How will increasing surgical volume affect mortality in the Pacific, Papua New Guinea, and Timor Leste?

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ABSTRACT

Background

Nine South Pacific nations, Papua New Guinea and Timor Leste, have collaborated to report and publish their surgical metrics as recommended by the Lancet Commission on Global Surgery (LCoGS). Currently, these countries experience about 750 postoperative deaths per year, representing 1% of crude mortality in the region. Given that more than 400,000 annual procedures are needed in the nine nations to reach the LCoGS target of 5,000/100,000, we aimed to calculate the potential contribution of perioperative mortality to national mortality where these procedures are performed.

Methods

We utilized reported surgical metrics with current rates for surgical volume (SV) and perioperative mortality (POMR), as well as World Bank/WHO mortality statistics, to predict the likely impact of surgical scale-up to recommended targets by 2030. We tested correlations between SV and POMR in countries from our region using Pearson's r statistic. Funnel plots were used to evaluate the dataset for outliers.

Results

Surgical scale up would result in perioperative mortality contributing on average to 3.3% of all national crude mortality. This prediction assumes POMR stays the same, which is challenging to predict. In our region countries that achieved the LCoGS target ($n=5$) had a lower POMR than countries that did not ($n=8$).

Conclusions

Surgical volumes in the South Pacific region must increase to meet the LCoGS target. Postoperative mortality as a proportion of all mortality may increase with the surgical scale up, however, the overall number of premature deaths is expected to reduce with better access to timely and safe surgical care.

Key Words: Universal Access to Surgery, General Surgery, Global Health

BACKGROUND

Five billion of the world's 7 billion population do not have access to safe, affordable and timely surgical and anaesthetic care. An additional 143 million procedures are needed annually to meet the surgical need across the world. Lack of access to appropriate surgical care results in poorer health outcomes, including premature mortality, avoidable disability and uncorrected deformities.^(1, 2) A conservative estimate is that up to 30% of the global burden of disease is due to surgically treatable conditions.⁽³⁾ Injuries and cancer are among several non-communicable conditions that are on the increase and whose treatment involves surgical care.⁽⁴⁾ Studies from Sweden, USA, Australia and New Zealand have found surgical procedures are performed for 25% to 35% of all hospital admissions.⁽⁵⁻⁸⁾

One challenge facing the Pacific Island nations, Papua New Guinea and Timor Leste during the period of implementing the Sustainable Development Goals is to provide access to surgery and anaesthesia care. Such access would reduce the burden of disease that is amenable to surgical treatment, hence would result in improved health and well-being for the Pacific Island populations. In low and middle-income countries such as the Pacific region, appropriate and timely surgical care has been shown to be cost-effective.⁽⁹⁾

Meeting surgical care needs in the region necessitates increasing the number of procedures in the expectation of averting mortality and morbidity from surgically treatable conditions. Such scale up must be delivered safely, minimizing perioperative morbidity and mortality. A recent paper published in the Lancet predicted that if surgical services were increased to achieve the surgical volume of 5000 procedures per 100,000 population then perioperative mortality (POMR) might increase the proportion of "postoperative deaths," even up to 7.7% of all global mortality.⁽¹⁰⁾

The aim of this study was to examine the relationship between surgical volume and POMR and calculate the additional perioperative deaths that may occur as health systems in the Pacific, and Papua New Guinea and Timor Leste, scale up their surgical activity.

METHODS

Context of the South Pacific, Papua New Guinea and Timor Leste

The South Pacific Region includes many Low-and Low-Middle Income Countries (LMICs, Table 1) with a very similar case mix throughout the nations. Non-communicable diseases (such as diabetes, cardiovascular disease, and cancer), injuries and complications of pregnancies account for a high proportion of the burden of disease. A Pacific regional collaborative study reported on the global surgical metrics for nine Pacific Island nations, Papua New Guinea and Timor Leste, with a combined population of just over 11.5 million people.⁽¹⁾ POMR for Australia and New Zealand was also reported in the Pacific regional study⁽¹⁾ but also in more detail by specific detailed POMR studies.⁽¹¹⁻¹⁴⁾

The surgical services of these small island states predominately manage emergencies with a case-mix focused on sepsis and trauma. Surgical outcomes for patients are hampered by a delayed presentation due to multiple reasons which include; a strong influence of traditional medicine, a fear of hospital treatment, lack of access due to geography, financial constraints (such as out of pocket transportation or hospital costs), and limited resources in terms of infrastructure and personnel. Combining these delays and the increasing incidence of cancer in the region results in many patients receiving delayed management that compromises outcomes. These delays are very evident in the Pacific Islands region where overall only 50%

of the population have 2 hour access to the Bellwether procedures, whilst in Papua New Guinea (PNG) this proportion is just 20% of the population.⁽¹⁵⁾

Calculations and Statistics

The reported Lancet Commission of Global Surgery (LCoGS) metrics for the Pacific Island region including PNG, Timor Leste, Australia and New Zealand¹ were used to calculate the additional procedures that would be required to meet LCoGS targets. The POMR was used to calculate the number of surgery related deaths currently and in the future, assuming the POMR remains constant even after surgical scale-up.

Based on data reporting national mortality published annually by WHO and the World Bank^(16, 17) we have estimated the percentage of deaths following surgery during the same hospital admission as LCoGS targets being met for each country in the region. Despite some over-servicing, we do not anticipate that High Income Countries (HICs) will perform less surgery between now and 2030, even if some low value procedures are replaced by higher value ones.

We interrogated our datasets using the D'Agostino-Pearson test for normal distribution, differences were considered significant at the $p=.05$ level. Correlation charts were formed and MedCalc version 9.6 (MedCalc Software, Ostend, Belgium) statistical software was used to calculate the Pearson's r statistic. Funnel plots were used to evaluate the dataset for outliers. Control limits for the funnel plots were formed at the 95% and 99.8% confidence intervals. We compared POMRs between countries which met the LCoGS surgical volume target and those that did not using the Mann-Whitney test.

Insert Table 1 here

Insert Table 2 here

RESULTS

Surgical volume

The current surgical volume achieved in nine island nations of the South Pacific, PNG and Timor Leste, that have reported their surgical metrics is just under 150,000 total procedures. This equates to a surgical volume of 1,224 procedures per 100,000 population, approximately one-third of the LCoGS target. The required increase for these 11 countries combined is approximately 436,000 procedures to achieve the Lancet Commission target of 5000/100,000 (Table 2). The calculated number of additional procedures required for each country will assist national surgical, obstetric and anaesthesia planning in the future.

POMR

Based on our current data, the South Pacific nations, PNG and Timor Leste, have an average POMR of 0.52. This means there are just over 77,000 deaths in the South Pacific region with perioperative deaths, currently representing approximately 1% of all national deaths.

Australia has a POMR of 0.19, with perioperative mortality, contributing 2.8% of all mortality in the country.

New Zealand has a POMR of 0.43 with perioperative mortality amounting to 3.4% of national mortality.

Correlation between Surgical Volume and POMR

The data sets for surgical volume (operations per 100,000 population) and for POMR were not different to that expected for a normal distribution when interrogated by the D'Agostino-Pearson test ($p=.284$, and $p=.355$, respectively). The correlation between POMR and surgical volume was inverse, moderate, and approached statistical significance (Figure 1; $r=-0.52$, $p=.070$).

The surgical volumes of five countries exceeded the LCoGS target (Australia, New Zealand, Tonga, Cook Islands, and Nauru). Comparing the POMRs of countries which exceeded the LCoGS targets to those that did not ($n=8$) identified a significant difference (medians 0.24 versus 0.66, respectively, $p=.024$) and relative risk of 2.8 for increased POMR with failing to meet the LCoGS target.

Insert Figure 1 here

Since surgical volume (a count of all procedures) is the denominator of POMR, we also created a funnel plot with total procedure count as the independent variable and POMR as the dependent variable (Figure 2).

The funnel plot shows a single outlier on the 3SE limits (New Zealand). Minor day surgery, endoscopies, and procedures performed in private practice were excluded from the NZ national database used to calculate POMR for New Zealand.^(1, 11, 12) Therefore, it is not unexpected to find NZ POMR marginally exceeding the control limits given their POMR denominator excluding low acuity cases. The funnel plot showed expected distributions of the data points, including a small number of data points which exceeded the 95% confidence interval.

Insert Figure 2 here

DISCUSSION

There was a moderate inverse correlation between POMR and surgical volume. Potentially, diseases which are amenable to treatment by surgery are seen earlier (in countries with higher surgical volume) before higher risk emergent conditions arise. Therefore, the assumption that POMR remains constant during surgical scale-up (toward LCoGS goals) is one that requires examination. Were this assumption and rate correct, across the 11 LMIC nations, scaling up to perform a further 400,000 procedures would result in a further 2000 perioperative deaths. Were it to fall, as countries in our region with a higher surgical volume had a lower POMR (Figure 1), there would be even less perioperative deaths. If POMR were to fall during surgical scale up, in line with countries that did achieve the LCoGS target in our region, that is from 0.66 to 0.24, then 1,370 surgical deaths would be avoided in those countries (57% less than predicted when POMR remains constant during scale up).

POMR is primarily a safety metric. The most important safety aspect is that it is recorded and reported. Every health service should know whether the patients it performs procedures on, survive to leave hospital or not. Those health systems able to report 30-day mortality are able to make a further step towards understanding who really benefits from surgical and anaesthesia care. Reporting and comparing POMR is challenging. Each country and each region have their own complexities in terms of access, referral patterns, funding, and surgical capacity.

Reporting surgical mortality as a proportion of total population mortality needs to be interpreted in the context of the whole health system. Total population mortality includes deaths associated with underlying surgical conditions, a proportion of which would be averted by timely and safe surgery and other non-surgical mortality. In a health system that is providing surgical services to the population, we would expect

the total number of deaths associated with conditions that are amenable to surgery to decrease, but would anticipate the proportion of deaths occurring as a result of surgery to actually increase. For example, in the United States where many patients are elderly or comorbid, if perioperative mortality were considered a disease it would represent the third leading cause of death in that country.⁽¹⁸⁾ This phenomenon is seen in the Australian and New Zealand data, with POMR contributing 2.8% and 3.4 % of mortality respectively, and above the rates seen in PNG, Timor Leste, and the Pacific. Scaling up surgical services may well cause an overall increase in the number of perioperative deaths, and the proportion of deaths that occur in the postoperative period. However, this is likely to be more than compensated for by the reduction in the number of surgically avertable mortality and the overall premature mortality should decrease.

Case-mix varies between countries and regions. The risk stratification of POMR against case-mix should be based on urgency, age, ASA score, and the procedure performed/condition treated.⁽¹⁹⁾ There may also be national or regional variations that relate to access, stage of disease, or capacity to treat, particularly when considering procedure performed/condition to be treated. This again means that many variables affect POMR which are unique to each country and, in larger populations such as PNG, to regions within the country as well. The concept of what constitutes a 'postoperative death' must also be examined and consideration should be given to the possibility of deaths occurring *after* surgery, but not *due to* surgery but as a result of the underlying condition for which treatment is being sought. It is possible that risk stratification and reporting condition specific POMRs could add context to the numbers, but this is highly unlikely to be achievable in low resource settings.

Urgency is a strong predictor of outcome. Emergency surgery has a higher perioperative mortality rate than elective⁽²⁰⁾, increasing surgical capacity would likely result in an increase of the proportion of cases being

done electively as well as providing better emergency access. The proportion of cases done electively will shift from 30% towards 50%, and perhaps even attain the 70% achieved in HIC's⁽¹⁹⁾ over time if surgery is scaled up and a surgical volume of over 5000 procedures per 100,000 population is achieved. The increased number of less urgent/elective cases would be expected to have a lower risk profile and be less likely to result in severe morbidity or mortality. In turn, a decreased load of urgent cases increases access to elective surgery. Australia and New Zealand perform approximately 2.4 million and 240,000 cases per year, respectively. Based on the Lancet Commission targets, Australasia is performing well above the required volume per capita. As such, with more people having access to surgery, less people dying from infectious diseases, and people having longer life expectancy, people dying from surgery may appear to be higher in Australasia. With an increased surgical volume, POMR is unlikely to remain static and we hypothesize that it will decrease as we do less emergencies and more elective work. For instance, in Australia, the POMR is 10 times higher in emergencies versus elective (0.1% vs 1%).⁽¹³⁾ The Australian and New Zealand Audit of Surgical Mortality (ANZASM) is a program of the Royal Australasian College of Surgeons (RACS) which manages the audit of surgical deaths in Australia and New Zealand. Their findings indicate POMR is higher after emergency surgery and in the aged (85% of ANZASM deaths are emergencies).⁽²¹⁾ Therefore, one cannot directly compare the POMR of a LMIC with that of a HIC without matching for case mix and the proportions of emergency vs elective cases. Furthermore, the presentation of cases in LMICs and HICs is quite different.

In the South Pacific access to the Bellwether procedures varies from 20% to 100% depending on the size of the island nation or income. Increased access would be expected to improve surgical volume, and eventually reduce POMR as patients present earlier and therefore are more likely to survive emergency presentations. Age is associated with postoperative risk of mortality. In High Income Countries, the health

sector would probably operate on more elderly, comorbid patients likely to suffer from an increased morbidity and mortality. HICs do more operations than potentially would be attempted in LMICs, therefore, increasing their at-risk population undergoing surgery. More elderly persons and less emergencies do not normally balance each other out as elective surgery on those over the age of eighty is still uncommon.

There is a lack of standardization of surgical volume as to what constitutes POMR's denominator. Some nations count procedures such as endoscopies, cataracts and those performed under local anaesthesia which fulfil the agreed definition of 'a procedure being conducted in an operating room.' These smaller, lower risk procedures were all appropriately included in our datasets although few gastrointestinal endoscopies are done in the South Pacific. New Zealand's POMRC⁽⁶⁾ did not count day procedures, endoscopies or cases done in the private sector in their data set. Malaysia⁽²²⁾ also excludes cataracts and endoscopies from their reported perioperative mortality rate. Obviously excluding low risk procedures will increase POMR by virtue of reducing the size of the denominator which may account for the different proportion of national deaths that are postoperative (3.4% versus 2.8%) between New Zealand and Australia, respectively.

Globally, if we achieve the target 470 million procedures and the average global POMR is 0.5% to 1%, then postoperative mortality might contribute 2.35 to 4.7 million of the world's current 55 million deaths. This is close to the figure of 7.7% in the recent Lancet article (4.3% to 8.5%).⁽¹⁰⁾ Assuming a stable POMR, in the Pacific Island countries, and in Timor Leste and Papua New Guinea, during up-scaling of surgical services, we predict postoperative deaths would contribute only 3.3% of total national deaths (95% CI: 1.7 to 5.0%). Given there is so much unmet need responsible for premature death that is amenable to surgery, many more premature deaths will be averted by access to surgery than will be lost by having surgery. Scaling

surgical services to the LCoGS target will also reduce avoidable disability and uncorrected deformity, promoting wellbeing and economic activity, in addition to the lives saved from timely treatment.

CONCLUSIONS

Across the nine countries of the South Pacific, Papua New Guinea and Timor Leste, there are around 750 postoperative deaths per year, representing 1% of crude mortality in the region. We project that if surgical and anaesthesia services were to be scaled-up, then the increase in surgical volume would result in a decrease in premature mortality. The ratio of postoperative deaths compared to total mortality would therefore increase three-fold, however, this should not result in adverse media. Many more premature deaths would be averted by treating elective and emergency conditions that are amenable to surgery. Doing more surgery in a timely and safe manner will save lives. Furthermore, we expect POMR to decrease, particularly once capacity increases sufficiently to ensure more elective procedures are performed. The correlations between up-scaling surgical services and mortality will need to be tested once we have sequential data from the individual Pacific Island nations.

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TABLES

Table 1: Population, GDP, Health Expenditure, Life Expectancy, POMR and Surgical Volume

Country	Population	GDP per capita [\$I PPP]	Health expenditure % GDP	Life expectancy at birth [Years]	POMR	Surgical volume [procedures per 100,000 population)	Actual expenditure on Health Care per capita [\$I PPP]
Australia	24 million	48,457	9.42	84.5	0.19	10,156	4,565
New Zealand	4.7 million	41,109	11	83.27	0.43	5,308	4,522
E Timor	1.3 million	7,213	3.1	70.43	0.84	433	224
Fiji	930,000	9,555	3.6	73.32	0.83	1,490	344
Tonga	103,000	5,957	5.9	75.94	0.24	5,061	351
Samoa	197,000	6,628	7.2	79.04	0.82	1,552	477
Vanuatu	260,815	3,208	3.6	74.22	0.28	1,277	115
Cook Islands	13,229	33,182	3.4	76.2	0.11	6,758	1,128
Solomon	602,000	2,423	8	72	0.46	868	194
Nauru	10,084	14,158	4.84	67.8	0.24	7,130	685
PNG	8 million	4,199	3.77	67.9	0.5	1,264	158
Kiribati	110,000	2,180	7.6	69.43	0.11	1,718	166
Tuvalu	10,800	3,925	15	67.2	1	3,417	589

Table footnote: Health expenditure of <1000/year is assumed to represent a LMIC^(15, 16)

Table 2: Modelling of Expected Deaths and Percentage Surgical Mortality if POMR is Constant

Country	Current total number of procedures	Deficit number of procedures to meet LCoGS target	POMR	Current absolute POMR deaths	Expected mortality after scale-up to meet LCoGS target	Crude total mortality	Current surgical mortality %	Surgical mortality % if LCoGS target were met
Australia	2,498,268	-1,234,656	0.19	4,631	2,280	167,856	2.759	1.4
New Zealand	254,560	-13,713	0.43	1,073	1,011	31,546	3.401	3.2
East Timor	5,629	59,371	0.84	47	546	6,869	0.688	7.9
Fiji	13,902	32,748	0.83	115	386	6,845	1.68	5.6
Tonga	5,213	-63	0.24	13	12	611	2.048	2.0
Samoa	3,057	6,793	0.82	25	81	985	2.546	8.2
Vanuatu	3,331	9,710	0.28	9	37	1,248	0.747	2.9
Cook Islands	894	-233	0.11	1	1	110	0.896	0.7
Solomon	5,225	24,875	0.46	24	138	2,790	0.861	5.0
Nauru	719	-215	0.24	2	1	59	2.9	2.0
PNG	101,120	298,880	0.5	506	2,000	56,640	0.893	3.5
Kiribati	1,890	3,610	0.11	2	6	759	0.270	0.8
Tuvalu	369	171	1	4	5	91	4	6.0

FIGURES

Figure 1: Correlation between POMR and Surgical volume was inverse, moderate, and approached statistical significance ($r = -0.52$, $p = .070$).

Figure 2: Funnel plot between POMR and procedure count showing a single outlier (New Zealand) that exceeded the control limits set for the funnel plot. This is not unexpected as low acuity day cases, and endoscopies were excluded from the calculation of POMR for New Zealand.

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