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Capacity for Essential Surgery and Anaesthesia Services in Papua New Guinea

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Capacity for Essential Surgery and Anaesthesia Services in Papua New Guinea

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Abstract

Objective: To assess capacity to provide essential surgical services including emergency, obstetric and anaesthesia care in Papua New Guinea in order to support planning for relevant post-2015 sustainable development goals for Papua New Guinea.

Design: Cross-sectional survey

Setting: Hospitals and health facilities in Papua New Guinea

Participants: 21 facilities including 3 national/provincial hospitals, 11 district/rural hospitals, and 7 health centres

Outcome Measures: The WHO Situational Analysis Tool to Assess Emergency and Essential Surgical Care (WHO-SAT) was used to measure each participating facility's capacity to deliver essential surgery and anaesthesia services, including 108 items related to relevant infrastructure, human resources, interventions, and equipment.

Results: While major surgical procedures were provided at each hospital, fewer than 30% had uninterrupted access to oxygen, and 57% had uninterrupted access to resuscitation bag and mask. Most hospitals reported capacity to provide general anaesthesia, though few hospitals reported having at least one certified surgeon, obstetrician, and anesthesiologist. Access to anaesthetic machines, pulse oximetry, and blood bank was severely limited. Many non-hospital health centres provide surgical services, but almost none had uninterrupted access to electricity, running water, oxygen, and basic supplies for airway management.

Conclusion: Capacity for essential surgery and anaesthesia services is severely limited in PNG due to shortfalls in physical infrastructure, human resources, and basic equipment and supplies. Achieving post-2015 sustainable development goals, including universal healthcare, will require significant investment in surgery and anaesthesia capacity in Papua New Guinea.

Trial Registration: None.

Strengths and Limitations of this Study:

- Provides a first-time cross-sectional measure of capacity to provide essential surgical, emergency, and anaesthesia services, with a broad representation of regions across Papua New Guinea.
- Detailed measures of infrastructure, human resources, interventions, supplies, and equipment reveals significant gaps for some of the most basic needs (personnel, oxygen, other basic resuscitative equipment), and provides evidence-based priorities for planning for achieving post-2015 Sustainable Development Goals, including essential surgery services as a component of Universal Healthcare
- Does not provide measures from every hospital and health centre in the country.
- In some cases, reported data relies on subjective reports or estimates from hospital administrators, without opportunity for objective verification.

Trial Registration: None.

Data sharing statement: Data for this study are available from the authors upon request.

INTRODUCTION

The Independent State of Papua New Guinea (PNG) is a nation of islands in the southwestern Pacific Ocean with a culturally and linguistically diverse population that is expected to exceed 13 million by 2030.¹⁻⁴ Over 80% of the population lives in rural settings across 300 islands, with over 800 official languages.⁵⁻⁸ Life expectancy at birth is 62.8 years.^{2,3} In the PNG Population Health Survey, maternal mortality rate was reported to be 733 per 100,000 live births (2006),⁴ while other estimates indicate the rate may be closer to 230 per 100,000 live births in recent years.² The under-five mortality rate has improved from 74.7 in to 61 per 1,000 live births in the recent 5 years.² The gross national income (GNI) per capita is \$2010, which meets the definition of low-middle income country (LMIC).⁵ On the United Nation's Human Development Index (HDI) ranking, PNG is 157 out of 187 countries worldwide,⁶ with a slow improvement over the past 30 years (**Figure 1**).

A global meta-analysis demonstrated clear reductions in perioperative mortality over the last 50 years, despite increasing complexity and baseline risk status of patients. However, rates of decline in perioperative mortality have been greatest in high HDI countries.⁹ Basic surgical and anaesthetic care is fundamental to providing effective primary care at the district and rural level.^{10,11} Renewed emphasis on the need for essential surgical services as an integral part of achieving universal health care has been the focus of the WHO's Emergency and Essential Surgical Care (EESC) program (<http://www.who.int/surgery/en>) and the Lancet Commission on Global Surgery.^{12,13} Recently, the 68th WHA passed resolution A68/15 on "Strengthening Emergency and Essential Surgical Care and Anaesthesia as a Component of Universal Health Coverage", which has catapulted the importance of essential surgery on the post-2015 sustainable goals development agenda.¹⁴ Yet wide gaps in infrastructure, trained personnel, and basic equipment in the LMIC setting are significant barriers to achieving this mandate.

The structure of health facilities in PNG is outlined in **Figure 2**. In 2010, an estimated 20 to 30% of 4,182 aid posts were no longer in operation, and concerns remain that this number has worsened due to challenges in maintaining a network of trained staff and supplies within remote areas with lacking roads and water transportation (**Table 1**).^{4,8} Trauma represents 60% of surgical admissions, and accidental injury, obstetric and gynecologic, and perinatal conditions, represent the 3rd to 5th leading causes of admission to hospitals, respectively, accounting for more than 700 admissions per 100,000 people in PNG.^{4,15} About 5% of the national budget is spent on health care, and PNG has an estimated 0.58 health workers per 1000 population.^{4,16}

Table 1. Healthcare facilities in PNG in 2010^{4,8}

Category	Government	Mission or Private	Total, n	%
National/Provincial Hospitals	20	2	22	0.5
Urban Clinics	48	21	69	1.6
District/Rural Hospitals	5	9	14	0.3
Health Centres	149	52	201	4.8
Health Sub-Centres	158	270	428	10.2
Aid Posts (open)	2672	-	-	63.9
Aid Posts (closed)	776	-	-	18.6
Total	3828	354	4182	-

Lack of access to essential surgery services contributes significantly to global morbidity and mortality. About 11-15% of the world's disability is due to surgically-treatable conditions,¹¹ yet more than 2 billion people lack access to even the most basic surgical care.^{11-13,17} Out of the 350 million surgeries performed each year worldwide, only 3.5% are performed on the poorest 1/3 of the global population.¹⁸ Injuries alone contribute to 5.7 million premature deaths annually, which outpaces the 3.8 million deaths due to malaria, AIDS, and tuberculosis combined. Southeast Asia is thought to be the region of the world with the largest unmet need, accounting for 48 million disease adjusted life-years (DALYs).¹⁹

The current state of emergency and surgical capacity across PNG is inadequately understood, and precludes setting specific benchmarks for measured action.^{4,15,16,20,21} To date, there have been no published surveys of capacity for essential emergency, surgery, and anaesthesia services within PNG. The purpose of this study was to assess key indicators of capacity to provide surgical services including emergency, obstetrics and anaesthesia across PNG, in order to support future evidence-based decision-making in this area.

METHODS

In 2009, a team from PNG National Department of Health (NDOH) and the WHO EESC program visited 6 health facilities in Hiri district, Rigo district, and Port Moresby General Hospital of Papua New Guinea.^{15,16,20} In addition, NDOH and WHO partnered workshops were provided at the PNG Medical Society Symposium to discuss opportunities for capacity-building in essential surgical services for conditions amenable to surgical intervention,^{15,16,20} and to introduce the WHO Situational Analysis Tool (WHO SAT, available at <http://www.who.int/surgery/en>).

The WHO SAT consists of a 108-item questionnaire for health care facilities to collect information about population served, infrastructure, human resources, interventions, equipment and supplies with a focus on emergency, trauma, obstetrics, surgery, and anaesthetic services.^{22,23} The WHO SAT was distributed during the workshop and during site visits. WHO SAT surveys were completed voluntarily by health care personnel or administrators within hospitals, health centres, or aid-posts in PNG. Surveys were submitted to WHO by email, mail, or fax or through the WHO country office. The survey data was entered by WHO personnel into the EESC Global database.

For this study, all surveys submitted by PNG facilities up to June 2013 were collected from the WHO EESC database. Categorization of data was planned according to the following facility types: national/provincial hospitals, district/rural hospitals, and health centres or aid-posts (called 'health centres', for simplicity). The designation of health facility type was verified through direct contact or through online searches of PNG websites.

Descriptive summary statistics were planned for each of these categories of facilities, including population served by the facility, number of admissions, number of functioning operating rooms, number of surgeries performed (major and minor combined) for adults, number of surgeries performed (major and minor combined) for pediatrics (age < 15 years), number of patients referred to other centres (due to insufficient local capacity), and distance travelled by patients to reach the facility for surgical services. In addition, details about infrastructure, equipment, and supplies were summarized through for each category of facility through heat map tables where green indicates uninterrupted supply, yellow indicates interrupted supply, and red indicates

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3 unavailable. Human resources were characterized by facility type, with particular emphasis on availability of
4 certified surgeons, obstetrician/gynecologists, anaesthesiologists, general physicians or other trained nurses,
5 health extension officers, midwives or paramedics performing surgery or anaesthesia. The proportion of
6 facilities that indicated capacity to provide each service listed within the WHO SAT was also summarized.
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10 When possible, information was validated through discussions with the submitter by email when survey data
11 was unclear or missing. If contact was unsuccessful, other members within the facility were emailed, or
12 members of the PNG Society for Rural & Remote Medicine were contacted for information. Through this
13 network, most of the missing and unclear data was successfully ascertained. Any remaining data not reported
14 is indicated by 'NR' in the summary tables.
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17 Proportions were summarized as percentage facilities with uninterrupted supply for the respective
18 infrastructure items. Medians and ranges were provided as a summary estimate for numeric data. Since the
19 earlier version of SAT (before 2012) provides preset categories for numeric data (ie, 3 to 4, 5 - 10, 11-20, 21-50,
20 etc), the median was reported in accordance with these definitions, and the range was reported as the lowest
21 and highest possible number for the extremes of the reported ranges. Descriptive comparisons between
22 national/provincial and district/rural centres was planned, without statistical inference.
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25 RESULTS

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29 A total of 25 WHO SAT surveys were identified in the WHO database, with submission dates ranging from 2008
30 to 2011. After removing duplicate reports (only the most recent report from each centre was retained), there
31 remained a total of 21 surveys including 3 national/provincial hospitals, 11 district/rural hospitals, and 7 health
32 centres. The surveys represented a broad geographic coverage of the provinces and regions of PNG, as shown
33 by the map in **Figure 3**. Most hospitals in PNG are represented in this study.
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37 **Table 2** provides a description of included facilities. District/rural hospitals generally served around 100,000,
38 1000-2000 admissions annually, with fewer than 100 beds and 1 or 2 functioning operating rooms (OR). Two
39 national/provincial hospitals had under 10 operating rooms to support several thousand surgeries annually.
40 Most hospitals provided adult and pediatric surgery. District/rural hospitals were more likely to refer a
41 significant proportion of patients to other facilities for surgery. Some patients travel a long distance to reach
42 referral centres (300 km to 700 km). While each national/provincial hospital reported devoted emergency
43 department (ED) and post-anaesthesia care unit (PACU) areas, less than 50% of district/rural hospitals reported
44 having these. The number of beds and ORs per facility was not necessarily commensurate with the size of
45 population served, number of admissions, and number of surgeries performed.
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Table 2. Description of PNG Healthcare facilities responding to WHO SAT Survey

	Population Served by this Facility	Beds	Admissions/yr	# ORs	Surgeries/yr	Pediatric Surgeries/yr	Referred out for surgery/yr	Km Travelled to this facility	Km travelled if referred out
National/Provincial Hospitals (n=3)									
N/P #1	6,000,000	501-700	>5000	5 to 10	>5000	201-300	5 to 10	5 to 10	5 to 10
N/P #2	26,000	201-300	>5000	3 to 4	1001-2000	81-100	5 to 10	21 to 50	NR
N/P #3	15000	21-50	301-400	2	51-80	5-10	11 to 20	201 to 300	81-100
Median (range)	26,000 (15,000 to 6m)	201-300 (21 to 700)	>5000 (301 to >5000)	3 to 4 (2 to 11)	1001-2000 (51 to >5000)	81-100 (5 to 300)	5 to 10 (5 to 20)	21 to 50 (5 to 300)	-
District/Rural District Hospitals (n=11)									
D/R #1	75,000	101-200	1001-2000	2	101-200	21-50	51-80	11-20	NR
D/R #2	100,000	51-80	NR	1	101-200	81-100	3-4	51-80	501-700
D/R #3	30,000	51-80	1001-2000	2	401-500	11-20	11-20	21-50	NR
D/R #4	40,000	21-50	401-500	1	101-200	51-80	5-10	5-10	101-200
D/R #5	10,000	11-20	201-500	1	11-20	5-10	21-50	201-300	2001-5000
D/R #6	30,000	51-80	701-1000	1	201-300	NR	11-20	NR	NR
D/R #7	122,000	51-80	2001-5000	2	301-400	81-100	81-100	5-10	5-10
D/R #8	256,000	101-200	2001-5000	2	2001-5000	201-300	21-50	11-20	NR
D/R #9	100,000	201-300	>5000	2	401-500	81-100	81-100	NR	81-100
D/R #10	118,000	101-200	2001-5000	2	401-500	81-100	5-10	51-80	101-200
D/R #11	100,000	51-80	1001-2000	1	301-400	21-50	11-20	21-50	201-300
Median (range)	100,000 (10,000 to 356,000)	51-80 (11 to 300)	1001-2000 (201 to >5000)	2 (1 to 2)	301-400 (11 to 5000)	81-100 (5 to 300)	21-50 (3 to 100)	21-50 (5 to 300)	201-300 (5 to 700)
Health Centres/Aid Posts (n=7)									
HC/AP #1	5000	21-50	701-1000	1	3-4	2	11-20	2	21-50
HC/AP #2	9000	0	0	1	11-20	0	11-20	5-10	NR
HC/AP #3	NR	0	0	1	11-20	0	11-20	5-10	NR
HC/AP #4	NR	0	21-50	1	51-80	21-50	11-20	21-50	81-100
HC/AP #5	NR	5-10	0	1	201-300	51-80	5-10	81-100	81-100
HC/AP #6	NR	0	0	1	301-400	201-300	51-80	3-4	11-20
HC/AP #7	NR	5-10	21-50	1	301-400	201-300	11-20	21-50	51-80
Median (range)	Unknown	0 (0, 50)	0 (0, 1000)	1	51-80 (3, 400)	21-50 (0, 300)	11-20 (5, 80)	5-10 (2, 100)	51-80 (11 to 100)

Provincial = N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

*functioning ORs only ^major and minor surgeries NR = not reported by the respondent and data unavailable from email contacts

Infrastructure

The heat map in Table 3 reveals several gaps in basic essential elements of infrastructure (yellow and red areas), with increasing gaps in district/rural hospitals and health centres. All national/provincial hospitals had uninterrupted access to essential infrastructure, including running water, electricity, oxygen, anaesthesia machine, pulse oximetry, blood bank, lab work, and x-ray machines. Whereas, at district/rural hospitals, most (but not all) reported uninterrupted access to running water and electricity, but fewer than 50% reported consistent access to oxygen cylinders or concentrators.

Table 3. Infrastructure

	Admissions/ yr	Surgeries/ yr	Pediatric Surgeries/ yr	Running Water	Electricity	Oxygen Cylinder	Oxygen concentrator	Anaesthesia Machine	Pulse Oximetry	Blood Bank	Hgb & Urinalysis	x-ray machine
National/Provincial Hospitals (n=3)												
N/P #1	>5000	>5000	201-300									
N/P #2	>5000	1001- 2000	81-100									
N/P #3	301-400	51-80	5-10									
National/Provincial Hospitals with Uninterrupted Supply				100%	100%	66%	100%	100%	100%	100%	100%	100%
District/Rural Hospitals (n=11)												
D/R #1	1001-2000	101-200	21-50									
D/R #2	NR	101-200	81-100									
D/R #3	1001-2000	401-500	11-20									
D/R #4	401-500	101-200	51-80									
D/R #5	201-500	11-20	5-10									
D/R #6	701-1000	201-300	NR									
D/R #7	2001- 5000	301-400	81-100									
D/R #8	2001- 5000	2001- 5000	201-300									
D/R #9	>5000	401-500	81-100									
D/R #10	2001- 5000	401-500	81-100									
D/R #11	1001-2000	301-400	21-50									
District/Rural Hospitals with Uninterrupted Supply				91%	91%	45%	36%	45%	36%	36%	72%	55%
Health Centres/Aid Posts (n=7)												
HC/AP #1	701-1000	3-4	2									
HC/AP #2	0	11-20	0									
HC/AP #3	0	11-20	0									
HC/AP #4	21-50	51-80	21-50									
HC/AP #5	0	201-300	51-80									
HC/AP #6	0	301-400	201-300									
HC/AP #7	21-50	301-400	201-300									
Health Centres with Uninterrupted supply				14%	57%	43%	0%	0%	0%	0%	43%	0%

Green = uninterrupted supply; Yellow = interrupted supply; Red = unavailable; N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

Fewer than half of district/rural hospitals had access to anaesthesia machines, and only 36% had consistent access to pulse oximetry, despite performing a large number of surgeries each year. Similarly, only 36% of centres reported consistent blood bank access. About half of district/rural hospitals had access to x-ray machines, and 72% had access to hemoglobin assay and urinalysis. Most district/rural hospitals reported multiple deficiencies in basic infrastructure, with only one district/rural hospital reporting no deficiencies.

Access to oxygen cylinders or concentrators, anaesthesia machines, and blood bank were the most commonly reported infrastructure deficiencies. In general, district/rural hospitals with the most severe infrastructure deficiencies performed relatively fewer surgeries than those reporting better infrastructure, despite the fact that they had several hundred or thousands of patient admissions annually and served a large population within PNG.

Infrastructure for facilities categorized as health centres was extremely limited, with only one reporting uninterrupted access to running water, and just over half reporting uninterrupted electricity, and less than 50% reporting consistent access to oxygen. None had access to anaesthesia machines, pulse oximetry, blood bank, or x-ray machines, despite performing up to 400 surgical procedures per year.

Human Resources

National/provincial hospitals had 2 to 9 qualified surgeons, and were supplemented by general doctors or nurse/health extension officers who also performed surgery (Table 4). In addition, they generally reported at least 1 qualified anaesthesiologist, supplemented by general doctors or nurse/health extension officers performing anaesthesia, and at least one obstetrician/gynecologist. In contrast, most district/rural hospitals did not have qualified surgeons, obstetrician/gynecologists, or anaesthesiologists. In general, district/rural hospitals were more likely to rely on general doctors or nurse/health extension officers to perform surgery and anaesthesia, some of whom were not certified. Most district/rural hospitals had at least 1 paramedic/midwife, with 1 hospital reporting up to 8 paramedic/midwives. The number of healthcare workers was low relative to patient admissions and surgeries performed. At the health centres, there were few qualified healthcare personnel. The health centres were more likely to rely on health extension officers and/or paramedics/midwives (ie, Community Health Workers).

Table 4. Human Resources

	Admissions/ yr	Surgeries/ yr	Pediatric Surgeries/ yr	Surgeons (FT or PT)	Obstetrician/ Gynecologists (FT or PT)	General MDs performing Surgery (FT or PT)	Nurse or Medical Officer performing Surgery	Anaesthesiologists (FT or PT)	General MDs performing Anaesthesia (FT or PT)	Nurse or Medical Officer performing Anaesthesia	Paramedics/ Midwives
National/Provincial Hospitals (n=3)											
N/P #1	>5000	>5000	201-300	9	5	10	0	14	4	4	0
N/P #2	>5000	1001-2000	81-100	3	1	1	1	2	0	0	0
N/P #3	301-400	51-80	5-10	2	0	4	4	1	1	1	2
Median (range) number in National/Provincial Hospitals				3 (2 to 9)	1 (0 to 5)	4 (1 to 10)	1 (0 to 5)	2 (1 to 14)	1 (0 to 4)	1 (0 to 4)	0 (0 to 2)
District/Rural Hospitals (n=11)											
D/R #1	1001- 2000	101-200	21-50	1	0	2	6	0	0	2	1
D/R #2	NR	101-200	81-100	0	0	1	1	0	0	1	0
D/R #3	1001- 2000	401-500	11-20	2	0	1	0	0	0	1	8
D/R #4	401-500	101-200	51-80	0	0	2	0	0	2	1	0
D/R #5	201-500	11-20	5-10	0	0	2	1	0	0	1	1
D/R #6	701-1000	201-300	NR	0	0	2	0	0	2	0	0
D/R #7	2001- 5000	301-400	81-100	1	1	1	1	1	1	2	3
D/R #8	2001- 5000	2001- 5000	201-300	1	0	6	1	0	0	2	2
D/R #9	>5000	401-500	81-100	0	1	1	1	0	0	2	4
D/R	2001-	401-500	81-100	0	0	2	2	0	0	1	1

#10	5000										
D/R	1001-2000	301-400	21-50	0	0	1	0	0	0	0	5
#11											
Median (range) number in Rural/District Hospitals				0 (0 to 2)	0 (0 to 1)	1 (1 to 6)	1 (0 to 6)	0 (0 to 1)	0 (0 to 2)	1 (0 to 2)	1 (0 to 5)
Health Centres/Aid Posts (n=7)											
HC/AP #1	701-1000	3-4	2	0	0	0	0	0	0	0	1
HC/AP #2	0	11-20	0	0	0	0	0	0	0	1	2
HC/AP #3	0	11-20	0	0	0	0	1	0	0	0	0
HC/AP #4	21-50	51-80	21-50	0	0	0	1	0	0	0	0
HC/AP #5	0	201-300	51-80	0	0	0	1	0	0	1	2
HC/AP #6	0	301-400	201-300	0	0	0	0	0	0	0	3
HC/AP #7	21-50	301-400	201-300	0	0	2	1	0	0	1	1
Median (range) number in Health Centres/Aid Posts				0	0	0 (0 to 2)	1 (0 to 1)	0	0	0 (0 to 1)	1 (3 to 3)

N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts; FT = fulltime; PT = part-time

Surgical & Anaesthetic Interventions

National/provincial hospitals indicated uniform capacity to provide general, regional, or spinal anaesthesia, while district/rural hospitals indicated less capacity to provide general anaesthesia. Health centres generally did not report capacity to provide anaesthesia, with the exception of one centre which provides ketamine sedation (Table 5). Routine use of guidelines for surgery, anaesthesia, and pain were reported in 66% of national/provincial hospitals, and only 20% of district/rural hospitals, and none of the health centres.

Table 5. Interventions (% of facilities reporting capacity to provide selected interventions)

	National/Provincial Hospital, n=3 (%)	District/Rural Hospital, n=11 (%)	Health Centre/Aid Posts, n=7 (%)
Anaesthesia			
General Anaesthesia	100	64	0
Spinal Anaesthesia	100	91	0
Regional Anaesthesia	100	100	0
Ketamine Anaesthesia	66	100	14
Surgical Procedures			
Resuscitation*	100	100	14
Cricothyroidotomy/Tracheostomy	66	64	0
Chest Tube	100	100	0
Cesarean Section	100	82	0
Dilatation & Curettage (D&C)	100	100	0
Obstetric Fistula Repair	66	36	0
Hydrocele	100	82	0
Cystostomy	100	55	0

Laparotomy	100	64	0
Tubal Ligation	100	91	0
Hernia Repair, strangulated	100	72	0
Hernia Repair, congenital	100	64	0
Cleft Lip & Palate Repair	66	18	0
Neonatal Surgery **	66	27	0
Club Foot Repair	66	55	0
Fracture Reduction, Closed	100	100	57
Fracture Reduction, Open	100	64	14
Amputation	100	72	14
Joint Dislocation	100	100	71
Male circumcision	100	100	0
Urethral stricture dilator	66	55	0
Appendectomy	100	64	0
Acute Burns	100	100	86
Contracture Release, Skin Grafting	100	91	0
Drainage of Osteomyelitis or Septic Arthritis	100	91	0
Abscess Incision & Drainage	100	100	100
Wound Debridement	100	100	71
Suturing	100	100	100
Foreign Body Removal	100	100	29
Biopsy	100	82	14
Cataract Surgery	66	18	0

*Resuscitation - Airway, hemorrhage, peripheral intravenous access, peripheral venous cut down ** Neonatal surgery – abdominal wall defect, colostomy, imperforate anus, intussusception

National/provincial hospitals reported capacity to provide most procedures listed in the WHO SAT (**Table 5**), although 1 of 3 national/provincial hospitals reported lack of capacity for cricothyroidotomy/tracheostomy, club foot, cleft lip, and neonatal surgery. In general, district/rural hospitals reported capacity to provide resuscitation, chest tube insertion, dilation and curettage, joint dislocation, male circumcision, acute burn management, skin grafting and contractures treatment, abscess incision and drainage, wound debridement, suturing, foreign body removal, drainage of osteomyelitis or septic arthritis, and closed fracture reduction. Capacity to provide caesarean section was indicated by 82% of national/provincial hospitals, and tubal ligation by 91%, but only 36% had capacity to provide obstetrical fistula repairs. Few district/rural hospitals provided neonatal surgery, cleft lip repair, or club foot repair. Health centres indicated limited capacity for most types of procedures. Of particular concern is the lack of reported capacity for *basic* resuscitation at the health centres.

Equipment & Supplies

The heat map in **Table 6** reveals frequent deficiencies in essential equipment and supplies, which progressively increases from national/provincial hospitals, to district/rural hospitals, and health centres. None of the facility types reported consistent access to all of the listed equipment. Even at the national/provincial hospitals, frequent shortages in essential equipment were reported. At district/rural hospitals, frequent deficiencies were reported for oxygen delivery, cricothyroidotomy supplies, IV fluid delivery, sterilization, and personal protective equipment including gloves. At the health centres, almost all categories of equipment and supplies were frequently or completely unavailable, including all basic resuscitation equipment.

Table 6. Equipment & Supplies

	Admissions per yr	Surgeries per yr	Pediatric Surgeries per yr	Resuscitator bag & mask (adult)	Resuscitator bag & mask (peds)	Oxygen and Mask Tubing to Connect Oxygen	Sterile Disposable Needles	Stethoscope	Cryothyroidotomy set	Oropharyngeal airway (adult)	Oropharyngeal airway (peds)	Sterilizer	Sterile Gloves	Protective face mask	IV fluid set bags
National/Provincial Hospitals (n=3)															
NP #1	>5000	>5000	201-300												
NP #2	>5000	1001-2000	81-100												
NP #3	301-400	51-80	5-10												
National/Provincial Hosp with Uninterrupted Supply				33%	33%	33%	66%	33%	33%	33%	33%	33%	33%	66%	66%
District/Rural Hospitals (n=11)															
DR #1	1001-2000	101-200	21-50												
DR #2	-	101-200	81-100												
DR #3	1001-2000	401-500	11-20												
DR #4	401-500	101-200	51-80												
DR #5	201-500	11-20	5-10												
DR #6	701-1000	201-300	-												
DR #7	2001-5000	301-400	81-100												
DR #8	2001-5000	2001-5000	201-300												
DR #9	>5000	401-500	81-100												
DR #10	2001-5000	401-500	81-100												
DR #11	1001-2000	301-400	21-50												
District/Rural Hospitals with Uninterrupted Supply				64%	72%	27%	72%	64%	27%	82%	82%	55%	55%	72%	45%
Health Centres/Aid Posts (n=6)															
HC/AP #1	701-1000	3-4	2												
HC/AP #2	0	11-20	0												
HC/AP #3	0	11-20	0												
HC/AP #4	21-50	51-80	21-50												
HC/AP #5	0	201-300	51-80												
HC/AP #6	0	301-400	201-300												
HC/AP #7	21-50	301-400	201-300												
HC/AP with Uninterrupted supply				0%	0%	0%	71%	43%	0%	0%	0%	0%	14%	14%	14%

Green = uninterrupted supply; Yellow = interrupted supply; Red = unavailable or frequently unavailable; PN/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

DISCUSSION

Much progress has been made in healthcare provision in recent years in PNG, and yet important deficiencies persist which reduce access to essential surgery. Rural facilities that are physically closest to where 80% of the population resides deal with the most severe restrictions in infrastructure, supply, and human resources. One of the most striking findings of this study was that no health facility reported having all infrastructure required to provide essential surgical surgery, despite providing thousands of surgeries annually. Many facilities manage to provide emergency and surgical services without a consistent supply of electricity, running water, oxygen, anaesthesia machines, pulse oximeters, blood bank access, IV fluid resuscitation, and personal protective

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3 equipment. The SAT provides a clear picture of the state of deficiencies across healthcare facilities, which has
4 likely contributed to the persistently low performance on key MDGs (high maternal and child mortality,
5 especially in the rural areas, where rates are known to be 2-fold higher than in urban areas of PNG),⁴ and will
6 preclude achievement of equitable and efficient universal health care in PNG in the post-2015 development
7 agenda.^{14,24}
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10 While this study provides only a partial snap-shot of the system, it provides a level of detail that has never
11 before been published for PNG.²⁵ Nevertheless, the results should be interpreted in light of typical limitations
12 typically of survey data. Given the formidable challenges including geographical and expense of achieving a
13 complete and formalized representation of all facilities country-wide, this study relied on volunteer submission
14 of the WHO SAT from health facilities. Accordingly, there will be deficiencies in representativeness. Perhaps the
15 most important limitation of this survey is the fact that only infrastructure and activity is measured. Since
16 outcomes are not measured, there is no opportunity to correlate the deficiencies in infrastructure and human
17 resources with clinical or population-based outcomes. However, we know from previous studies within PNG²⁶
18 and other LMICs^{9,27-30} that deficits in health infrastructure, medical technology, and integration of resources to
19 provide surgery have been consistently correlated with mortality, and that intervention to alleviate these
20 deficiencies has a tangible impact on mortality.²⁶
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25 While the magnitude of unmet need experienced by PNG is only indirectly informed by this study, the emerging
26 picture of greatest restrictions to those who need it most represents a specific call to action. Reducing
27 maternal and child mortality will require essential surgery to be bolstered through sequenced steps to address
28 the facility infrastructure and trained human resources to address common debilitating conditions in PNG.^{31,32}
29 In PNG, deaths due to trauma, accidents, obstetric and neonatal conditions considered together represent a
30 high proportion of life lost which rivals that of deaths due to HIV/AIDs, malaria and pneumonia. Many of these
31 deaths could be prevented through essential surgery, if it was available. Beyond premature deaths, there exists
32 a myriad of common conditions for which surgical services would reduce morbidity, including obstetric fistulas,
33 maternal haemorrhage, club foot, cleft lip and palate, acute abdominal conditions, hernias, cataracts,
34 malignant and benign tumors, ruptured spleen (due to malaria), burns, contractures, fractures, and trauma
35 complications, male circumcision (HIV transmission reduction), among others.^{16,33}
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39 Although surgery is one of the most cost-effective interventions in LMICs,^{11,34} perceptions remain that it is too
40 expensive and complex to provide in austere settings.¹⁶ Greater efforts should be devoted to prioritizing
41 essential on the political agenda and for aid providers,^{9,35} since simple life-altering procedures can bring greater
42 value for money than other commonly-supported public health interventions in LMICs.³⁴
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45 The government of PNG has taken important steps to place renewed focus on strengthening the healthcare
46 system, after initial gains in the 1990s were partly defeated by setbacks in progress, revealed by “brain drain”
47 of qualified healthcare workers from remote areas to urban areas or out-of-country, and the closing of several
48 aid-posts.^{4,36} PNG has an estimated 0.58 healthcare workers per 1000 people, and fewer than 1 qualified
49 anaesthetic provider per 100,000, which is at the lowest end of recent global surveys.^{4, 17, 30, 37-39} To put this into
50 perspective, in the USA and UK there is an estimated ratio of 1:4000 or 1:5000 of anaesthetic providers per
51 capita.⁴⁰
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55 Despite much progress and many successes to be celebrated in PNG (ie, increased oxygen supply, medical
56 records and clinical guidelines use, health extension officers and community health workers, medical residency
57 and surgical training networks),^{4,32,36} in order to achieve post-2015 development targets, increasing essential
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3 surgical services will need become a high priority to operationalize the National Health Plan. Without
4 rehabilitation of current facilities to be outfitted with basic infrastructure including electricity, water, and
5 essential supplies, along with functional operating rooms, EDs, PACUs, adequately resourced with essential
6 equipment and with trained healthcare workers at the rural level, the Vision 2050 and the post-2015
7 development agenda will remain theory rather than a reality.^{4,24,36}
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10 **Conclusions:** Despite important progress in healthcare provision in PNG, capacity for essential surgery is
11 severely limited and unevenly provided due to limitations in physical infrastructure, human resources, and basic
12 equipment and supplies. Appropriate solutions to these gaps should be sought through collaborative and
13 context-sensitive approaches, and with a degree of urgency that is commensurate with the severity of lives
14 lost and disability disproportionately affecting the livelihoods of the most disadvantaged.
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Figure Legends

Figure 1. Human Development Index (HDI): Trends for PNG relative to other Low HDI countries, and relative to the East Asia and the Pacific: 1980 - present.⁶

Figure 2. Structure of PNG's health care system.⁴

Figure 3: Location of health facilities included in this study (clustering and overlaps prevents 2 of the pins from being visible near Port Moresby and near Kundiawa)

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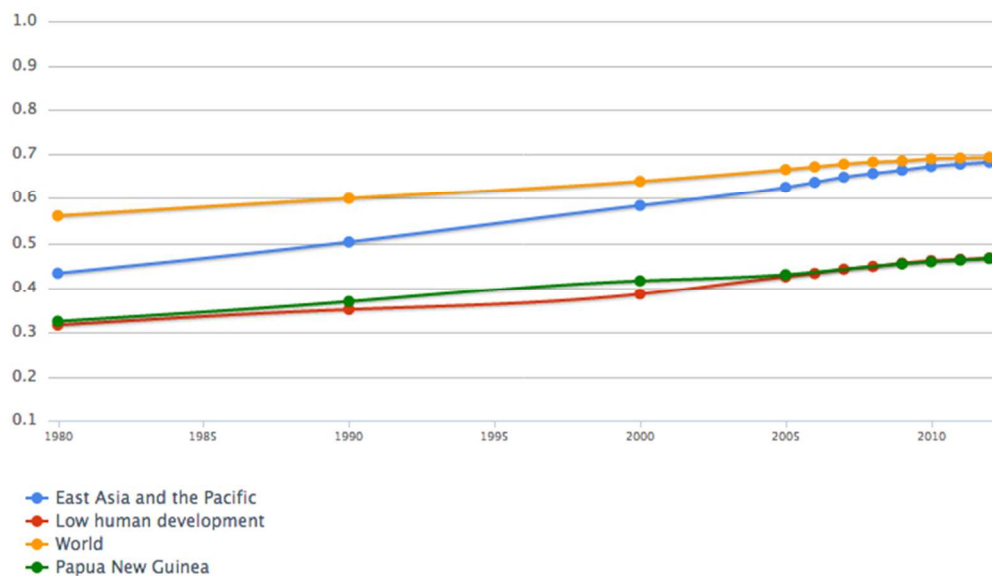


Figure 1. Human Development Index (HDI): Trends for PNG relative to other Low HDI countries, and relative to the East Asia and the Pacific: 1980 - present.⁶
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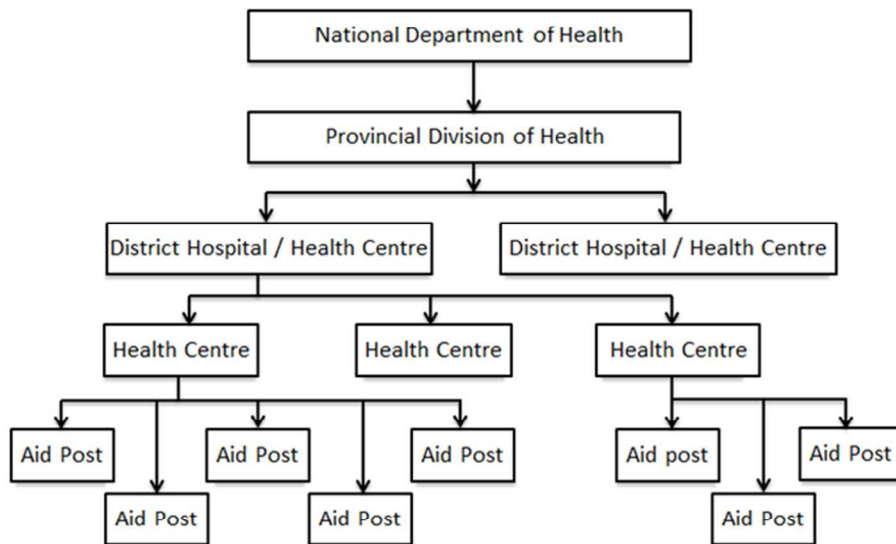


Figure 2. Structure of PNG's health care system.4
129x88mm (150 x 150 DPI)

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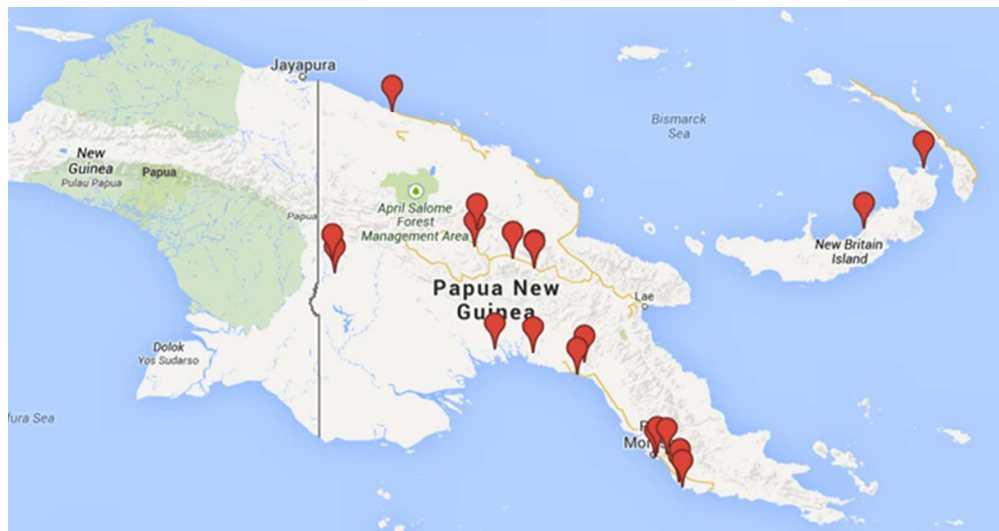


Figure 3: Location of health facilities included in this study (clustering and overlaps prevents 2 of the pins from being visible near Port Moresby and near Kundiawa)
119x62mm (150 x 150 DPI)

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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract (abstract)	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale (p.5-6)	2	Explain the scientific background and rationale for the investigation being reported
Objectives (p.5-6)	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design (p.6-7)	4	Present key elements of study design early in the paper
Setting (p.6-7)	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants (p.8)	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants
Variables (p.6-7)	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement (p. 6-7)	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias (p.7)	9	Describe any efforts to address potential sources of bias
Study size (p.7)	10	Explain how the study size was arrived at
Quantitative variables (p.6-7)	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods (p.7)	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses

Continued on next page

Results

Participants (p.8)	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram
Descriptive data (p.7-13)	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data (p.7-13)	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures
Main results (p.7-13)	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses (N/A)	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion

Key results (p.13-15)	18	Summarise key results with reference to study objectives
Limitations (p.13-15)	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation (p.13-15)	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability (p.14)	21	Discuss the generalisability (external validity) of the study results

Other information

Funding (p.16)	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based
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*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Survey of the Capacity for Essential Surgery and Anaesthesia Services in Papua New Guinea

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Survey of the Capacity for Essential Surgery and Anaesthesia Services in Papua New Guinea

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Abstract

Objective: To assess capacity to provide essential surgical services including emergency, obstetric and anaesthesia care in Papua New Guinea in order to support planning for relevant post-2015 sustainable development goals for Papua New Guinea.

Design: Cross-sectional survey

Setting: Hospitals and health facilities in Papua New Guinea

Participants: 21 facilities including 3 national/provincial hospitals, 11 district/rural hospitals, and 7 health centres

Outcome Measures: The WHO Situational Analysis Tool to Assess Emergency and Essential Surgical Care (WHO-SAT) was used to measure each participating facility's capacity to deliver essential surgery and anaesthesia services, including 108 items related to relevant infrastructure, human resources, interventions, and equipment.

Results: While major surgical procedures were provided at each hospital, fewer than 30% had uninterrupted access to oxygen, and 57% had uninterrupted access to resuscitation bag and mask. Most hospitals reported capacity to provide general anaesthesia, though few hospitals reported having at least one certified surgeon, obstetrician, and anesthesiologist. Access to anaesthetic machines, pulse oximetry, and blood bank was severely limited. Many non-hospital health centres providing basic surgical procedures, but almost none had uninterrupted access to electricity, running water, oxygen, and basic supplies for resuscitation, airway management, and obstetric services.

Conclusion: Capacity for essential surgery and anaesthesia services is severely limited in PNG due to shortfalls in physical infrastructure, human resources, and basic equipment and supplies. Achieving post-2015 sustainable development goals, including universal healthcare, will require significant investment in surgery and anaesthesia capacity in Papua New Guinea.

Trial Registration: None.

Strengths and Limitations of this Study:

- Provides a first-time cross-sectional measure of capacity to provide essential surgical, emergency, and anaesthesia services, with a broad representation of regions across Papua New Guinea.
- Detailed measures of infrastructure, human resources, interventions, supplies, and equipment reveals significant gaps for some of the most basic needs (personnel, oxygen, other basic resuscitative equipment), and provides evidence-based priorities for planning for achieving post-2015 Sustainable Development Goals, including essential surgery services as a component of Universal Healthcare
- Does not provide measures from every hospital and health centre in the country.
- In some cases, reported data relies on subjective reports or estimates from hospital administrators, without opportunity for objective verification.

Trial Registration: None.

Data sharing statement: Data for this study are available from the authors upon request.

INTRODUCTION

The Independent State of Papua New Guinea (PNG) is a nation of islands in the southwestern Pacific Ocean with a culturally and linguistically diverse population that is expected to exceed 13 million by 2030.¹⁻⁴ Over 80% of the population lives in rural settings across 300 islands, with over 800 official languages.⁵⁻⁸ Life expectancy at birth is 62.8 years.^{2,3} In the PNG Population Health Survey, maternal mortality rate was reported to be 733 per 100,000 live births (2006),⁴ while other estimates indicate the rate may be closer to 230 per 100,000 live births in recent years.² The under-five mortality rate has improved from 74.7 in to 61 per 1,000 live births in the recent 5 years.² The gross national income (GNI) per capita is \$2010, which meets the definition of low-middle income country (LMIC).⁵ On the United Nation's Human Development Index (HDI) ranking, PNG is 157 out of 187 countries worldwide,⁶ with a slow improvement over the past 30 years (**Figure 1**).

A global meta-analysis demonstrated clear reductions in perioperative mortality over the last 50 years, despite increasing complexity and baseline risk status of patients. However, rates of decline in perioperative mortality have been greatest in high HDI countries.⁹ Basic surgical and anaesthetic care is fundamental to providing effective primary care at the district and rural level.^{10,11} Renewed emphasis on the need for essential surgical services as an integral part of achieving universal health care has been the focus of the WHO's Emergency and Essential Surgical Care (EESC) program (<http://www.who.int/surgery/en>) and the Lancet Commission on Global Surgery.^{12,13} Recently, the 68th WHA passed resolution A68/15 on "Strengthening Emergency and Essential Surgical Care and Anaesthesia as a Component of Universal Health Coverage", which has catapulted the importance of essential surgery on the post-2015 sustainable goals development agenda.¹⁴ Yet wide gaps in infrastructure, trained personnel, and basic equipment in the LMIC setting are significant barriers to achieving this mandate.

The structure of health facilities in PNG is outlined in **Figure 2**. In 2010, an estimated 20 to 30% of 4,182 aid posts were no longer in operation, and concerns remain that this number has worsened due to challenges in maintaining a network of trained staff and supplies within remote areas with lacking roads and water transportation (**Table 1**).^{4,8} Trauma represents 60% of surgical admissions, and accidental injury, obstetric and gynecologic, and perinatal conditions, represent the 3rd to 5th leading causes of admission to hospitals, respectively, accounting for more than 700 admissions per 100,000 people in PNG.^{4,15} About 5% of the national budget is spent on health care, and PNG has an estimated 0.58 health workers per 1000 population.^{4,16}

Table 1. Healthcare facilities in PNG in 2010^{4,8}

Category	Government	Mission or Private	Total, n	%
National/Provincial Hospitals	20	2	22	0.5
Urban Clinics	48	21	69	1.6
District/Rural Hospitals	5	9	14	0.3
Health Centres	149	52	201	4.8
Health Sub-Centres	158	270	428	10.2
Aid Posts (open)	2672	-	-	63.9
Aid Posts (closed)	776	-	-	18.6

Total	3828	354	4182	-
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Lack of access to essential surgery services contributes significantly to global morbidity and mortality. About 11-15% of the world's disability is due to surgically-treatable conditions,¹¹ yet more than 2 billion people lack access to even the most basic surgical availability.^{11-13,17} Out of the 350 million surgeries performed each year worldwide, only 3.5% are performed on the poorest 1/3 of the global population.¹⁸ Injuries alone contribute to 5.7 million premature deaths annually, which outpaces the 3.8 million deaths due to malaria, AIDS, and tuberculosis combined. Southeast Asia is thought to be the region of the world with the largest unmet need, accounting for 48 million disease adjusted life-years (DALYs).¹⁹

The current state of emergency and surgical capacity across PNG is inadequately understood, and precludes setting specific benchmarks for measured action.^{4,15,16,20,21} To date, there have been no published surveys of capacity for essential emergency, surgery, and anaesthesia services within PNG. The purpose of this study was to assess key indicators of capacity to provide surgical services including emergency, obstetrics and anaesthesia across PNG, in order to support future evidence-based decision-making in this area.

METHODS

In 2009, a team from PNG National Department of Health (NDOH) and the WHO EESC program visited 6 health facilities in Hiri district, Rigo district, and Port Moresby General Hospital of Papua New Guinea.^{15,16,20} These centres were chosen based on a convenience sample representing a number of regions, but within limits of accessibility within a short availability of time. In addition, NDOH and WHO partnered workshops were provided at the PNG Medical Society Symposium to discuss opportunities for capacity-building in essential surgical services for conditions amenable to surgical intervention,^{15,16,20} and to introduce the WHO Situational Analysis Tool (WHO SAT, available at <http://www.who.int/surgery/en>).

The WHO SAT consists of a 108-item questionnaire for health care facilities to collect information about population served, infrastructure, human resources, interventions, equipment and supplies with a focus on emergency, trauma, obstetrics, surgery, and anaesthetic services.^{22,23} The WHO SAT was distributed during the workshop and during site visits. WHO SAT surveys were completed voluntarily by health care personnel or administrators within hospitals, health centres, or aid-posts in PNG. Surveys were submitted to WHO by email, mail, or fax or through the WHO country office. Hospitals and peripheral health centres were invited to participate in a cross-sectional survey of surgery and anesthesia capacity across PNG. The invitation was primarily disseminated during NDOH- and WHO-sponsored workshops which included health care workers from many rural and urban centres. Health care workers and administrators who participated in the survey were also encouraged to contact other hospitals and health centres to invite them to participate. The survey data was entered by WHO personnel into the EESC Global database.

For this study, all surveys submitted by PNG facilities up to June 2013 were collected from the WHO EESC database. Categorization of data was planned according to the following facility types: national/provincial hospitals, district/rural hospitals, and health centres or aid-posts (called 'health centres', for simplicity). The designation of health facility type was verified through direct contact or through online searches of PNG websites.

Descriptive summary statistics were planned for each of these categories of facilities, including population served by the facility, number of admissions, number of functioning operating rooms, number of surgeries performed (major and minor combined) for adults, number of surgeries performed (major and minor combined) for pediatrics (age < 15 years), number of patients referred to other centres (due to insufficient local capacity), and distance travelled by patients to reach the facility for surgical services. In addition, details about infrastructure, equipment, and supplies were summarized through for each category of facility through heat map tables where green indicates uninterrupted supply, yellow indicates interrupted supply, and red indicates unavailable. Human resources were characterized by facility type, with particular emphasis on availability of certified surgeons, obstetrician/gynecologists, anaesthesiologists, general physicians or other trained nurses, health extension officers, midwives or paramedics performing surgery or anaesthesia. The proportion of facilities that indicated capacity to provide each service listed within the WHO SAT was also summarized. The tables and heat maps describe the results separately for national/provincial and district/rural hospitals (where different levels of surgery are generally expected to be provided) versus primary health centres (where surgery is not a primary aim, but rather where basic resuscitation, limited “surgical” capabilities for first aid, burns, wounds, and obstetric care would be expected).

When possible, information was validated through discussions with the submitter by email when survey data was unclear or missing. If contact was unsuccessful, other members within the facility were emailed, or members of the PNG Society for Rural & Remote Medicine were contacted for information. Through this network, most of the missing and unclear data was successfully ascertained. Any remaining data not reported is indicated by ‘NR’ in the summary tables.

Proportions were summarized as percentage facilities with uninterrupted supply for the respective infrastructure items. Medians and ranges were provided as a summary estimate for numeric data. Since the earlier version of SAT (before 2012) provides preset categories for numeric data (ie, 3 to 4, 5 - 10, 11-20, 21-50, etc), the median was reported in accordance with these definitions, and the range was reported as the lowest and highest possible number for the extremes of the reported ranges. Descriptive comparisons between national/provincial and district/rural centres was planned, without statistical inference.

RESULTS

A total of 25 WHO SAT surveys were identified in the WHO database, with submission dates ranging from 2008 to 2011. After removing duplicate reports (only the most recent report from each centre was retained), there remained a total of 21 surveys including 3 national/provincial hospitals, 11 district/rural hospitals, and 7 health centres. The surveys represented a broad geographic coverage of the provinces and regions of PNG, as shown by the map in **Figure 3**. Most hospitals in PNG are represented in this study.

Table 2 provides a description of included facilities. District/rural hospitals generally served around 100,000, 1000-2000 admissions annually, with fewer than 100 beds and 1 or 2 functioning operating rooms (OR). Two national/provincial hospitals had under 10 operating rooms to support several thousand surgeries annually. Most hospitals provided adult and pediatric surgery. District/rural hospitals were more likely to refer a significant proportion of patients to other facilities for surgery. Some patients travel a long distance to reach referral centres (300 km to 700 km). While each national/provincial hospital reported devoted emergency department (ED) and post-anaesthesia care unit (PACU) areas, less than 50% of district/rural hospitals reported having these. The number of beds and ORs per facility was not necessarily commensurate with the size of population served, number of admissions, and number of surgeries performed.

Table 2. Description of PNG Healthcare facilities responding to WHO SAT Survey

	Population Served by this Facility	Beds	Admissions/yr	# ORs	Surgeries/yr	Pediatric Surgeries/yr	Referred out for surgery/yr	Km Travelled to this facility	Km travelled if referred out
National/Provincial Hospitals (n=3)									
N/P #1	6,000,000	501-700	>5000	5 to 10	>5000	201-300	5 to 10	5 to 10	5 to 10
N/P #2	26,000	201-300	>5000	3 to 4	1001-2000	81-100	5 to 10	21 to 50	NR
N/P #3	15000	21-50	301-400	2	51-80	5-10	11 to 20	201 to 300	81-100
Median (range)	26,000 (15,000 to 6m)	201-300 (21 to 700)	>5000 (301 to >5000)	3 to 4 (2 to 11)	1001-2000 (51 to >5000)	81-100 (5 to 300)	5 to 10 (5 to 20)	21 to 50 (5 to 300)	-
District/Rural District Hospitals (n=11)									
D/R #1	75,000	101-200	1001-2000	2	101-200	21-50	51-80	11-20	NR
D/R #2	100,000	51-80	NR	1	101-200	81-100	3-4	51-80	501-700
D/R #3	30,000	51-80	1001-2000	2	401-500	11-20	11-20	21-50	NR
D/R #4	40,000	21-50	401-500	1	101-200	51-80	5-10	5-10	101-200
D/R #5	10,000	11-20	201-500	1	11-20	5-10	21-50	201-300	2001-5000
D/R #6	30,000	51-80	701-1000	1	201-300	NR	11-20	NR	NR
D/R #7	122,000	51-80	2001-5000	2	301-400	81-100	81-100	5-10	5-10
D/R #8	256,000	101-200	2001-5000	2	2001-5000	201-300	21-50	11-20	NR
D/R #9	100,000	201-300	>5000	2	401-500	81-100	81-100	NR	81-100
D/R #10	118,000	101-200	2001-5000	2	401-500	81-100	5-10	51-80	101-200
D/R #11	100,000	51-80	1001-2000	1	301-400	21-50	11-20	21-50	201-300
Median (range)	100,000 (10,000 to 356,000)	51-80 (11 to 300)	1001-2000 (201 to >5000)	2 (1 to 2)	301-400 (11 to 5000)	81-100 (5 to 300)	21-50 (3 to 100)	21-50 (5 to 300)	201-300 (5 to 700)
Health Centres/Aid Posts (n=7)									
HC/AP #1	5000	21-50	701-1000	1	3-4	2	11-20	2	21-50
HC/AP #2	9000	0	0	1	11-20	0	11-20	5-10	NR
HC/AP #3	NR	0	0	1	11-20	0	11-20	5-10	NR
HC/AP #4	NR	0	21-50	1	51-80	21-50	11-20	21-50	81-100
HC/AP #5	NR	5-10	0	1	201-300	51-80	5-10	81-100	81-100
HC/AP #6	NR	0	0	1	301-400	201-300	51-80	3-4	11-20
HC/AP #7	NR	5-10	21-50	1	301-400	201-300	11-20	21-50	51-80
Median (range)	Unknown	0 (0, 50)	0 (0, 1000)	1	51-80 (3, 400)	21-50 (0, 300)	11-20 (5, 80)	5-10 (2, 100)	51-80 (11 to 100)

Provincial = N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

*functioning ORs only ^major and minor surgeries NR = not reported by the respondent and data unavailable from email contacts

Infrastructure

The heat map in Table 3 reveals several gaps in basic essential elements of infrastructure (yellow and red areas), with increasing gaps in district/rural hospitals and health centres. All national/provincial hospitals had uninterrupted access to essential infrastructure, including running water, electricity, oxygen, anaesthesia machine, pulse oximetry, blood bank, lab work, and x-ray machines. Whereas, at district/rural hospitals, most (but not all) reported uninterrupted access to running water and electricity, but fewer than 50% reported consistent access to oxygen cylinders or concentrators.

Table 3. Infrastructure

	Admissions/ yr	Surgeries/ yr	Pediatric Surgeries/ yr	Running Water	Electricity	Oxygen Cylinder	Oxygen concentrator	Anaesthesia Machine	Pulse Oximetry	Blood Bank	Hgb & Urinalysis	x-ray machine
National/Provincial Hospitals (n=3)												
10N/P #1	>5000	>5000	201-300									
11N/P #2	>5000	1001- 2000	81-100									
13N/P #3	301-400	51-80	5-10									
National/Provincial Hospitals with Uninterrupted Supply				100%	100%	66%	100%	100%	100%	100%	100%	100%
District/Rural Hospitals (n=11)												
17D/R #1	1001-2000	101-200	21-50									
18D/R #2	NR	101-200	81-100									
19D/R #3	1001-2000	401-500	11-20									
20D/R #4	401-500	101-200	51-80									
21D/R #5	201-500	11-20	5-10									
22D/R #6	701-1000	201-300	NR									
23D/R #7	2001- 5000	301-400	81-100									
24D/R #8	2001- 5000	2001- 5000	201-300									
26D/R #9	>5000	401-500	81-100									
27D/R #10	2001- 5000	401-500	81-100									
29D/R #11	1001-2000	301-400	21-50									
District/Rural Hospitals with Uninterrupted Supply				91%	91%	45%	36%	45%	36%	36%	72%	55%
Health Centres/Aid Posts (n=7)												
34HC/AP #1	701-1000	3-4	2									
36HC/AP #2	0	11-20	0									
38HC/AP #3	0	11-20	0									
40HC/AP #4	21-50	51-80	21-50									
42HC/AP #5	0	201-300	51-80									
44HC/AP #6	0	301-400	201-300									
46HC/AP #7	21-50	301-400	201-300									
Health Centres with Uninterrupted supply				14%	57%	43%	0%	0%	0%	0%	43%	0%

Green = uninterrupted supply; Yellow = interrupted supply; Red = unavailable; N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

Fewer than half of district/rural hospitals had access to anaesthesia machines, and only 36% had consistent access to pulse oximetry, despite performing a large number of surgeries each year. Similarly, only 36% of centres reported consistent blood bank access. About half of district/rural hospitals had access to x-ray machines, and 72% had access to hemoglobin assay and urinalysis. Most district/rural hospitals reported

multiple deficiencies in basic infrastructure, with only one district/rural hospital reporting no deficiencies. Access to oxygen cylinders or concentrators, anaesthesia machines, and blood bank were the most commonly reported infrastructure deficiencies. In general, district/rural hospitals with the most severe infrastructure deficiencies performed relatively fewer surgeries than those reporting better infrastructure, despite the fact that they had several hundred or thousands of patient admissions annually and served a large population within PNG.

Infrastructure for facilities categorized as health centres was extremely limited, with only one reporting uninterrupted access to running water, and just over half reporting uninterrupted electricity, and less than 50% reporting consistent access to oxygen. None had access to anaesthesia machines, pulse oximetry, blood bank, or x-ray machines, despite performing up to 400 surgical procedures per year.

Human Resources

National/provincial hospitals had 2 to 9 qualified surgeons, and were supplemented by general doctors or nurse/health extension officers who also performed surgery (Table 4). In addition, they generally reported at least 1 qualified anaesthesiologist, supplemented by general doctors or nurse/health extension officers performing anaesthesia, and at least one obstetrician/gynecologist. In contrast, most district/rural hospitals did not have qualified surgeons, obstetrician/gynecologists, or anaesthesiologists. In general, district/rural hospitals were more likely to rely on general doctors or nurse/health extension officers to perform surgery and anaesthesia, some of whom were not certified. Most district/rural hospitals had at least 1 paramedic/midwife, with 1 hospital reporting up to 8 paramedic/midwives. The number of healthcare workers was low relative to patient admissions and surgeries performed. At the health centres, there were few qualified healthcare personnel. The health centres were more likely to rely on health extension officers and/or paramedics/midwives (ie, Community Health Workers).

Table 4. Human Resources

	Admissions/ yr	Surgeries/ yr	Pediatric Surgeries/ yr	Surgeons (FT or PT)	Obstetrician/ Gynecologists (FT or PT)	General MDs performing Surgery (FT or PT)	Nurse or Medical Officer performing Surgery	Anaesthesiologists (FT or PT)	General MDs performing Anaesthesia (FT or PT)	Nurse or Medical Officer performing Anaesthesia	Paramedics/ Midwives
National/Provincial Hospitals (n=3)											
N/P #1	>5000	>5000	201-300	9	5	10	0	14	4	4	0
N/P #2	>5000	1001-2000	81-100	3	1	1	1	2	0	0	0
N/P #3	301-400	51-80	5-10	2	0	4	4	1	1	1	2
Median (range) number in National/Provincial Hospitals				3 (2 to 9)	1 (0 to 5)	4 (1 to 10)	1 (0 to 5)	2 (1 to 14)	1 (0 to 4)	1 (0 to 4)	0 (0 to 2)
District/Rural Hospitals (n=11)											
D/R #1	1001- 2000	101-200	21-50	1	0	2	6	0	0	2	1
D/R #2	NR	101-200	81-100	0	0	1	1	0	0	1	0
D/R #3	1001- 2000	401-500	11-20	2	0	1	0	0	0	1	8
D/R #4	401-500	101-200	51-80	0	0	2	0	0	2	1	0
D/R #5	201-500	11-20	5-10	0	0	2	1	0	0	1	1
D/R #6	701-1000	201-300	NR	0	0	2	0	0	2	0	0
D/R #7	2001- 5000	301-400	81-100	1	1	1	1	1	1	2	3
D/R #8	2001- 5000	2001- 5000	201-300	1	0	6	1	0	0	2	2

D/R #9	>5000	401-500	81-100	0	1	1	1	0	0	2	4
D/R #10	2001-5000	401-500	81-100	0	0	2	2	0	0	1	1
D/R #11	1001-2000	301-400	21-50	0	0	1	0	0	0	0	5
Median (range) number in Rural/District Hospitals				0 (0 to 2)	0 (0 to 1)	1 (1 to 6)	1 (0 to 6)	0 (0 to 1)	0 (0 to 2)	1 (0 to 2)	1 (0 to 5)
Health Centres/Aid Posts (n=7)											
HC/AP #1	701-1000	3-4	2	0	0	0	0	0	0	0	1
HC/AP #2	0	11-20	0	0	0	0	0	0	0	1	2
HC/AP #3	0	11-20	0	0	0	0	1	0	0	0	0
HC/AP #4	21-50	51-80	21-50	0	0	0	1	0	0	0	0
HC/AP #5	0	201-300	51-80	0	0	0	1	0	0	1	2
HC/AP #6	0	301-400	201-300	0	0	0	0	0	0	0	3
HC/AP #7	21-50	301-400	201-300	0	0	2	1	0	0	1	1
Median (range) number in Health Centres/Aid Posts				0	0	0 (0 to 2)	1 (0 to 1)	0	0	0 (0 to 1)	1 (3 to 3)

N/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts; FT = fulltime; PT = part-time

Surgical & Anaesthetic Interventions

National/provincial hospitals indicated uniform capacity to provide general, regional, or spinal anaesthesia, while district/rural hospitals indicated less capacity to provide general anaesthesia. Health centres generally did not report capacity to provide anaesthesia, with the exception of one centre which provides ketamine sedation (Table 5). Routine use of guidelines for surgery, anaesthesia, and pain were reported in 66% of national/provincial hospitals, and only 20% of district/rural hospitals, and none of the health centres.

Table 5. Interventions (% of facilities reporting capacity to provide selected interventions)

	National/Provincial Hospital, n=3 (%)	District/Rural Hospital, n=11 (%)	Health Centre/Aid Posts, n=7 (%)
Anaesthesia			
General Anaesthesia	100	64	0
Spinal Anaesthesia	100	91	0
Regional Anaesthesia	100	100	0
Ketamine Anaesthesia	66	100	14
Surgical Procedures			
Resuscitation*	100	100	14
Cricothyroidotomy/Tracheostomy	66	64	0
Chest Tube	100	100	0
Cesarean Section	100	82	0
Dilatation & Curettage (D&C)	100	100	0
Obstetric Fistula Repair	66	36	0

Hydrocele	100	82	0
Cystostomy	100	55	0
Laparotomy	100	64	0
Tubal Ligation	100	91	0
Hernia Repair, strangulated	100	72	0
Hernia Repair, congenital	100	64	0
Cleft Lip & Palate Repair	66	18	0
Neonatal Surgery **	66	27	0
Club Foot Repair	66	55	0
Fracture Reduction, Closed	100	100	57
Fracture Reduction, Open	100	64	14
Amputation	100	72	14
Joint Dislocation	100	100	71
Male circumcision	100	100	0
Urethral stricture dilator	66	55	0
Appendectomy	100	64	0
Acute Burns	100	100	86
Contracture Release, Skin Grafting	100	91	0
Drainage of Osteomyelitis or Septic Arthritis	100	91	0
Abscess Incision & Drainage	100	100	100
Wound Debridement	100	100	71
Suturing	100	100	100
Foreign Body Removal	100	100	29
Biopsy	100	82	14
Cataract Surgery	66	18	0

*Resuscitation - Airway, hemorrhage, peripheral intravenous access, peripheral venous cut down ** Neonatal surgery – abdominal wall defect, colostomy, imperforate anus, intussusception

National/provincial hospitals reported capacity to provide most procedures listed in the WHO SAT (Table 5), although 1 of 3 national/provincial hospitals reported lack of capacity for cricothyroidotomy/tracheostomy, club foot, cleft lip, and neonatal surgery. In general, district/rural hospitals reported capacity to provide resuscitation, chest tube insertion, dilation and curettage, joint dislocation, male circumcision, acute burn management, skin grafting and contractures treatment, abscess incision and drainage, wound debridement, suturing, foreign body removal, drainage of osteomyelitis or septic arthritis, and closed fracture reduction. Capacity to provide caesarean section was indicated by 82% of national/provincial hospitals, and tubal ligation by 91%, but only 36% had capacity to provide obstetrical fistula repairs. Few district/rural hospitals provided neonatal surgery, cleft lip repair, or club foot repair. Health centres indicated limited capacity for most types of procedures. Of particular concern is the lack of reported capacity for *basic* resuscitation at the health centres.

Equipment & Supplies

The heat map in Table 6 reveals frequent deficiencies in essential equipment and supplies, which progressively increases from national/provincial hospitals, to district/rural hospitals, and health centres. None of the facility types reported consistent access to all of the listed equipment. Even at the national/provincial hospitals, frequent shortages in essential equipment were reported. At district/rural hospitals, frequent deficiencies were reported for oxygen delivery, cricothyroidotomy supplies, IV fluid delivery, sterilization, and personal protective equipment including gloves. At the health centres, almost all categories of equipment and supplies were frequently or completely unavailable, including all basic resuscitation equipment.

Table 6. Equipment & Supplies

	Admissions per yr	Surgeries per yr	Pediatric Surgeries per yr	Resuscitator bag & mask (adult)	Resuscitator bag & mask (peds)	Oxygen and Mask Tubing to Connect Oxygen	Sterile Disposable Needles	Stethoscope	Cryothyroidotomy set	Oropharyngeal airway (adult)	Oropharyngeal airway (peds)	Sterilizer	Sterile Gloves	Protective face mask	IV fluid set bags
National/Provincial Hospitals (n=3)															
NP #1	>5000	>5000	201-300												
NP #2	>5000	1001-2000	81-100												
NP #3	301-400	51-80	5-10												
National/Provincial Hosp with Uninterrupted Supply				33%	33%	33%	66%	33%	33%	33%	33%	33%	33%	66%	66%
District/Rural Hospitals (n=11)															
D/R #1	1001-2000	101-200	21-50												
D/R #2	-	101-200	81-100												
D/R #3	1001-2000	401-500	11-20												
D/R #4	401-500	101-200	51-80												
D/R #5	201-500	11-20	5-10												
D/R #6	701-1000	201-300	-												
D/R #7	2001-5000	301-400	81-100												
D/R #8	2001-5000	2001-5000	201-300												
D/R #9	>5000	401-500	81-100												
D/R #10	2001-5000	401-500	81-100												
D/R #11	1001-2000	301-400	21-50												
District/Rural Hospitals with Uninterrupted Supply				64%	72%	27%	72%	64%	27%	82%	82%	55%	55%	72%	45%
Health Centres/Aid Posts (n=6)															
HC/AP #1	701-1000	3-4	2												
HC/AP #2	0	11-20	0												
HC/AP #3	0	11-20	0												
HC/AP #4	21-50	51-80	21-50												
HC/AP #5	0	201-300	51-80												
HC/AP #6	0	301-400	201-300												
HC/AP #7	21-50	301-400	201-300												
HC/AP with Uninterrupted supply				0%	0%	0%	71%	43%	0%	0%	0%	0%	14%	14%	14%

Green = uninterrupted supply; Yellow = interrupted supply; Red = unavailable or frequently unavailable; PN/P = National/Provincial hospitals; D/R = District/Rural Hospital; HC/AP = Health Centre/Aid-Posts

DISCUSSION

While much progress has been made in healthcare provision in recent years in PNG, important deficiencies persist which severely restrict access to essential surgery and anesthesia services across the country. Rural facilities, including district/rural hospitals and primary health centres/aid posts, that are physically closest to where 80% of the population resides deal with the most severe restrictions in infrastructure, supply, and human resources. One of the most striking findings is the lack (14%) of even basic resuscitative and primary trauma capacity in peripheral primary care centres, including basic airway and first aid equipment, which could

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3 potentially save more lives than more advanced surgical services per se. Another striking finding was that,
4 even when all types of facilities were considered in aggregate, no health facility reported having all
5 infrastructure required to provide essential surgical surgery, despite providing thousands of surgeries annually.
6 Many facilities manage to provide emergency and surgical services without a consistent supply of electricity,
7 running water, oxygen, anaesthesia machines, pulse oximeters, blood bank access, IV fluid resuscitation, and
8 personal protective equipment. District/rural hospitals reported provision of most types of anaesthesia (100%
9 ketamine, 100% regional, 91% spinal, 64% general), while most primary health centres did not report anesthetic
10 capacity (with the exception of 14% providing ketamine), which raises important concerns about the lack of
11 available anaesthesia for initial management of trauma and orthopaedic emergencies in the peripheral regions.
12 While most facilities reported capability for primary obstetric care, including most peripheral centres, the near
13 absence of basic airway equipment and intravenous resuscitative supplies in the peripheral primary care health
14 centres remains of concern for the provision of safe obstetric care.
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19 This survey provides a clear picture of the state of deficiencies across healthcare facilities, which has likely
20 contributed to the persistently low performance on key MDGs (high maternal and child mortality, especially in
21 the rural areas, where rates are known to be 2-fold higher than in urban areas of PNG),⁴ and will preclude
22 achievement of equitable and efficient universal health care in PNG in the post-2015 development agenda.^{14,24}
23 Deficiencies in capacity and access result from a combination of barriers including geospatial (PNG is comprised
24 of primarily rural populations spread over 300 islands), financial (public financing of healthcare in PNG is still in
25 development), infrastructural (lacking roads and waterway services to connect the rural and urban areas),
26 together with other factors that have not been well-characterized (800 distinct cultures and languages exist
27 within PNG, and a significant proportion of peripheral aid posts remain abandoned).²⁻⁵
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31 While this study provides only a partial snap-shot of the system, it provides a level of detail that has never
32 before been published for PNG.²⁵ Nevertheless, the results should be interpreted in light of the typical
33 limitations associated with survey data. Given the formidable challenges including geographical and expense of
34 achieving a complete and formalized representation of all facilities country-wide, this study relied on a non-
35 random convenience sample from volunteer submission of the WHO SAT from the health facilities invited to
36 participate. Accordingly, there will be deficiencies in representativeness. Another severe limitation of the
37 survey is that it is derived from reports and estimates provided by the respondents, rather than by direct
38 inspection of the facilities for infrastructure, human resources, and supplies. Perhaps the most important
39 limitation of this survey is the fact that only infrastructure and activity is measured. Since clinical outcomes are
40 not measured, there is no opportunity to correlate the deficiencies in infrastructure and human resources with
41 clinical or population-based outcomes. However, we know from previous studies within PNG²⁶ and other
42 LMICs^{9,27-30} that deficits in health infrastructure, medical technology, and integration of resources to provide
43 surgery have been consistently correlated with mortality, and that intervention to alleviate these deficiencies
44 has a tangible impact on mortality.²⁶
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49 While the magnitude of restrictions in surgical and anesthesia capacity experienced by PNG is only indirectly
50 informed by this study, the emerging picture of greatest restrictions to those who need it most represents a
51 specific call to action. Reducing maternal and child mortality will require essential surgery to be bolstered
52 through sequenced steps to address the facility infrastructure and trained human resources to address
53 common debilitating conditions in PNG.^{31,32} In PNG, deaths due to trauma, accidents, obstetric and neonatal
54 conditions considered together represent a high proportion of life lost which rivals that of deaths due to
55 HIV/AIDs, malaria and pneumonia. Many of these deaths could be prevented through essential surgery, if it was
56 available. Beyond premature deaths, there exists a myriad of common conditions for which surgical services
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3 would reduce morbidity, including obstetric fistulas, maternal haemorrhage, club foot, cleft lip and palate,
4 acute abdominal conditions, hernias, cataracts, malignant and benign tumors, ruptured spleen (due to
5 malaria), burns, contractures, fractures, and trauma complications, male circumcision (HIV transmission
6 reduction), among others.^{16,33}
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10 The WHO SAT survey tool, as well as other surveys developed for similar purposes including the Surgeons
11 Overseas Personnel, Infrastructure, Procedures, Equipment and Supplies (PIPES) survey, and the Harvard
12 Humanitarian Initiative (HHI) survey tool have been applied in a number of developing countries, with similar
13 conclusions regarding the severe gaps in infrastructure, human resources and supplies in various regions of the
14 world.³⁴⁻⁴¹ Although surgery is one of the most cost-effective interventions in LMICs,^{11,42} perceptions remain
15 that it is too expensive and complex to provide in austere settings.¹⁶ Greater efforts should be devoted to
16 prioritizing essential on the political agenda and for aid providers,^{9,43} since simple life-altering procedures can
17 bring greater value for money than other commonly-supported public health interventions in LMICs.⁴²
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21 The government of PNG has taken important steps to place renewed focus on strengthening the healthcare
22 system, after initial gains in the 1990s were partly defeated by setbacks in progress, revealed by “brain drain”
23 of qualified healthcare workers from remote areas to urban areas or out-of-country, and the closing of several
24 aid-posts.^{4,44} PNG has an estimated 0.58 healthcare workers per 1000 people, and fewer than 1 qualified
25 anaesthetic provider per 100,000, which is at the lowest end of recent global surveys.^{4, 17, 30, 34,35,45} To put this
26 into perspective, in the USA and UK there is an estimated ratio of 1:4000 or 1:5000 of anaesthetic providers per
27 capita.⁴⁶
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31 Despite much progress and many successes to be celebrated in PNG (ie, increased oxygen supply, medical
32 records and clinical guidelines use, health extension officers and community health workers, medical residency
33 and surgical training networks),^{4,32,44} in order to achieve post-2015 development targets, increasing essential
34 surgical services will need become a high priority to operationalize the National Health Plan. While the National
35 Health Plan does not address surgery and anaesthesia services specifically, this should be encouraged. Without
36 rehabilitation of current facilities to be outfitted with basic infrastructure including electricity, water, and
37 essential supplies, along with functional operating rooms, EDs, PACUs, adequately resourced with essential
38 equipment and with trained healthcare workers at the rural level, the Vision 2050 and the post-2015
39 development agenda will remain theory rather than a reality.^{4,24,46}
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42 **Conclusions:** Despite important progress in healthcare provision in PNG, capacity for essential surgery is
43 severely limited and unevenly provided due to limitations in physical infrastructure, human resources, and basic
44 equipment and supplies. Appropriate solutions to these gaps should be sought through collaborative and
45 context-sensitive approaches, and with a degree of urgency that is commensurate with the severity of lives
46 lost and disability disproportionately affecting the livelihoods of the most disadvantaged.
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For peer review only

Figure Legends

Figure 1. Human Development Index (HDI): Trends for PNG relative to other Low HDI countries, and relative to the East Asia and the Pacific: 1980 - present.⁶

Figure 2. Structure of PNG's health care system.⁴

Figure 3: Location of health facilities included in this study (clustering and overlaps prevents 2 of the pins from being visible near Port Moresby and near Kundiawa)

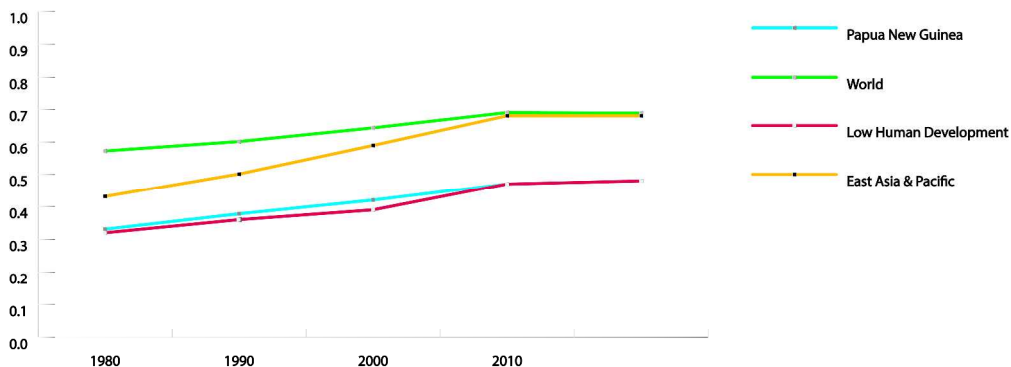


Figure 1. Human Development Index (HDI): Trends for PNG relative to other Low HDI countries, and relative to the East Asia and the Pacific: 1980 - present.6
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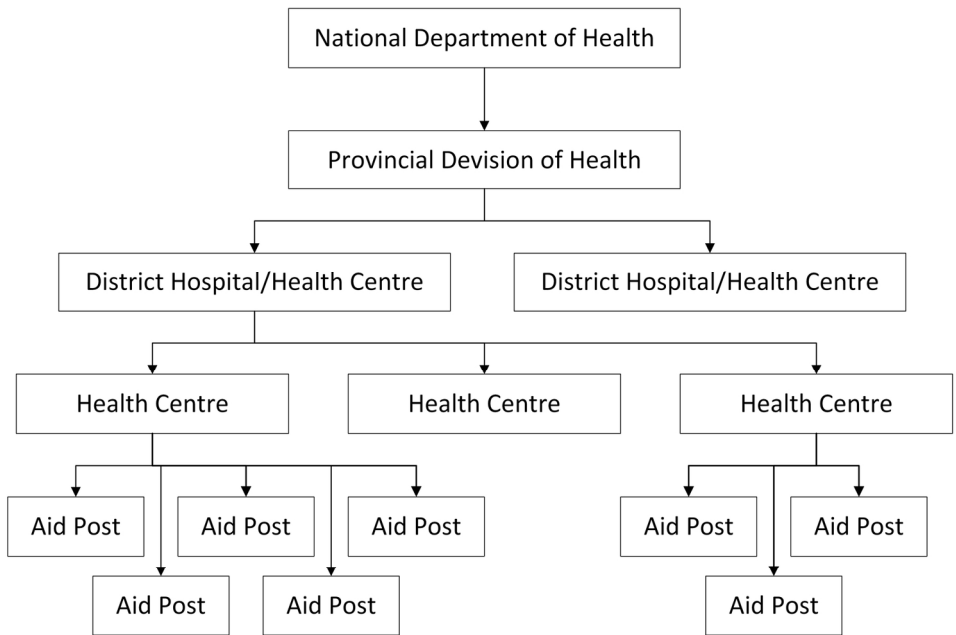


Figure 2. Structure of PNG's health care system.⁴

162x111mm (300 x 300 DPI)

View only



Figure 3: Location of health facilities included in this study (clustering and overlaps prevents 2 of the pins from being visible near Port Moresby and near Kundiawa)
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STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract (abstract)	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale (p.5-6)	2	Explain the scientific background and rationale for the investigation being reported
Objectives (p.5-6)	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design (p.6-7)	4	Present key elements of study design early in the paper
Setting (p.6-7)	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants (p.8)	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants
Variables (p.6-7)	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement (p. 6-7)	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias (p.7)	9	Describe any efforts to address potential sources of bias
Study size (p.7)	10	Explain how the study size was arrived at
Quantitative variables (p.6-7)	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods (p.7)	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses

Continued on next page

Results		
Participants (p.8)	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram
Descriptive data (p.7-13)	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)
Outcome data (p.7-13)	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures
Main results (p.7-13)	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses (N/A)	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results (p.13-15)	18	Summarise key results with reference to study objectives
Limitations (p.13-15)	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation (p.13-15)	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability (p.14)	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding (p.16)	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.