World J Surg (2018) 42:3432–3442
https://doi.org/10.1007/s00268-018-4613-y

ORIGINAL SCIENTIFIC REPORT

A Nationwide Assessment of Pediatric Surgical Capacity in Mongolia

Laura F. Goodman[1] · Erdenetsetseg Chuluun[2] · Burmaa Sanjaa[2] · Sanchin Urjin[2] · Sarnai Erdene[2] · Narantuya Khad[3] · Adiyasuren Jamiyanjav[4] · Jacob Stephenson[5,6] · Diana L. Farmer[7]

Published online: 4 April 2018

Abstract

Background Mongolia is a country characterized by its vast distances and extreme climate. An underdeveloped medical transport infrastructure makes patient transfer from outlying regions dangerous. Providing pediatric surgical care locally is crucial to improve the lives of children in the countryside. This is the first structured assessment of nationwide pediatric surgical capacity.

Methods Operation rates were calculated using data from the Mongolian Center for Health Development and population data from the Mongolian Statistical Information Service. The Pediatric Personnel, Infrastructure, Procedures, Equipment, and Supplies (PediPIPES) survey tool was used to collect data at all survey sites. Descriptive data analyses were completed using Excel. Studies of association were completed using Stata. All reported percentages are of the hospitals outside of the capital (n = 21).

Results All provincial hospitals have general surgeons; seven (33.3%) of them have pediatric surgeon(s). One facility has no anesthesiologist. All facilities perform basic procedures and provide anesthesia. Four (19%) can treat common congenital anomalies. All facilities have basic operating room equipment. Nine hospitals do not have pulse oximetry available. Twelve hospitals do not have pediatric surgical instruments always available. Pediatric supplies are lacking.

Conclusions Provincial hospitals in Mongolia can perform basic procedures. However, essential pediatric supplies are lacking. Consequently, certain life-saving procedures are not available to children outside of the capital. Only a few improvements would be amendable to low-cost process improvement adjustment, and the majority of needs require resource additions. Procedure, equipment, and supply availability should be further explored to develop a comprehensive nationwide pediatric surgical program.

This work was completed while Laura Goodman was a graduate student at the Harvard T.H. Chan School of Public Health.

✉ Laura F. Goodman
laurafgoodman@gmail.com

Erdenetsetseg Chuluun
erdenetsetseg.ch@mnums.edu.mn

Burmaa Sanjaa
burmaa.s@mnums.edu.mn

Sanchin Urjin
sanchin0209@yahoo.com

Narantuya Khad
khadnaraa@yahoo.com

Adiyasuren Jamiyanjav
adiya.zev@gmail.com

Jacob Stephenson
jstephenson@ucdavis.edu

Diana L. Farmer
dlfarmer@ucdavis.edu

[1] Department of Surgery, University of California Davis Health, 2315 Stockton Boulevard OP512, Sacramento, CA 95817, USA

Background information

Mongolia is a parliamentary republic of approximately three million people located between eastern Russia and the northern border of China. One-third of its population remains semi-nomadic herders. The Gross National Income is US$3550 per capita (2016) [1].

From 1990 to 2015, Mongolia reduced under-five childhood mortality by over two-thirds [2, 3]. Under-five mortality decreased from 107.8 per 1000 live births in 1990 to 22.4 per 1000 in 2015—a 79.2% decline. Infant mortality decreased from 76.9 per 1000 live births in 1990, to 19 in 2015. Neonatal (first 28 days of life) mortality rate declined from 31.8 per 1000 live births in 1990, to 11.1 per 1000 in 2015 [1].

The post-Soviet era medical system in Mongolia follows Disease Control Priorities definitions of levels of care [4]. Primary or first-level care is provided at different types of first-access centers including village hospitals (Fig. 1). Provincial center hospitals and regional diagnostic and treatment centers provide secondary-level care. These centers are frequent initial points of contact for patients [5, 6]. Tertiary care is only available in the capital. Direct self-referral is possible at all levels.

Within Mongolia, infant mortality rates range from four per 1000 live births in certain areas, and up to 29 per 1000 in others [7]. The under-five mortality rates vary from 10.6 per 1000 live births in the capital city, to 39.4 in rural areas [7]. Much of the progress in reducing childhood mortality in Mongolia has been due to interventions in infectious diseases, particularly respiratory infections and diarrhea.

One effect of this progress is that congenital anomalies, or birth defects, have become a proportionately larger factor as a cause of mortality. The World Health Organization (WHO) estimates that the percentage of under-five deaths in Mongolia attributable to congenital anomalies has doubled from 8.4% in 2000 to 16.7% in 2013 [8]. Congenital anomalies are now the third leading cause of infant mortality in Mongolia and the fourth leading cause of under-five mortality.

An estimated 60% of congenital anomalies worldwide are potentially treatable with surgery [9]. Indeed, anomalies such as intestinal atresia and gastroschisis have no known preventive measure, but are surgically correctable [10, 11]. Children who survive with untreated congenital anomalies often have disabilities that are costly for the family and society in terms of lost income and the specialized care required [12, 13]. Untreated fractures (or those set by traditional bone setters) can result in lifelong disability, as can untreated or improperly treated burns.

Safe pediatric surgery requires dedicated training for providers, as well as reliable stocks of medication, equipment, and supplies. Treatable conditions in adults become dangerous to manage in children without appropriately trained and equipped staff. Without the appropriate medications and training, unforeseen complications can be deadly. For example, children are much more likely than adults to experience anesthesia emergencies such as bradycardia or laryngospasms [14].

Mongolia participated in the WHO Emergency and Essential Surgical Care Program (WHO EESC) starting in 2005 [15]. This 256-point tool focused on surgical capacity at the first-level hospitals, but included just two indicators for pediatric surgery [16].

The Surgeons Overseas (SOS) Personnel, Infrastructure, Procedures, Equipment, and Supplies (PIPES) tool was developed in Sierra Leone and later validated in Bolivia [17, 18]. Based upon PIPES, a pediatric-specific assessment tool (PediPIPES) was created and piloted across 37 facilities in 10 West African countries [19]. PediPIPES allows for the calculation of an index to facilitate comparisons across facilities and through time. While not yet validated, the pediatric-specific nature of PediPIPES made it the best tool available for use in our assessment.

In Mongolia, the need for pediatric surgical care has yet to be clarified for two reasons. First, the number of children born with surgically correctible congenital conditions and/or in need of surgical care later in childhood is not known. Second, the country's pediatric surgical capabilities have not yet been described. We sought to quantify pediatric surgical care capability using the PediPIPES tool during in-person assessments at each of the 21 provincial center hospitals, a sample which includes the five regional diagnostic and treatment centers. The town and district hospitals, despite serving as the "core site for surgical and anesthesia care delivery," [20] were not chosen for this analysis after expert input from our authors who have practiced pediatric surgery and anesthesia in Mongolia for

[2] Mongolian National University of Medical Sciences, S. Zorig Street-3, Sukhbaatar District, P.O. Box 48/111, Ulaanbaatar 14210, Mongolia

[3] Department for Statistics and Information Technology, Center for Health Development, Enkhtaivan Street - 13b, Sukhbaatar District, Ulaanbaatar, Mongolia

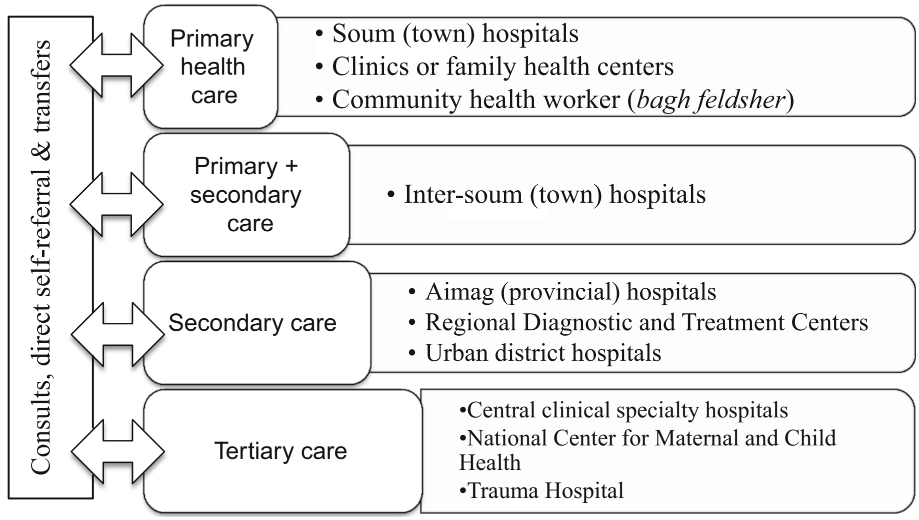
[4] Department of Pediatric Surgery, National Center for Maternal and Child Health, Khuvsgalch Road, Bayangol District, Ulaanbaatar 16060, Mongolia

[5] Uniformed Services University of the Health Sciences, Bethesda, MD, USA

[6] Division of Pediatric Surgery, Department of Surgery, University of California Davis Health, 2221 Stockton Boulevard, Sacramento, CA 95817, USA

[7] Department of Surgery, University of California Davis Health, 2221 Stockton Boulevard, Sacramento, CA 95817, USA

Fig. 1 The organization of the medical system in Mongolia, following Disease Control Priorities definitions of levels of care. Primary care includes generalists and/or few specialties. Secondary care includes more specialty services, and care is highly differentiated, e.g., surgery and internal medicine. Tertiary care includes highly specialized staff and advanced equipment. Direct self-referral is possible at all levels



decades. Instead, we focused on the most advanced hospital in each of the provinces, as these represent the highest level of care available to children in the provinces within a 12-hour travel distance. We analyzed the geographic and population patterns of the indices and calculated surgical rates for each province. We sought to verify an association between the PediPIPES index and under-five mortality by province.

Methods

Anonymized summary surgical volume data were obtained from the hospitals and the Mongolian Center for Health Development. Population data were obtained from the Mongolian Statistical Information Service [21]. Operation rates were calculated standardized to 100,000 population.

The PediPIPES survey was translated into Mongolian. Data were collected in-person by the authors LFG, SE, BS, SU, and EC, via interviews with hospital staff surgeons, anesthesiologists, nurses, and support staff, with visual verification where possible, at each of the 21 provincial hospitals, one district hospital, and the national hospital. The site visits were completed in October–December 2016 and April 2017. The data were entered into the REDCap data system [22].

During the site visits, authors SU and EC, Mongolian trained and licensed surgeons, performed operations with local staff, teaching, and reinforcing techniques. BS, a Mongolian trained and licensed anesthesiologist, worked with local staff to anesthetize the patients for surgery and provide training. The perspectives of these authors were used to correct the surveys, where indicated.

A summary score for each domain was calculated. Procedures were grouped by type and tallied. The PediPIPES index was calculated using the method as described by Okoye et al. [19]. We assessed for trends regarding distance from the capital, population, and mortality rates using unadjusted linear regression. Specific capacity components, shortfalls, and associated factors were assessed using descriptive statistics.

The PediPIPES index, as well as overall and child-specific procedure rates, was mapped. For the purposes of this study, we considered children <15 years of age.

This research was approved by the Mongolian National University of Medical Sciences Ethical Committee of Research (2016/3/2016–2017 #1). It was designated “not human subjects research” by the University of California Davis Institutional Review Board (IRB 939,081-2) and by the Harvard T.H. Chan School of Public Health Office of Human Research Administration (IRB 17-0446). Excel version 14.5.9 (Microsoft Corp., Redmond, WA, USA) and Stata/SE 14.0 (Stata Corp., College Station, TX, USA) were used for analyses.

Results

In the five regional and diagnostic treatment centers, we found that all complex cases are referred to the capital where general and thoracic, urologic, ophthalmologic, and otorhinolaryngologic surgical services were provided. Orthopedic, burn, cardiac, and neurologic surgical services for children are provided at other specialty hospitals in the capital.

The total number of beds in each of the 21 facilities surveyed ranged from 100 to 440 (median 210). Pediatric beds ranged from 12 to 50 (median 35) (Table 1). The percentage of the under 15 population ranged from 27.7% in Orkhon Province to 34.3% in Bayan-Olgii. Those under

Table 1 Hospital size, population, and operations by province (2015 data)

Hospital type	Province	Hospital beds	Pediatric hospital beds	Total population	Population <15 years	Percentage of population <15 years	Total operations	Operations children <15 years	Surgical rate per 100,000 population	Surgical rate per 100,000 population <15 years
Regional diagnostic and treatment center	Omnogobi	210	24	61,655	18,657	30.3%	1572	146	2549.7	782.5
	Dornod	200	25	76,476	22,700	29.7%	1678	245	2194.2	1079.3
	Khovd	250	40	83,517	27,331	32.7%	1892	325	2265.4	1189.1
	Orkhon	440	35	100,731	27,873	27.7%	2501	376	2482.9	1349.0
	Overkhangai	310	40	112,353	33,785	30.1%	2604	496	2317.7	1468.1
Provincial general hospital	Gobisumber	100	12	16,522	5239	31.7%	347	45	2100.2	858.9
	Dundgobi	130	35	44,429	12,799	28.8%	848	124	1908.7	968.8
	Gobi-Altai	147	28	56,209	16,955	30.2%	1393	180	2478.3	1061.6
	Sukhbaatar	196	20	59,034	17,428	32.5%	922	116	1561.8	665.6
	Bulgan	160	18	60,014	16,800	28.0%	715	166	1191.4	988.1
	Dornogobi	210	25	65,267	19,735	30.2%	1662	162	2546.5	820.9
	Zavkhan	205	40	69,916	20,924	29.9%	1093	189	1563.3	903.3
	Khentii	120	25	72,609	21,854	30.1%	1209	206	1665.1	942.6
	Uvs	250	44	80,763	26,727	33.1%	1187	177	1469.7	662.3
	Bayankhongor	295	48	83,936	25,701	30.6%	1845	363	2198.1	1412.4
	Tuv	226	28	90,421	26,059	28.8%	5558	718	6146.8	2755.3
	Arkhangai	293	43	92,059	27,510	29.9%	1063	218	1154.7	792.4
	Bayan-Olgii	311	45	100,189	34,398	34.3%	2222	509	2217.8	1479.7
	Darkhan-Uul	400	45	100,939	28,066	27.8%	2954	495	2926.5	1763.7
	Selenge	150	34	106,292	30,390	28.6%	5279	970	4966.5	3191.8
	Khuvsgul	280	50	128,159	38,734	30.2%	2177	316	1698.7	815.8
Multiple	Ulaanbaatar (capital)	–	–	1,396,288	399,380	28.6%	139,972	26,287	10,024.6[a]	6582.0[a]
Total		–	–	3,057,778	899,045	29.4%	180,693	32,829	5909.3	3627.5

[a]The surgical rates do not account for referrals from rural areas

age 15 comprise 29.4% of the population of Mongolia, with a greater concentration of that age range in the provinces (30.1, 95% CI 30.0–30.1) compared to the capital (28.6, 95% CI 28.5–28.7).

There were 180,693 operations in 2015, of which 77.5% were in the capital. In that year, 32,829 or 18.2% were on children under age 15. Of the pediatric operations, 80.1% were done in the capital. The surgical rate per 100,000 population was 5909, ranging from 1155 in Arkhangai Province to 10,025 in the capital. The surgical rate for population under age 15 was 3652 overall, ranging from 662 per 100,000 in Uvs Province to 6582 in the capital.

Personnel at the assessed hospitals include general surgeons (range 2–7, median 4) (Table 2). Twenty of 21 hospitals have anesthesiologists (range 1–13). The median was 3. Two hospitals have pediatric anesthesiologists. Seven hospitals have pediatric surgeons. All hospitals have pediatricians, ranging from three to nine. The median is 5. Eighteen (85.7%) hospitals have pediatric-trained nurses, ranging from 0 to 32. The median is 9. The personnel score ranges from 7 to 61. The median is 22.

All provincial-level hospitals have consistent running water and at least one operating room (range 1 to 6, median 2, Table 3). Twenty hospitals (95.2%) have consistent electricity. One has recurring outages for a period of a few minutes every day. Fifteen hospitals (71.4%) report having a functioning backup generator. Eighteen hospitals (85.7%) have incinerators. All study hospitals have medical records; nineteen have blood banks. Twenty hospitals have emergency departments; 17 (81.0%) have postoperative recovery areas. Fifteen (71.4%) have neonatal intensive care areas. Twenty-one hospitals have ultrasound; 19 have X-ray (90.5%). Eleven have functioning computed tomography capability (52.4%). Sixteen have neonatal incubators (76.2%). Fifteen have functioning ventilators in intensive care areas. The infrastructure scores ranged from 12 to 26, with a median of 17.

Table 2 Personnel by type and availability at 21 hospitals, including personnel count

Personnel type	Hospitals with personnel type (*n*, %)	Personnel count (median, range)
General surgeons	21 (100)	4 (2–7)
Anesthesiologists	20 (95.2)	3 (0–13)
Pediatric anesthesiologist	2 (9.5)	0 (0–1)
Pediatric surgeons	7 (33.3)	0 (0–2)
Pediatricians	21 (100)	5 (3–9)
Pediatric-trained nurses	18 (85.7)	9 (0–32)
Personnel score total, all hospitals median (range). No maximum		22 (7–61)

Table 3 Infrastructure available at 21 surveyed hospitals

	Hospitals with always available (*n*, %)
Operating rooms	21 (100)
External electricity	20 (95.2)
Backup generator	15 (71.4)
Running water	21 (100)
Incinerator	18 (85.7)
Medical records	21 (100)
Blood bank	19 (90.5)
Emergency department	20 (95.2)
Postoperative care area	17 (81.0)
Neonatal intensive care area	15 (71.4)
Neonatal incubators	16 (76.2)
Ventilator in intensive care	15 (71.4)
Functioning X-ray	19 (90.5)
Functioning ultrasound	21 (100)
Functioning CT scanner	11 (52.4)
Infrastructure score total, all hospitals median. No maximum	17 (range 13–28)

All hospitals perform basic procedures (Table 4). Eight (38.1%) do skin grafting. All hospitals do laparotomy, bowel resection, appendectomy, hernia repair, and circumcision. Fifteen (71.4%) treat testicular torsion. Fifteen do thoracotomy. Twelve (57.1%) do laparoscopy. Eleven (52.4%) remove airway and esophageal foreign bodies. Seven (33.3%) do pyloromyotomy. Seven repair abdominal wall defects. Four (19.0%) repair imperforate anus. Five (23.8%) do pull-through operations. Twenty create intestinal stomas (95.2%); 21 close stomas (100%). Five (23.8%) repair intestinal atresia. One (0.48%) does repair of esophageal atresia. Of 12 pediatric index and pediatric-specific procedures (Table 5), two hospitals performed zero. The maximum number performed was seven (58.3%, Table 5). The median was 4 (33.3%). Of the 46 total procedure questions, the range was 27–40. The median was 35. General and ketamine anesthesia is available at all facilities. Nineteen (90.5%) facilities provide regional anesthesia, while 20 (95.2%) provide spinal.

Twenty hospitals have compressed cylinder oxygen always available (95.2%, Table 6). Twenty facilities have an oxygen concentrator always available. Twenty have pediatric resuscitation bag valve masks (95.2%), 14 (66.7%) pediatric oropharyngeal airways, 17 (81.0%) pediatric endotracheal tubes, and 17 functioning anesthesia machines. Nineteen (90.5%) have pulse oximeters, 16 (76.2%) blood pressure cuffs for children, and 16 apnea alarms. All have sterilizers, suction, and electrocautery. Sixteen have pediatric surgical instrument sets. Thirteen (61.9%) have endoscopes. The equipment score ranged

Table 4 Facilities reporting procedures performed, by type of procedure

Anesthesia type (*n*, %)	Respiratory (*n*, %)	Gastrointestinal (*n*, %)	Urogenital (*n*, %)	Orthopedic (*n*, %)	Unclassified (*n*, %)
Ketamine 21 (100)	Chest tube insertion 21 (100)	Appendectomy 21 (100)	Male circumcision 21 (100)	Fracture splinting 21 (100)	Resuscitation 21 (100)
General 21 (100)	Tracheostomy 14 (66.7)	Bowel resection and anastomosis 21 (100)	Hernia repair 21 (100)	Casting of fracture 21 (100)	Suturing 21 (100)
Regional 19 (90.5)	Thoracotomy 15 (71.4)	Creation of intestinal stoma 20 (95.2)	Orchidopexy 19 (90.5)	Traction of closed fracture 21 (100)	Wound debridement 20 (95.2)
Spinal 20 (95.2)	Repair of esophageal atresia 1 (0.47)	Closure of intestinal stoma 21 (100)	Repair of testicular torsion 15 (71.4)	Treatment of open fracture 21 (100)	Incision and drainage of abscess 21 (100)
	Removal airway and esophageal foreign bodies 11 (52.4)	Pyloromyotomy 7 (33.3)	Repair of imperforate hymen 6 (28.6)	Amputation 20 (95.2)	Laparotomy 21 (100)
		Rectal biopsy 11 (52.4)	Ovarian cystectomy 18 (85.7)	Osteomyelitis management 20 (95.2)	Pediatric abdominal wall defect repair 7 (33.3)
		Intestinal atresia repair 5 (23.8)		Non-operative treatment of clubfoot 9 (42.9)	Burn management 21 (100)
		Ladd procedure 4 (19.0)			Skin grafting 8 (38.1)
		Pull-through for Hirschsprung disease 5 (71.4)			Contracture release 15 (71.4)
		Repair of imperforate anus 4 (19.0)			Resection solid abdominal mass 14 (66.7)
		Insertion of gastrostomy tube 19 (90.5)			Laparoscopic surgery 12 (57.1)
		Non-operative reduction of intussusception 19 (90.5)			

from 15 to 21 with a median of 18.5. The highest possible score was 22.

All hospitals have sterile and examination gloves available (Table 7). All have disposable needles. Nineteen (90.5%) have intravenous (IV) cannulae, IV infusion sets, and blood transfusion sets. Twenty (95.2%) have syringes. Ten (47.6%) have pediatric nasogastric tubes, four (19.0%) have pediatric urinary catheters, and nine (42.9%) have tracheostomy tubes. One (4.78%) has pediatric-sized chest tubes. Thirteen (61.9%) have laparoscopic supplies. Twenty (95.2%) have sterile gauze and bandages. Nineteen have absorbable and non-absorbable suture always available, while two (9.5%) have neither. All have scalpel blades; 20 (95.2%) have safe sharps disposal containers. Twenty (95.2%) have gowns, and 19 (90.5%) facemasks. Sixteen (76.2%) have aprons; 15 (71.4%) theater boots; 8 (38.1%) have eye protection. Of 26 possible supply items, the minimum score was eight, and highest score 24, with a median of 22.

Discussion

These data demonstrate a wide variation in pediatric surgical capacity in secondary-level hospitals outside of the capital. These hospitals performed just 19.9% of operations for children under age 15 in 2015, despite over half of children under age 15 in Mongolia living outside of the capital. There is room to improve capacity in each of the domains assessed. Many of the hospitals are undertaking their own improvement efforts.

What follows are the team observations. We hope they may provide some inspiration to hospital leadership, surgical and anesthesia staff, ministry of health, and other officials seeking to improve the surgical care of children in Mongolia. Some low-cost improvements that change resource allocations—such as reassigning nursing staff to postoperative monitoring, and increasing continuing education focused on safe anesthesia and surgery for children—may make a large difference. Making small and

Table 5 Pediatric trained staff and core pediatric procedures performed

Province	Type of facility	Pediatric surgeons	Pediatric anesthesiologists	Pediatric procedures performed [*n* = 12, *n* (%)]
Dornod	RDTC	0	0	2 (16.7)
Khovd	RDTC	0	0	4 (33.3)
Orkhon	RDTC	0	0	6 (50)
Overkhangai	RDTC	1	0	7 (58.3)
Omnogobi	RDTC	1	0	5 (41.7)
Arkhangai	GH	0	0	0 (0)
Bayan-Olgii	GH	0	0	1 (8.3)
Bayankhongor	GH	0	0	0 (0)
Bulgan	GH	0	0	2 (16.7)
Darkhan-Uul	GH	0	0	3 (25)
Dornogobi	GH	0	0	3 (25)
Dundgobi	GH	0	0	4 (33.3)
Gobi-Altai	GH	0	0	4 (33.3)
Gobisumber	GH	0	0	5 (41.7)
Khentii	GH	0	0	5 (41.7)
Khuvsgul	GH	0	0	6 (50)
Selenge	GH	1	0	1 (8.3)
Sukhbaatar	GH	1	0	3 (25)
Tuv	GH	1	1	4 (33.3)
Uvs	GH	1	0	4 (33.3)
Zavkhan	GH	2	0	2 (16.7)

The 12 procedures selected from PediPIPES procedures include: removal esophageal or tracheal foreign body, pyloromyotomy, non-operative clubfoot treatment, repair abdominal wall defects, repair intestinal atresia, repair imperforate anus, Ladd procedure, rectal biopsy, pull-through for Hirschsprung disease, repair esophageal atresia, repair imperforate hymen, and repair spina bifida

RDTC regional diagnostic and treatment center, *GH* general hospital

Table 6 Equipment: selected items available at hospitals. Maximum score 22

Equipment	Hospitals with always available (*n*, %)
Oxygen, compressed cylinder	20 (95.2)
Oxygen compressor	20 (95.2)
Electrocautery, suction machine, OR lights	21 (100)
Pediatric ambu bag and mask	20 (95.2)
Pediatric oropharyngeal airway	14 (66.7)
Pediatric endotracheal tube	17 (81.0)
Pulse oximeter	19 (90.5)
Pediatric blood pressure cuff	16 (76.2)
Apnea monitor	16 (76.2)
Anesthesia machine	17 (81.0)
Endoscope (any bronch- or esophago-)	13 (61.9)
Equipment score total, all hospitals median	18.5 (range 15–21)

large changes that allow for more children to access the surgical care they need will avert disability and save lives.

Personnel

There are a relatively high number of physicians per capita in Mongolia. However, their distribution is unequal. There are 4.39 physicians per 1000 population in Ulaanbaatar, while there are only 1.74 per 1000 in Bayan-Olgii. The mean is 2.54 [23]. Anesthesia staff are similarly maldistributed. We observed that though every hospital has surgeons, there were usually not enough, and the level of training was inconsistent. Our secondary hospital results differ from those of Spiegel et al. [16] who assessed primary-level town hospitals, none of which had surgeons or anesthesiologists, but many of which performed basic operations.

The model proposed by the conduct of our research—i.e., Mongolian senior specialists visit remote locations and provide on-site team education on a periodic basis, coupled with research/capacity assessments—is a promising one. Funding may limit this model, although the cost-effectiveness of this approach should be further investigated. There are ongoing continuing medical education visits conducted by the Mongolian National University of Medical Sciences (MNUMS) in rural areas. Adding content on

Table 7 Supplies: selected items available at hospitals. Maximum score 26

	Hospitals with always available (*n*, %)
Gloves (sterile and exam)	21 (100)
Drapes (for operations)	21 (100)
Scalpel blades	21 (100)
Suture (absorbable and non-absorbable)	19 (90.5)
Sterile gauze and bandages	20 (95.2)
Adhesive tape	21 (100)
Tourniquet	21 (100)
Disposable needles	21 (100)
Syringes	20 (95.2)
IV cannulae	19 (90.5)
IV infusion sets	19 (90.5)
Blood transfusion sets	19 (90.5)
Nasogastric tubes (≤12 French)	10 (47.6)
Urinary catheter (pediatric including 6 French)	4 (19.0)
Tracheostomy tubes	9 (42.9)
Chest tubes (≤12 French)	1 (4.78)
Face masks	19 (90.5)
Eye protection	8 (30.1)
Gowns	20 (95.2)
Aprons	16 (76.2)
Theater boots	15 (71.4)
Sharps disposal container	20 (95.2)
Laparoscopic supplies	13 (61.9)
Supplies score, all hospitals median	22 (range 8–24)

safe anesthesia and surgery for children would cost little, but potentially have high yield.

We observed that hospital services are divided in ways that may be less than efficient. Frequently, patients must enter one area of the hospital for internal medicine complaints and a different area for injury or surgical problems. This division carries through to the allocation of resources and staff. Thus, not all resources captured in PediPIPES are available to pediatric surgical patients. All provincial hospitals have pediatricians, but in only one hospital the pediatricians were engaged in care for pediatric surgical patients. Typically, children with surgical problems go to the surgical ward before and after any operation. Consequently, they are cared for by surgeons who, for the most part, have no pediatric training.

One hospital has no anesthesiologist, but reported providing anesthesia care. We found that many local staff answered the question about the number of nurse anesthetists with the number of nurses in the anesthesia department, but these nurses do not have a scope of practice consistent with independent practitioners or practice extenders. Therefore, we corrected this number to zero in every instance. This contradicts the findings by Speigel et al. [16].

Finally, over-tasking or underutilization of training of staff should be addressed. For example, anesthesia staff in provincial hospitals are responsible for perioperative care, staffing the emergency room, attending to traumas outside of the hospital, transport of those trauma patients, management of critical care units, and (in the two hospitals with dialysis units) running dialysis. There are pediatric-trained surgeons practicing in general surgery at lower-level rural hospitals in Mongolia. Not all of these hospitals have anesthesiologists trained to provide safe care for children. Ensuring that all specialists are in positions to utilize their skills is critical. Future evaluations can provide insight for a more efficient allocation of labor in such cases.

Infrastructure

Compared to primary-level facilities, infrastructure in provincial centers is largely adequate. However, some provincial hospitals were originally built with two operating rooms, but now have just one functioning operating room.

Four hospitals do not have postoperative recovery areas. The 17 hospitals with recovery areas do not all have pulse oximeters or nurses available to monitor them. Most often, only simple beds in otherwise unequipped rooms are available, with one nurse responsible for the operating room circulation and the recovery area. Fully functional recovery areas could be instituted for relatively low cost at all hospitals, with the provision of additional pulse oximeters, and the assignment of a nurse to monitor postoperative patients while free from other duties.

Procedures

All provincial hospitals reported performing resuscitation, incision and drainage, and laparotomy. Based on the team's in-person assessments—particularly of anesthesia capabilities—we do not believe a neonatal laparotomy is possible or advisable in most hospitals outside of the capital. However, laparotomy for two-year-old patients may be possible.

The twelve index pediatric procedures examined separately from the remaining procedures (Table 5) may give a better picture of the operative treatment for the youngest patients. Of these twelve procedures, two hospitals performed none. The maximum was 7 and median 4. This implies that children living rural areas lack access to surgical care for all but the most basic conditions.

There were variations between surgery staff responses in the same hospitals about which procedures are done at least once. We consulted with the most senior surgeon and our pediatric surgeon and author EC to settle such cases. Some procedures, e.g., airway foreign body removal and thoracotomy, were reported and confirmed in this manner during the data collection, but based on personal experience, the authors agree these are unlikely to actually be done outside of the capital. There remains uncertainty with respect to the ages for which the procedures were performed. All surveys were identical and introduced with a focus on children; however, age limits were not specified or uniformly re-emphasized when the procedures questions were asked. PediPIPES has not yet been validated, but in the Bolivian study, the PIPES tool inter-rater reliability was moderate for procedures (kappa 0.43) [18].

Definitive care for pediatric conditions frequently requires transport to the capital at parents' expense. Alternatively, pediatric surgeons and anesthesiologists may travel to the patient. However, this reduces hospital staff levels, adds expense for the health system, and (due to extreme weather and poor road infrastructure) puts traveling personnel at risk. The creation of a national pediatric and neonatal transport team based in the capital would be costly, but may be needed to provide timely and appropriate services for the most critically ill patients.

We observed that lack of anesthesia capability was the primary limiting factor for many pediatric procedures. Only one hospital outside of the capital had a pediatric-trained anesthesiologist. Team member BS taught local anesthesia staff during pediatric operations conducted by EC and local surgery staff and noted room for improvement in knowledge. Further training of rural staff in the care of children may be costly, but is not necessarily so. It is required, in our view. This education may be conducted in a variety of ways, including through the most economical method—distance learning—as MNUMS has already begun in other specialty areas. Other methodologies may include focused multi-day trainings in the capital, and on-site continuing education and training by experts as was done in conjunction with this research. Visiting teaching teams are supported by MNUMS could be adjusted to include pediatric surgical and anesthesia education for a small additional cost. Short- or long-term placement of fully pediatric-trained personnel in rural areas will require investment for hardship pay and bonuses. BS also noted anesthesia-related supply and equipment shortages, described above.

Better access to pediatric procedures will improve the prospects of children in rural Mongolia. Those procedures that do not require intensive postoperative recovery or support, e.g., foreign body removal, testicular torsion repair, pyloromyotomy, and skin grafting, are a natural place to start. Neonatal operations, however, should remain centralized at this time. To facilitate this, improved mechanisms of transfer are needed.

Equipment and supplies

Provincial hospitals are relatively well equipped, with minimum score of 15 out of 22. They mainly lack pediatric-specific disposables, e.g., endotracheal tubes and endoscopes. The lowest scoring facility has a supply score of 8 out of 26.

All provincial second-level hospitals have some form of oxygen consistently available. However, local staff noted disruption of supply continuity, particularly when roads are muddiest in spring and fall.

Pulse oximeters are nearly ubiquitous. However, we found two broken LifeBox oximeters in hospitals that did not have the maintenance budget to replace the out-of-warranty units. Six hospitals lack apnea monitors.

Some details about critical equipment were not defined clearly enough in PediPIPES. For example, we counted pediatric bag valve masks as present if there was one in the emergency room or in the operating room, despite the fact that a delay in transporting one from the emergency room to the operating room could have fatal consequences.

All hospitals report performing general anesthesia. However, five lack functional anesthesia machines. Anesthesiologists at all hospitals utilize manual bag valve mask ventilation for the duration of operations, including in those hospitals that report having functional anesthesia machines. Thus, more detail is required to distinguish functional from non-functional machines. The inter-rater reliability of PediPIPES must also be established. In the Bolivian study, the equipment and supply sections inter-rater reliability scores were 0.26 and zero, respectively, indicating poor correlation [18]. However, our results are strengthened by direct observation.

Equipment and supply capacity have two main areas in need of improvement: (1) greater precision regarding what supplies and equipment should be present in each hospital in order to best serve their pediatric surgical populations, and (2) implementation of timely logistical controls including the reporting of out of stock or low stock items, systematized stock ordering, and consistent restocking of equipment and supplies.

Additional limitations

These assessments are cross-sectional and not necessarily representative of the continuous state of the hospitals. We did not assess private hospitals. We assessed one primary-level facility, but did not include it here due to space limitations. Future assessments should include more facilities of different levels.

Conclusions

Children outside of Ulaanbaatar face obstacles to surgical care. Those who live provincial centers have relatively better access, but as we have shown, even regional centers lack the capacity to do key procedures.

It is our hope that our study can aid the development of standards regarding Mongolia's pediatric surgical capacity, staffing requirements, and necessary training. Standards regarding infrastructure, equipment, and supplies to perform pediatric procedures safely must also be established. In many cases, we found that simple deficiencies could be addressed through reallocation or sharing of resources, even within a given hospital. Process-oriented solutions that could improve care with minimal additional investment include assigning one nurse to consistently monitor postoperative patients in the recovery area and movement of monitors to that room when needed. Increasing education in the care of children in the perioperative period may also be a low-cost improvement. Other solutions that would require sharing of resources or increased investment include establishing the minimum consumable supplies in each hospital, adding equipment where needed including oximeters and capnography monitors. Packages of equipment, training, and maintenance plans are needed to accomplish certain procedures in the provincial hospitals, including airway and esophageal foreign body removal, as an example, including rigid esophagoscopes. National guidelines, modeled upon international consensus such as the Optimal Resources for Children's Surgery, may help to increase the capacity of rural hospitals to provide care for children [24].

PediPIPES, like other capacity assessment tools, is intended as an iterative tool to track progress over time [16, 17]. Future work should include regular reassessments with some modifications to the tool, as described. Further study on the prevalence of surgical disease among children via household surveys in a cluster-randomized fashion should be performed, as well as analyses of morbidity and mortality related to surgical conditions.

Significance

These baseline data are essential for improving resources to increase pediatric surgical capacity. This work provides preliminary data for planning and funding future in-depth household and hospital surveys that can help Mongolia determine how to further decrease the burden of untreated congenital malformations and other pediatric surgical diseases.

Acknowledgements The authors would like to thank Harvard University, the Harvard T.H. Chan School of Public Health, the UC Davis Department of Surgery, and the Fulbright Commission for support of this work. The corresponding author is indebted to Dean Michelle Williams and E. Fran Cook of the Harvard T.H. Chan School of Public Health for their guidance and support of this research. The authors thank the surgical trainees of the Second National Hospital for their assistance with data collection, and the surgeons and hospital staff at each of the provincial hospitals, who generously hosted the research team and participated in the data collection. Dr. Ray Price provided invaluable introductions and advice, and Dr. Sergelen Orgoi graciously encouraged and supported the project. We appreciate the Ger Community Mapping Center collaboration and their assistance with visualizing the data. Finally, we thank Marc Parenteau for your assistance with editing.

Funding This research was supported by a Harvard University Frederick Sheldon Traveling Fellowship, a Harvard T. H. Chan School of Public Health Rose Traveling Fellowship, a Fulbright Fellowship, and salary support was provided by the University of California Davis Department of Surgery as well as the Mongolian National University of Medical Sciences. For the use of the REDCap data collection system, the project described was supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health (NIH), through Grant UL1 TR000002. The funders had no say in the study design, conduct, or reporting.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This research was approved by the Mongolian National University of Medical Sciences Ethical Committee of Research (2016/3/2016–2017 #1). It was designated "not human subjects research" by the University of California Davis Institutional Review Board (IRB 939081-2) and by the Harvard T.H. Chan School of Public Health Office of Human Research Administration (IRB 17-0446).

References

1. The World Bank Group (2017) World Bank Data: The World Bank. http://data.worldbank.org/indicator/SH.DYN.MORT?locations=MN. Accessed 22 July 2017
2. Child Mortality Estimates (2014) http://www.childmortality.org/. Accessed 22 July 2017
3. Liu L, Oza S, Hogan D et al (2015) Global, regional, and national causes of child mortality in 2000–13, with projections to inform post-2015 priorities: an updated systematic analysis. Lancet 385(9966):430–440
4. Mulligan J-A, Fox-Rushby, JA, Taghreed, A, et al (2003) Unit costs of health care inputs in low and middle income regions. Disease control priorities project working paper no 9
5. Gunsentsoodol B, Nachin B, Dashzeveg T (2006) Surgery in Mongolia. Arch Surg 141(12):1254–1257
6. Tsolmongerel T, Evlegsuren SO, Bulganchimeg B et al (2013) Mongolia health systems review. Health Syst Trans 3(2):184
7. UNICEF Annual Report 2012 for Mongolia, EAPRO (2012) https://www.unicef.org/about/annualreport/files/Mongolia_2015_COAR.pdf. Accessed 10 Feb 2017
8. World Health Organization, Global Health Observatory Data Repository (2015). http://apps.who.int/gho/data/node.cco.ki-MNG?lang=en. Accessed 22 July 2017

9. World Health Organization (2015) Congenital anomalies fact sheet, number 370 http://www.who.int/mediacentre/factsheets/fs370/en/. Accessed 22 July 2017
10. Apfeld JC, Wren SM, Macheka N et al (2015) Infant, maternal, and geographic factors influencing gastroschisis related mortality in Zimbabwe. Surgery 158(6):1475–1480
11. Chirdan LB, Ngiloi PJ, Elhalaby EAE (2012) Neonatal surgery in Africa. Semin Ped Surg 21(2):151–159
12. Badrinath R, Kakembo N, Kisa P et al (2014) Outcomes and unmet need for neonatal surgery in a resource-limited environment: estimates of global health disparities from Kampala, Uganda. J Ped Surg 49(12):1825–1830
13. Farmer DL, Sitkin N, Lofberg K, Surgical Interventions for Congenital Anomalies et al (2015) Essential surgery disease control priorities, vol 1. International Bank for Reconstruction and Development/The World Bank, Washington, pp 129–149
14. Gonzalez LP, Pignaton W, Kusano PS et al (2012) Anesthesia-related mortality in pediatric patients: a systematic review. Clinics 67(4):381–387
15. Henry JA, Orgoi S, Govind S et al (2012) Strengthening surgical services at the soum (first-referral) hospital: the WHO emergency and essential surgical care (EESC) program in Mongolia. World J Surg 36(10):2359–2370. https://doi.org/10.1007/s00268-012-1668-z
16. Spiegel DA, Choo S, Cherian M et al (2011) Quantifying surgical and anesthetic availability at primary health facilities in Mongolia. World J Surg 35(2):272–279. https://doi.org/10.1007/s00268-010-0904-7
17. Groen RS, Kamara TB, Dixon-Cole R et al (2012) A tool and index to assess surgical capacity in low-income countries: an initial implementation in Sierra Leone. World J Surg 36(8):1970–1977. https://doi.org/10.1007/s00268-012-1591-3
18. Markin A, Barbero R, Leow JJ et al (2014) Inter-rater reliability of the PIPES tool: validation of a surgical capacity index for use in resource-limited settings. World J Surg 38(9):2195–2199. https://doi.org/10.1007/s00268-014-2522-2
19. Okoye MT, Ameh EA, Kushner AL et al (2015) A pilot survey of pediatric surgical capacity in West Africa. World J Surg 39(3):669–676. https://doi.org/10.1007/s00268-014-2868-5s
20. Meara JG, Leather AJ, Hagander L et al (2015) Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Surgery 158(1):3–6
21. Mongolian Statistical Information Service (2017) Statistical database by sector, population. http://www.1212.mn. Accessed 9 June 2017
22. Harris PA, Taylor R, Thielke R et al (2009) Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 42(2):377–381
23. Mongolian Statistical Information Service (2015) Public health of population data. http://www.1212.mn/en/contents/stats/contents_stat_fld_tree_html.jsp. Accessed 29 July 2017
24. Goodman LF, St-Louis E, Yousef Y et al (2018) The global initiative for children's surgery: optimal resources for improving care. Eur J Ped Surg 28(1):51–59