Papua New Guinea

Papua New Guinea (PNG), located in the Western Pacific region, has an estimated population of 7,014,000, with over 87 % of its population living outside urban areas. Despite strong economic growth in recent years, and rich mineral resources, PNG is classified by the World Bank as a low middle-income country (LMIC) (gross national income per capita $2,570 PPP. int $) [26, 27]. The 2014 PNG national budget is US$5.9 billion, with health services receiving US$560 million [28]. In 2013, PNG spent 9.8 % of its total government expenditure on health, approximately US$79 per capita [26, 27]. The health indicators for PNG are considered poor in a regional and global context (Table 1) [26]. The DALYs lost per 100,000 population in PNG are estimated to be 51,718 [29].

Alotau is the capital of Milne Bay Province, which covers the southern tip of Papua New Guinea's mainland. The province covers some 14,000 km^2 of land and 252,990 km^2 of sea, which includes many islands across the Coral and Solomon Seas. It has an estimated population of 210,000, served by Alotau General Hospital. The annual hospital expenditure was estimated at 23 m Kina (US$9 m for 2012/2013 financial year), which included all staff

Table 1 Papua New Guinea selected health indicators (2011), updated 2013 [26]

	PNG	Regional average	Global average
Total population (thousands)	7014	–	–
Population living in urban areas (%)	12	54	52
Gross national income per capita (PPP. int $)	2570	10.925	3665
Total government expenditure as % of GDP			
2000	4 %	5.9 %	8.2 %
2010	4.1 %	6.4 %	9.2 %
General government expenditure on health as % of total government expenditure			
2000	9.9 %	13.9 %	13.5 %
2010	9.8 %	14.4 %	15.1 %
Total government expenditure on health per capita (PPP. int $)			
2000	56	189	318
2010	76	417	599
Life expectancy at birth (years)			
Male	61	74	68
Female	65	78	72
Both sexes	63	76	70
Neonatal mortality rate (per 1000 live births)			
Both sexes	23	9	22
Under-five mortality rate (per 1000 live births)			
Both sexes	58	16	51
Adult mortality rate (probability of dying between 15 and 60 years per 1000 population)			
Both sexes	248	116	176
Maternal mortality ratio (per 100 000 live births)	230	49	210

salaries. Detailed information pertaining to hospital and department expenditure, however, was not available. All specialist medical and surgical staff working at Alotau General Hospital have trained through the University of PNG Masters of Medicine (MMed) Program, with the support from Australian aid and the Royal Australasian College of Surgeons (RACS) through various iterations of PNG Tertiary Health Services Project (PNG THS to 2010) and Health Education and Clinical Services PNG HECS. [30–32]. The success of surgical training in Papua New Guinea has been in prevention of "brain drain" that has often faced LMICs training medical and surgical specialists. The sub-specialisation of general surgeons began in 1994 and appears to have found a balance in allowing qualified surgeons to further specialise in urban areas, whilst encouraging the continued practice of their general surgical procedures and work in provincial healthcare setting [33, 34].

There are unique challenges in the delivery of health care in PNG, particular were the landscape compromises efficient transport across sea or land. Thus, advanced disease and late presentations are common. The range of surgical pathology in PNG is similar to other LMICs, where trauma, acute intra-abdominal surgical emergencies, obstetric complications and neoplasm are the most common surgical presentations. Trauma accounts for 30 % of all surgical admissions in the national capital, Port Moresby and 40 % in the Highlands [35, 36]. Non-communicable diseases of "affluence" such as diabetes mellitus and its complications, gallstones and coronary artery disease are on the rise, making the provision of EESC in Papua New Guinea even more challenging [37, 38].

We used the World Health Organization's (WHO) and Global Initiative for Emergency and Essential Surgical Care (GISEEC)'s Monitoring and Evaluation Tool for Emergency and Essential Surgical Care (IMEESC) [39] (http://www.who.int/surgery/globalinitiative/esc_contribute/en/) developed by WHO's Global Initiative for Emergency and Essential Surgical Care (GIEESC), to evaluate Alotau General Hospital's surgical capacity. The IMEESC tool collects data on infrastructure, human resources, interventions provided and surgical care equipment.

We calculated the DALYs averted for each patient treated with a surgical procedure in Alotau General Hospital during a prospective 3-month period, from 1 September—30 November 2013. The definition of a surgical procedure was any procedure that took place in an operating theatre, with or without anaesthesia. Data were

obtained by a representative of the study and included age, sex, operative diagnosis and surgical treatment provided. There was no electronic database of performed procedures, so data were obtained from the admission notes, paper-based surgical ward and operative registries. Neither the American Society of Anaesthesiologists (ASA) score, nor co-morbidities were available. This 3-month period was busier than the rest of the year when compared with the annual surgical report and so to estimate the DALYs averted for the whole year, the 3-month period of study was multiplied by 3.7 to adjust for all 1645 operations in the 1-year period represented by 447 procedures between September and November.

DALY Estimation

DALYs averted = YLL (discounted life expectancy) × severity of disease weight × effectiveness of treatment weight × disability weighting (if applicable), consistent with the original description by McCord et al. and simplified by Gosselin et al. [20–22]. "Appendix" demonstrates of McCord and Chowdhury [24] approach to DALY estimation for specific cases, utilised in this study.

The burden of a condition/disease was estimated in terms of severity of disease and effectiveness of treatment (Table 2) [20–22]. Adopting the simplified approach from McCord and Chowdhury [24], severity of disease was weighted 0, 0.3, 0.7 or 1.0, based on how likely the disease was fatal or disabling without treatment. Similarly, effectiveness of treatment was given a weight of 0, 0.3, 0.7 or 1.0 based on the chance of survival or cure. Table 3 lists the specific conditions treated, and the specific estimation of severity of disease and effectiveness of treatment applied.

"Discounted" years of life lost (YLL) for a particular sex and age were based on the 2004 Global Burden of Disease Study and obtained from The World Health Organization "national tools" section on Global Burden of Disease [40, 41]. For the years lived with disability (YLDs), weighted values from the Global Burden of Disease (GBD) Study were used when available, and when these were unavailable, the authors agreed on a conservative estimate.

The perioperative mortality rate was calculated as the number of deaths before discharge following a procedure conducted in an operating theatre death as the numerator and the number of procedures conducted in an operation theatre as the denominator [42].

Table 2 Scoring system adopted from McCord et al. and modified by Gosselin et al. [21, 22, 24]

Scoring System	Weight
Severity of disease	
>95 % fatal or disabling without treatment	1.0
<95 % and >50 %	0.7
<50 % and >5 %	0.3
<5 %	0
Effectiveness of treatment	
>95 % chance of survival or cure	1.0
<95 % and >50 %	0.7
<50 % and >5 %	0.3
<5 %	0

Results

Patient Numbers

Surgical capacity was evaluated over a retrospective 1-year period (1 July 2012—30 June 2013). There were in excess of 5000 inpatient admissions across all medical and surgical wards, with 1645 surgical procedures performed in the same time period. A total of 823 (50 % of total surgical procedures) were General Surgical procedures, 752 (46 %) were Obstetrics/Gynaecology, and 70 (4 %) were Ophthalmology or ear, nose and throat (ENT) surgical procedures, the latter being performed by visiting medical specialist team. The annual surgical volume was 783 per 100,000 population.

The IMEESC surgical capacity survey tool addresses infrastructure, human resources, interventions and equipment for emergency and essential surgical care.

Infrastructure

There are two functioning operating rooms for major and minor surgical procedures, with a designated recovery area for post-operative care. These operate simultaneously, shared by General Surgery and Obstetrics/Gynaecology (O/G), prioritising emergency cases over elective cases. Virtually, 100 % occupancy of General Surgery and O/G surgical beds was achieved, with the aim to keep two beds in the General Surgical Ward free for potential emergency surgical cases; however, these often filled. The operating theatres functioned for emergency cases only afterhours, and Friday–Sunday. Ophthalmological surgical procedures were provided an appropriate sized list of elective cases had been accrued, typically 10–12 cases. The hospital offers a high dependency (HDU) or intensive care unit (ICU), with one ventilated bed and seven monitored beds, an adult and paediatric medical ward and a 10 bed emergency department.

The hospital had a reliable source of electricity and running water, but relied on bottled oxygen cylinders, with

Table 3 Estimated burden of surgical disease averted, example of disease/procedure weightings (condition/procedure, distribution by sex and median age)

Emergency and essential surgery	Severity of disease weight	Effectiveness of treatment weight	Total	Males (median age)	Females (median age)	DALYs averted
General surgical inpatient ward						
Fractures/dislocations	0.7	0.7	43	29 (18)	14 (11)	151
Acute appendicitis	0.7	1.0	35	7 (30)	28 (19.5)	372
Laparotomies (for acute abdomen)	1	1	16	5 (15)	11 (40)	403
Penetrating abdo injury	1	1				
Bowel obstruction	1	1				
Hirschsprung's disease	1	1				
Emergency hernia	1	1				
Perforated viscus	1	1				
Hernias (elective)	0.3	0.7	20	19 (45)	1 (60)	15
Excision			22	12 (27)	10 (42)	58
Oral SCC	0.3	0.7				
Lipoma	0.3	0.7				
Amputations			7	2 (53.5)	5 (10)	29
Diabetic foot	0.7	1				
Sepsis/gangrenous foot	1	1				
Crush injury (leg)	1	0.7				
Debridements			5	5 (44)	–	13
Necrotising fasciitis	1	0.7				
Diabetic ulcer	0.7	0.7				
Infected wound	0.7	0.7				
Tendon repair			8	6 (25)	2 (27.5)	33
Calcaneal tendon	0.7	0.7				
Patella tendon	1	0.7				
Incision and drainage (e.g. abscess)	0.3	0.7	10	6 (30.5)	4 (22)	24
Burrhole/Craniectomy (head injury)	1	0.7	8	4 (26)	4 (27.5)	60
EUA/Suturing (e.g. laceration)	0.3	1	5	5 (23)	–	57
ENT cases			9	4 (3.5)	5 (41)	25
Foreign body—Nose/Ear/Throat	0.3	1				
EUA/biopsy	0.3	0.7	7	3 (54)	4 (41)	5
Circumcision			4	4 (20.5)	–	5
Phimosis	0.3	0.7				
ICC insertion and UWSD			1	1 (61)	–	11
Pneumothorax	1	1				
SPC formation (spinal injury)	1	0.7	1	1 (40)	–	5
Haemorrhoid/perianal surgery	0.3	1	1	1 (50)	–	1
Surgery for breast Ca	0.7	0.7	3	–	3 (42)	3
Surgery for testicular Ca	0.7	0.7	1	1 (32)	–	1
SSG	0.7	0.7	2	1 (40)	1 (11)	2
Tracheostomy formation						
Facial trauma, compromised airway	1	0.7	1	1 (42)	–	6
Other (ROS, removal of hardware, etc.)	0.3	1	6	5 (13)	1 (4)	40

Table 3 continued

Emergency and essential surgery	Severity of disease weight	Effectiveness of treatment weight	Total	Males (median age)	Females (median age)	DALYs averted
Subtotal			215	122	93	1319
Obstetrics/gynaecology						
Bilateral tubal ligation (BTL)	0.3	1	83	–	83 (31)	861
LUSCS			56	–	56 (25)	1729
Obstructed labour and foetal distress	1	1				
Breech presentation (elective)	0.7	1				
Laparotomies			13	–	13 (23)	303
Leaking/ruptured ectopic, Acute abdo	1	1				
Ovarian cystectomy	0.3	1				
Sub/total Hysterectomy ± BSO			7	–	7 (46)	42
Endometrial Ca	0.7	0.7				
Uterine fibroid(s)	0.3	0.7				
EUA/Suturing			9	–	9 (21)	166
2nd/3rd degree vaginal tear	0.7	1				
RPOC (D&C/Evac)	0.7	1	7	–	7 (27)	145
Retained Placenta (manual removal)	0.7	1	4	–	4 (31)	63
Diagnostic D&C (for Ix)	0.3	1	10	–	10 (28)	143
EUA/Biopsy (Ca staging)			1	–	1 (44)	1
Cervical Ca staging	0.7	0.7				
Incision and drainage			1	–	1 (23)	10
Abscess	0.3	0.7				
Subtotal			191	–	191	3463
Eye Surgery						
ECCE/PIOL—cataract surgery			38	24 (60)	14 (65.5)	143
Prolapsed/Trapped Iris—Repair			3	2 (28)	1 (50)	29
Subtotal			41	26	15	172
Total			447	148	299	4954

less reliability. There were basic pathology services on site, including blood bank capabilities, and basic pathological studies, including haemoglobin and urine testing. There was one functioning X-ray machine.

Human Resources

During the study period, general surgical care was provided by a general surgical team consisting of one full-time employed general surgeon, general surgical registrar and junior doctor. The surgical team also had a "Health Extension Officer" (HEO), trained in limited surgical and anaesthesia care, who assisted the surgeon or surgical registrar in theatres, and when required, performed minor surgical procedures such as incision/drainage, simple excisions and debridements. Obstetric and Gynaecological surgical care was provided by an O/G team consisting of one full-time employed Obstetrician/Gynaecologist, O/G registrar and junior doctor. Anaesthesia was delivered by an anaesthetics team consisting of a full-time employed anaesthetist, one part-time employed anaesthetist, and four anaesthetic technical officers. Additionally, there was one specialist anaesthetist and one specialist surgeon who were in full-time medical administration but could provide emergency or relief cover. Surgical, Anaesthetic and Obstetric care was provided by a total of 12 trained surgeons, anaesthetists (including nurse anaesthetists) and obstetricians (SAO) and one HEO, or 5.7 SAO per 100,000. If only medically trained providers were included, this number would be 3.2 per 100,000 population.

Interventions

Alotau General Hospital performed all major and minor surgical and anaesthetic procedures listed in the Situational Analysis Tool on a regular basis, with the exception of Obstetric Fistula repair. Low numbers (<1 % of surgical patients in the previous year) were transferred on to the National Referral Hospital in Port Moresby.

A summary of surgical admissions, surgical procedures and their distribution during the 3-month study period can be found in Table 4. A total of 465 surgical procedures were performed during the 3-month study period, of which 217 were General Surgical, 209 Obstetrics/Gynaecology and 39 Ophthalmology. Of all the surgical procedures performed, 48 % were emergency/semi-urgent admissions, and 52 % for elective admissions. The elective procedure numbers were boosted by a large number of bilateral tubal ligations and elective cataract surgery. Other models of care including surgery by sub-specialist teams were also delivered to provide all, but one of the essential or emergency procedures listed in the IMEESC Toolkit. The exception was repair of obstetric fistulas, which in Milne Bay Province is referred to the National Referral Hospital in Port Moresby or repaired locally during the visit of a Urological Specialist team.

Emergency and Essential Surgical Equipment and Supplies for Resuscitation

At the time of evaluation, all emergency and essential equipment and consumable supplies for surgical care and resuscitation listed in the Situational Analysis form were available. Synthetic absorbable suture was available, but with frequent shortages, and the appropriate suture sizes for particular procedures were usually available.

DALY Estimation and Effectiveness

Table 3 outlines the various conditions/procedures performed during the study period, and number of DALYs averted. A total of 4954 DALYs were averted by surgical interventions during the 3-month study period. Obstetrics and Gynaecological procedures averted 3463 DALYs. General Surgery, although performing a larger number of surgical procedures, averted some 1319 DALYs. Ophthalmological procedures averted a total of 172 DALYs. Caesarean sections averted the largest number of DALYs, totalling 729.

Table 5 shows and estimated 47,619 DALYs per 100,000 population in Papua New Guinea with 21,249 from communicable diseases, 23,348 from non-communicable and 3022 from injuries. For the Milne Bay Province with a population of 210,000, this equates to 100,000 DALYs.

During the 3-month study period, of the total 4954 DALYs averted, 3453 (69 %) were for communicable and maternal conditions, 1216 (24.5 %) for non-communicable diseases and 285 (5.75 %) for injuries (Table 5). If the 3-month study period (447 procedures) is representative of the annual total (1645 procedures), which was confirmed by the Annual Report and our 1-year retrospective audit, the total DALYs averted for the year can be estimated to be 18,330. Were the PNG Global Burden of Disease estimates accurate this would represent 18 % of the disease burden of the province.

Safety and Quality of Emergency and Essential Surgical Care: Perioperative Mortality Rate

During the study period, the overall peri-operative mortality rate (POMR) was 1.29 %, which is consistent with the hospital's own report of 1.2 %. The emergency and elective POMR were 2.25 and 0.41 %, respectively, as shown in Table 4.

Discussion

This study helps to quantify how the burden of surgical disease can be averted, by a relatively small number of specialist staff—a surgeon, obstetrician, anaesthetist, four anaesthetic nurses, a trained allied health assistant and two

Table 4 Admissions to a "Surgical ward" and their distribution during the study period (Sep–Nov 2013)

	Total admissions	Number of surgical procedures	% of admissions requiring surgical procedure	Median age (years)	Deaths and peri-operative mortality rate
General Surgery	248	217	87.5 %	24	4 (all emergency)
O/G	816	209	25.6 %	30	2 (1 emergency/1 elective)
Eye Surgery	39	39	100 %	60	0
Total	1103	465	42.15 %		6 (1.29 %)

Table 5 Global Burden of Disease by Group (GBD Study 2013) and DALYs averted by Alotau General Hospital [29]

Region	Group I conditions (%)	Group II conditions (%)	Group III conditions (%)	Total number of estimated DALYs
Papua New Guinea				
Per 100,000	21,249.42	23,348.01	3021.54	47,618.97
Milne Bay				
Adjusted for population of 210,000 (X 2.1)	44,624	49,031	6,345	100,000
3-month study period (Alotau district hospital)	3453 (69 %)	1216 (24.5 %)	285 (5.75 %)	4954
Adjusted study period (12 months) (X 3.7)	12,776	4499	1,055	18,330 (18 %)

Group I conditions: Communicable, maternal, perinatal and nutritional conditions

Group II conditions: Non-communicable diseases

Group III conditions: Injuries

specialist trainees. Including the four nurse anaesthetists and one HEO, this equates to 12 trained SAO providers for 210,000 population or 5.7 per 100,000.

Measuring the POMR has been shown to be a credible regional indicator that is relevant to EESC. It is an appropriate indictor of access to and safety of surgery and anaesthesia implemented at a district hospital level [42, 43]. The calculated POMR in Milne Bay Province of 1.29 % in our study is consistent with the 1.2 % in the unpublished annual report from 2013, and 1.4 % in another report from the Southern Highlands Province in PNG (Dagam B and Kulau R, personal communication). It is lower than the POMR in National Referral Hospital in Port Moresby a decade earlier, which has a higher proportion of emergency surgery [43]. POMR is affected by urgency and thus by the emergency/elective ratio which is approaches 50 % or more in LMICs. Our POMR for elective and emergency procedures was 0.41 and 2.25 %, respectively. High-income countries tend to have a higher proportion of elective surgery. For example, in Australian public hospitals, emergencies constitute only 30 % of all procedures. POMR is in the range of 1.0–1.2 % for emergency procedures, but around 1 % for elective surgery [44]. Similar findings relating to surgical urgency and POMR were reported from a district hospital in Uganda, where the POMR was 0.57 %, however, 1.3 % for major surgery and 0.1 % for minor surgery [45]. Mortality is a much rarer outcome after caesarean section and other obstetric or gynaecological procedures, and Alotau had only 2 deaths in 816 cases (0.24 %) and is 0.15 % in Port Moresby (Prof GlenMola, personal communication). The caesarean section POMR was reported as 0.53 % from 7 MSF projects in Democratic Republic of Congo, Central African Republic and South Sudan [46]. Although our POMR calculations suggest room for improvement, particularly in emergency procedures, the POMR is lower than reported from other LMICs [42, 43, 45–47]. The aversion of almost 5,000 DALYS (4954) by one surgical and one obstetric team in a 3-month period was achieved with an overall POMR of 1.29 %, a testament to the safety of EESC provided at Alotau District Hospital, especially considering that large proportion of emergency cases.

Our calculations of DALYSs averted only considered the 87 % of general surgical admissions who had a surgical procedure, and not those who were also admitted for surgical care but did not have surgery. For Obstetrical procedures, our calculations only estimated DALYs averted for the mothers having a procedure, and not those related to the newborn. Nor does it include the management of labour that did require operative intervention. Thus, the DALYs averted for obstetrical procedures are an underestimate of the overall maternal health care.

Our calculated DALYs averted equates approximately to 18 % of the disease burden of the Milne Bay Province when adjusted over a 1-year period and contributes in all three major groups of disease (Table 5). This probably represents limited capacity, particularly in view of there being a surgical volume of 734/100,000 when the Lancet Commission recommended 5000/100,000 [3]. It is also half the figure obtained when considering that surgically related conditions contribute to 32 % of global mortality and 28–32 % of global conditions require a procedure [3, 48]. These calculations were made by multiplying the "per 100,000 population" figure from GBD Study 2013 by 2.1, in order to represent the estimated population of Milne Bay Province of 210,000 [49].

Limitations exist with regards to direct comparisons of our DALYs averted figures with those from the GBD Study 2013. Our DALYs averted calculations did consider disability age-weighting, whereas GBD DALYs do not, thus

the figure of 18 % of total DALYs averted in Milne Bay Province over an adjusted 1-year period is an approximation.

Gosselin and colleagues reported that a trauma hospital in Battambang, Cambodia and a small district hospital in Sierra Leone was able to perform 895 and 5801 procedures, respectively, for a total number of 3786 and 4455 DALYs averted [21, 22]. In comparison, our study averted 4954 DALYs for 447 procedures during the same time period. The likely explanation for the larger number of DALYs averted by fewer surgical procedures in our study is the inclusion of obstetric procedures in our study, which have a higher DALY averted rate per procedure.

A study of surgical but not obstetric services conducted at Port Moresby General Hospital, of similar design showed that a total of 921 general and specialist surgical procedures performed, averted a total of 5683 DALYs averted over a 3-month study period with an overall POMR of 1.37 [50].

There was a lack of financial data such that the authors were not able to calculate the cost to avert the above number of DALYs, and therefore cost-effectiveness measured in US$ per DALY averted.

In conclusion, there currently exists little published literature on the current burden of surgical disease and the burden averted by surgical services in Papua New Guinea, and the wider pacific region. Through the estimation of surgical volume, DALYs averted and the calculation of the perioperative mortality rate, we have demonstrated the effectiveness of the provision of Emergency and Essential Surgical Services as outlined by the WHO, delivered at a district hospital level.

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Compliance with ethical standards

Conflicts of interest None.

Appendix: Example of McCord et al. Approach to DALY Estimation, Simplified by Gosselin et al.

- YLL (based on actual age and sex of patient, derived from age weightings from GBD study) X severity of disease X effectiveness of treatment X chance of permanent disability (weighting) = DALYs averted.
- 12-year-old male with acute appendicitis with perforation and generalised peritonitis who undergoes successful surgery (>95 % mortality or disability without treatment, with >95 % chance of cure from disease), 37.54 (YLL for males aged 12) X 1.0 X 1.0 = 31.10 DALYs averted by surgery.
- 20-year-old female in obstructed labour who undergoes successful caesarean section (>95 % mortality without surgical treatment, >95 % chance of cure from condition) 31.10 (YLL for woman aged 20) X 1.0 X 1.0 = 35.24 DALYs averted by surgery.
- 18-year-old male who undergoes manipulation and plaster of paris application for closed tibial and fibular fracture (< 95 % and > 50 % disabling without treatment with disability weight of 0.27 < 95 % and > 50 % effectiveness of treatment) 35.84 (YLL for males aged 18) X 0.7 X 0.7 X 0.2 = 17.56 DALYs averted by surgical intervention.

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