THE ORTHOPAEDIC FORUM

Orthopaedic Trauma Care Capacity Assessment and Strategic Planning in Ghana: Mapping a Way Forward

Barclay T. Stewart, MD, MScPH, Adam Gyedu, MD, MPH, Gavin Tansley, MD, Dominic Yeboah, MD, MPH, Forster Amponsah-Manu, MD, Charles Mock, MD, PhD, Wilfred Labi-Addo, MD, and Robert Quansah, MD, PhD

Investigation performed at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Background: Orthopaedic conditions incur more than 52 million disability-adjusted life years annually worldwide. This burden disproportionately affects low and middle-income countries, which are least equipped to provide orthopaedic care. We aimed to assess orthopaedic capacity in Ghana, describe spatial access to orthopaedic care, and identify hospitals that would most improve access to care if their capacity was improved.

Methods: Seventeen perioperative and orthopaedic trauma care-related items were selected from the World Health Organization's *Guidelines for Essential Trauma Care*. Direct inspection and structured interviews with hospital staff were used to assess resource availability and factors contributing to deficiencies at 40 purposively sampled facilities. Cost-distance analyses described population-level spatial access to orthopaedic trauma care. Facilities for targeted capability improvement were identified through location-allocation modeling.

Results: Orthopaedic trauma care assessment demonstrated marked deficiencies. Some deficient resources were low cost (e.g., spinal immobilization, closed reduction capabilities, and prosthetics for amputees). Resource nonavailability resulted from several contributing factors (e.g., absence of equipment, technology breakage, lack of training). Implants were commonly prohibitively expensive. Building basic orthopaedic care capacity at 15 hospitals without such capacity would improve spatial access to basic care from 74.9% to 83.0% of the population (uncertainty interval [UI] of 81.2% to 83.6%), providing access for an additional 2,169,714 Ghanaians.

Conclusions: The availability of several low-cost resources could be better supplied by improvements in organization and training for orthopaedic trauma care. There is a critical need to advocate and provide funding for orthopaedic resources. These initiatives might be particularly effective if aimed at hospitals that could provide care to a large proportion of the population.

Peer review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Disclosure: This study was funded by grants R25-TW009345 and D43-TW007267 from the Fogarty International Center, U.S. National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. On the **Disclosure of Potential Conflicts of Interest** forms, which are provided with the online version of the article, one or more of the authors checked "yes" to indicate that the author received payment and/or services from a third party (government, commercial, private foundation, etc.) for an aspect of the submitted work.

Orthopaedic conditions incur more than 52 million disability-adjusted life years (DALYs) annually worldwide, comprising more than 16% of the global disease burden¹. This burden falls disproportionately on low and middle-income countries (LMICs), which are least equipped to provide orthopaedic care^{2,3}. The delivery of safe and timely care for orthopaedic conditions can prevent disability and minimize health-care costs by avoiding the complexity and expense associated with delayed treatment^{4,5}. Therefore, LMICs have the greatest need for accurate estimates of the burden of orthopaedic conditions, assessment of orthopaedic capacity, and targeted health-system strengthening interventions⁶.

The burden of orthopaedic trauma conditions in Ghana has been grossly defined. Injuries incur an estimated 2,772 DALYs per 100,000 people annually⁷. For reference, this is 44% more than the DALYs incurred from injury in Egypt and 30% more than in Canada⁷. Population-based studies of injury have reported 53 to 83 deaths per 100,000 people^{8,9}.

In 2014 through 2015, a national assessment of trauma care capacity in Ghana was performed¹⁰. We used a subset of data from that assessment to describe essential orthopaedic trauma care capacity countrywide¹¹. Additionally, we mapped population-level spatial access to orthopaedic trauma care and identified hospitals that would most improve access to care if their capacity was improved. The findings might inform health-system planning exercises.

Materials and Methods

Setting

Ghana is a heavily indebted LMIC in West Africa with a population of 26 million people and an annual per capita income of \$1,760 U.S.¹². Ghana has 10 regions that are divided into 216 districts. There are 4 tertiary hospitals, 9 referral hospitals, and 155 mission or government-run first-level hospitals¹³.

First-level hospitals are typically staffed by general medical officers (i.e., doctors with 2 years of house officer training) and nurse anesthetists, and have between 50 and 100 beds; some provide surgical services^{14,15}. Conditions requiring more complex care are referred to 1 of the referral or tertiary hospitals. Referral hospitals are typically staffed by 1 or more specialist provider(s) (e.g., general and/or orthopaedic surgeons) and contain between 100 and 400 beds. Each of the tertiary hospitals offers more specialized care.

Capacity Assessment

The Kwame Nkrumah University of Science and Technology in Ghana and the University of Washington in Seattle gave ethical approval for the study. A complete description of the methods used for the capacity assessment has been published previously¹⁰. Briefly, all tertiary and referral hospitals and a selection of first-level hospitals (totaling 40 facilities) were purposively sampled to represent hospitals most likely to care for injuries. At least 1 district-level hospital in each region was selected by being (1) in a populous area, near heavily-trafficked roads likely to produce road-traffic injuries; or (2) identified by the respective regional health directorate as caring for a higher injury volume than others within the region; or (3) designated as a trauma hospital; as well as being (4) outside of an hour's transport to a regional or tertiary hospital, to avoid hospitals that often get bypassed by those in need of trauma care.

We used a structured assessment tool adapted from the World Health Organization (WHO) *Guidelines for Essential Trauma Care* (GETC) that included 17 resources required for perioperative and musculoskeletal trauma care as proxies for overall orthopaedic trauma care capacity (e.g., radiography, image intensification, closed reduction, skeletal traction, external and internal fixation, and open fracture debridement)¹⁶.

We systematically interviewed each staff member performing the functions of the following positions at each sampled hospital (if the position was filled at the facility): surgeons, anesthetists, medical officers, administrators, accountants, procurement and logistic officers, technicians, biomedical engineers, and/or department in-charge nurses. Some hospitals did not have 1 or more of these positions (e.g., surgeon, logistics officer, or technician at a first-level hospital). Staff members rated item availability as 0 if it was absent but should be present; 1 if it was inadequate, available to less than half of those who need it; 2 if it was partially adequate, available to more than half, but not to all who need it; or 3 if it was adequate, present, and readily available to almost everyone in need and used when needed.

The median rating was used if there were disagreements on the same resource. For each resource rated 0 to 2, factors that contributed to deficiency were systematically explored. Direct inspection of items was performed to corroborate ratings and troubleshoot reasons for nonavailability. Direct inspection included visually determining if the item was present or absent, examining it for functional availability, and evaluating why it was not available at times if rated ≤ 2 (e.g., stock management practices, training deficiencies, and breakage). Item availability rating (median and range) and factors contributing to nonavailability (percent of hospitals reporting that factor for each item rated ≤ 2) were described.

Data for Mapping Spatial Access

The number and type of surgical procedures performed at first-level and referral hospitals countrywide are reported monthly to the Ministry of Health using the DHIS-2 platform (Health Information Systems Programme). The vast majority of hospitals are compliant with this mandate¹⁷. Smaller and more remote hospitals report data less reliably; these hospitals are also the least likely to provide any surgical care. Similar data from tertiary hospitals are not reported. Thus, orthopaedic trauma care capabilities at tertiary hospitals were determined by site visits during the capacity assessment.

Using these data from 2014 and 2015, hospitals were sorted into 3 groups: hospitals that performed basic orthopaedic trauma care (i.e., nonoperative care, including closed reduction and skeletal traction, as well as debridement of open fracture), hospitals that performed intermediate orthopaedic care (i.e., external fixation and internal fixation), and hospitals that performed advanced orthopaedic care (i.e., complex long-bone and articular fracture management, and spine, pelvis, and hand surgery).

GIS (Geographic Information System) Data Management

Hospitals were geolocated using Google Earth. National population data were represented by a 100-m²-gridded population surface generated by the WorldPop Project, which was created using the 2010 census adjusted to 2015 estimates with the United Nations population projections¹⁸.

We created a national road network by combining primary and secondary road data from OpenStreetMap (OSM; Open Street Map Foundation), and tertiary road data from the Centre for Remote Sensing and Geographic Information Services (CERSGIS)^{19,20}. Following topological verification, travel speed was assigned to each class of road based on national traffic laws: 100, 50, and 30 km/hr for primary, secondary, and tertiary roads, respectively^{21,22}.

Spatial Access to Orthopaedic Trauma Care

Cost-distance analyses were performed to determine population-level spatial access to each level of orthopaedic trauma care^{23,24}. The cost surface was constructed by superimposing the road network and corresponding speed limit over the country. Background cells were assigned a value of 5 km/hr (i.e., walking speed). The value of each cell represented the time required to traverse that cell. The proportion of the population with spatial access to care was evaluated by overlaying the gridded population surface over the cost surface and calculating the proportion of the population within 60 and 120 minutes of a hospital capable of providing orthopaedic care. To evaluate model stability, 2 additional cost surfaces were built where travel speed for each road segment was augmented by $\pm 20\%$ (i.e., uncertainty interval [UI]).

Location-Allocation Model

Three location-allocation models were built to identify the facilities with the greatest impact on population-level spatial access to each level of orthopaedic trauma care^{25,26}. The analyses used lists of candidate facilities to identify 15, 10, and 2 additional hospitals to provide basic, intermediate, and advanced orthopaedic care, respectively. Each candidate list represented the hospitals that would require the lowest resource investment to attain a higher level of orthopaedic care. Basic facilities were chosen from a list of facilities already providing some trauma care in Ghana, but not full basic orthopaedic care (e.g., splinting, but not closed reduction or traction); intermediate facilities were chosen from the same list plus facilities already providing basic orthopaedic care; and advanced facilities were chosen from a list of facilities currently providing intermediate orthopaedic care.

The population-weighted geographic centroid of each district represented demand points in the model. After combining the existing and expanded facilities, repeat cost-distance analyses were performed to quantify improvements in population-level spatial access following the simulated capability expansions.

Results**Capacity Assessment**

In total, 29 first-level, 8 referral, and 3 tertiary hospitals were assessed (Table I). Overall, pulse oximetry, blood transfusion capabilities, hemoglobin determination, radiograph capabilities, and basic general surgery were relatively reliably available

at all 3 levels of care (i.e., first-level, referral, and tertiary hospitals). Major general surgery, closed reduction of fractures, and image intensification were rarely available at the first-level hospitals, but reliably available at larger hospitals. Vascular repair, skin-grafting, external fixation of fractures, and spinal fixation were rarely available outside of tertiary hospitals.

Orthopaedic trauma care capacity was generally low and variable between and within hospital levels. Spinal immobilization was rarely performed at any hospital level despite its low cost (median rating of 1 at tertiary hospitals; range, 0 to 3). Radiograph capabilities had a median rating of 2 at all levels (range, 0 to 3 at both first-level and referral hospitals). Portable radiograph machines were rarely available, even at tertiary hospitals (median rating of 1 at tertiary hospitals; range, 0 to 3). Conversely, image intensification was reliably available at all of the tertiary hospitals (median rating of 3; range, 3 to 3).

While closed reduction of fractures had a median rating of 2 at first-level hospitals and a median rating of 3 at referral hospitals, its availability varied markedly within both levels (range, 0 to 3). Orthopaedic procedures were

TABLE I Median Availability Ratings and Ranges of Orthopaedic Care Items and Services at Hospitals in Ghana

Orthopaedic Care Items and Services	Median Item Availability Rating (Range)*		
	First-Level Hospital	Referral Hospital	Tertiary Hospital
Number assessed	29	8	3
Pulse oximetry	3 (0-3)	2 (2-3)	3 (3-3)
Blood transfusion capabilities	2 (1-3)	2 (1-3)	2 (2-3)
Hemoglobin determination	3 (1-3)	3 (2-3)	3 (3-3)
Radiograph capabilities	2 (0-3)	2 (0-3)	2 (2-3)
Portable radiograph machines	0 (0-3)	0 (0-1)	1 (0-3)
Basic general surgery†	3 (0-3)	3 (0-3)	3 (3-3)
Major general surgery†	1 (0-3)	3 (0-3)	3 (3-3)
Vascular repair	0 (0-2)	0 (0-2)	2 (0-2)
Skin-grafting	0 (0-3)	0 (0-2)	2 (1-3)
Closed reduction	2 (0-3)	3 (0-3)	3 (3-3)
Skeletal traction	0 (0-3)	1.5 (0-3)	3 (3-3)
External fixation	0 (0-3)	0 (0-3)	3 (3-3)
Internal fixation§	N/A	0 (0-1)	1 (1-2)
Prosthetics for amputees	0 (0-3)	0	0 (0-1)
Image intensification	0 (0-3)	1 (1-2)	3 (3-3)
Spine immobilization#	0 (0-3)	0 (0-1)	1 (0-3)
Spinal fixation	N/A	0	3 (0-3)

*Item availability was rated by hospital staff: 0 = absent but should be present; 1 = inadequate, available to less than half of those who need it; 2 = partially adequate, available to more than half, but not to all who need it; or 3 = adequate, present, and readily available to almost everyone in need and used when needed. †Basic general surgery = wound debridement, 1% total body surface area burn excision, digital amputation, surgical airway, and debridement of open fracture. ‡Major general surgery = neck exploration, exploratory laparotomy, major amputation, as well as basic neurosurgery (burr hole, treatment of open depressed skull fracture). §Internal fixation = Kirschner wires, plate and screws, and intramedullary nails. #Spine immobilization = cervical collar and back board. N/A = not applicable (a first-level hospital would not have these orthopaedic care items and services available).

TABLE II Percentage of Hospitals Reporting Factors Contributing to Specific Item Nonavailability in Ghana*

	Resource Absence (%)	Broken Equipment (%)	Personnel Shortage (%)	Lack of Training (%)	Lack of Reagents, Supplies (%)	Out of stock, Insufficient Quantity (%)	User Fees Necessary (%)
First-level hospitals							
Pulse oximetry	7	21				24	
Hemoglobin		14			24		
Radiographs	24	45	14	4		10	
Basic general surgery†	4		7	35			
Skin or skeletal traction	72			28			
Spine immobilization‡	55					31	
Referral and tertiary hospitals							
Pulse oximetry		27				36	
Hemoglobin		18	9				
Radiographs	9	46	27			9	9
Major general surgery§			9	9			
External fixation	46			36		9	9
Internal fixation#	46			9			45
Image intensification	36	18	10	36			
Prosthetics for amputees	91						9

*Contributing factors to item nonavailability were systematically captured for all items rated ≤ 2 . Factors were not considered mutually exclusive except when items had never been present at a facility; therefore, some lines sum to $>100\%$. †Basic general surgery = wound debridement, 1% total body surface area burn excision, digital amputation, surgical airway, and debridement of open fracture. ‡Spine immobilization = cervical collar and back board. §Major general surgery = neck exploration, exploratory laparotomy, and major amputation, as well as basic neurosurgery (burr hole, treatment of open depressed skull fracture). #Internal fixation = Kirschner wires, plate and screws, and intramedullary nails.

rarely available at first-level hospitals (median rating of 0 for both traction and external fixation; range, 0 to 3). Similarly, external fixation and internal fixation had low availability ratings at referral hospitals (median rating of 0). Internal fixation was often not available at tertiary hospitals (median rating of 1; range, 1 to 2). Although available at some tertiary facilities, spinal fixation capacity varied within the tertiary level (median rating of 3; range, 0 to 3). Prosthetics for amputees were rarely available at any level (median rating of 0 at all levels).

Factors Contributing to Low Capacity

Resource absence (i.e., having never been present at a facility) was the most commonly reported factor that contributed to deficiency (Table II). However, long periods of broken equipment, lack of training, and poor supply chain management practices (e.g., lack of reagents and other supplies as well as out-of-stock equipment and insufficient quantity) often led to resource deficiency. User fees were prohibitively expensive for internal fixation at 45% of referral and tertiary hospitals.

Population-Level Spatial Access to Orthopaedic Trauma Care

Just over half of Ghanaians can reach a facility capable of providing basic orthopaedic care within 1 hour from their

home (57.8%; UI of 52.6% to 62.9%) and 74.1% can reach a facility within 2 hours (UI of 70.8% to 77.3%) (Table III). Intermediate orthopaedic care is mainly provided at the same facilities that perform basic care; thus, the percent of the population with spatial access to intermediate care is similar. Around one-third of the population has spatial access to advanced care within 1 hour (35.3%; UI of 30.8% to 39.7%); 59.2% of the population can access advanced care within 2 hours (UI of 50.0% to 68.3%).

Hospitals Targeted for Orthopaedic Trauma Care Capability Improvements

The increase in potential spatial access to orthopaedic care following the inclusion of the hospitals identified by the location-allocation models for targeted capability improvements is illustrated in Figure 1 and described in Table III. Building basic orthopaedic care capacity at 15 hospitals would improve 2-hour spatial access to basic care from 74.9% to 82.4% of the population (UI of 81.2% to 83.6%; 2,169,714 additional Ghanaians). Similarly, 2-hour spatial access to intermediate care would improve from 74.6% to 80.8% of the population (UI of 78.9% to 82.7%; 1,875,062 additional Ghanaians) if this level of care was developed at 10 targeted hospitals. Finally, providing advanced orthopaedic care at 2 additional hospitals would increase 2-hour spatial access from 59.4% to 66.6% of the population (UI of 59.6% to 73.6%; 2,357,221 additional Ghanaians).

TABLE III Current and Potential Population-Level Spatial Access to Orthopaedic Care in Ghana

Orthopaedic Care Capacity	Before Capacity Improvement				After Capacity Improvement	
	Within 1 Hour		Within 2 Hours		Within 2 Hours	
	Population Access (% of population)	Uncertainty Interval (%)	Population Access (% of population)	Uncertainty Interval (%)	Population Access* (% of population)	Uncertainty Interval (%)
Basic†	57.8	52.6-62.9	74.1	70.8-77.3	82.4	81.2-83.6
Intermediate‡	54.3	48.0-60.6	73.5	69.8-77.1	80.8	78.9-82.7
Advanced§	35.3	30.8-39.7	59.2	50.0-68.3	66.6	59.6-73.6

*The location-allocation models identified 15 hospitals with basic orthopaedic care capacity, 10 hospitals with intermediate orthopaedic care capacity, and 2 hospitals with advanced capacity that would most improve spatial access to orthopaedic care if strengthened from a candidate list of all hospitals that performed no, basic, and intermediate orthopaedic care, respectively. †Basic orthopaedic care capacity = nonoperative care, including closed reduction, skeletal traction, and debridement of open fracture. ‡Intermediate orthopaedic care capacity = external fixation and internal fixation. §Advanced orthopaedic care capacity = complex long-bone and articular fracture management, and spine, pelvis, and hand surgery.

Fig. 1

Population-level spatial access to orthopaedic care and candidates for orthopaedic care capacity expansion in Ghana. Basic orthopaedic care capacity is nonoperative care, including closed reduction and skeletal traction, as well as debridement of open fracture. Intermediate orthopaedic care capacity is external fixation and internal fixation. Advanced orthopaedic care capacity is complex long-bone and articular fracture management, as well as spine, pelvis, and hand surgery. The location-allocation models identified 15, 10, and 2 facilities that would most improve spatial access to orthopaedic care if strengthened from a candidate list of all hospitals that performed no, basic, and intermediate orthopaedic care, respectively.

Discussion

This study assessed orthopaedic trauma care capacity country-wide throughout Ghana, mapped population-level spatial access to orthopaedic care, and identified hospitals that would most improve access to care if capacity was improved. We documented widespread deficiencies in orthopaedic trauma care capacity, particularly for radiography and procedural care (e.g., skeletal traction, external fixation, debridement of open fracture). Several factors contributed to orthopaedic trauma care resource deficiencies: resource absence (i.e., never present at the hospital before), broken equipment, lack of training, and prohibitively expensive user fees. Currently, >40% of the population cannot access orthopaedic trauma care within 1 hour, and 25% cannot access care within 2 hours. We identified hospitals that would most improve access to care if orthopaedic trauma capacity was strengthened.

Surgical care capacity assessments from LMICs have consistently reported inadequate orthopaedic care capacity. A similar assessment of 56 first-level and 29 large hospitals (i.e., referral and tertiary hospitals) was performed in Nepal²⁷. At first-level hospitals, the mean rating for spine immobilization, radiography, closed reduction, and external fixation was 0 at the facilities. Even at large hospitals, closed reduction, traction, and external fixation were not reliably available. Prosthetics had a mean rating of 0. In Sierra Leone, an orthopaedic care capacity assessment reported that only 3 of the 10 assessed hospitals could care for an open fracture or perform an amputation if needed²⁸. These examples demonstrate that LMICs urgently need orthopaedic capacity improvement to avert preventable death and disability from the growing burden of injury and other musculoskeletal conditions.

A similar capacity assessment also was performed in Ghana in 2004²⁹. Comparing the assessment described herein to the initial assessment in 2004, the availability rating of many trauma care resources improved: pulse oximetry increased from 0 to 3, basic general surgery increased from 1 to 3, and major general surgery increased from 0 to 1 at the first-level hospitals³⁰. However, most resources for orthopaedic trauma care did not improve or were less available: external fixation did not improve at any hospital level, radiograph capabilities and internal fixation did not improve at referral or tertiary hospitals, portable radiograph machines decreased at all hospital levels (rating 2 to 1 or 1 to 0), and skeletal traction decreased from 1 to 0 at first-level hospitals. While improvements in general trauma care are laudable, the lack of improvements in orthopaedic care capacity calls for urgent attention.

Trained staff performing manipulation and casting can treat stable fractures inexpensively^{4,31,32}. However, unstable fractures typically require some form of fixation. Patients are often responsible for purchasing implants in Ghana, as in other LMICs³². As a result, casting or traction is commonly employed in the management of unstable lower-extremity fractures. Therefore, many fractures are undertreated and incur preventable disability. A recent cost analysis from Kenya demonstrated that surgical fixation was less expensive, associated with equivalent complications, and produced better functional outcomes

than traction³³. Studies from Uganda and Cambodia have demonstrated both the feasibility and cost-effectiveness of treating long-bone fractures with the Surgical Implant Generation Network (SIGN) intramedullary nail system without the need for image intensifiers, fracture tables, or power-reaming^{4,34}. Outcomes of SIGN intramedullary nailing from over 34,000 patients in 55 LMICs have shown better outcomes than current local standards of care and acceptably low complication rates³⁵. However, it should be noted that only 18% of patients who received a SIGN intramedullary nail had follow-up data for analysis in the aforementioned study. Prioritizing affordable access to hardware may result in fewer costs to the health-care system and less productivity losses for patients as a result of improved functional outcomes in the long run. The orthopaedic community must advocate for representation in the global health dialogue and dedicated funding for orthopaedic capacity improvements in LMICs given the potential to effectively reduce a large burden of disease^{36,37}.

Several limitations require consideration while interpreting these results. First, the rating scheme was somewhat subjective. To strengthen its validity, key informants from multiple departments that interacted with the same resource (e.g., radiography, emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, radiograph technicians, and biomedical engineers) were asked about its availability to triangulate responses. Additionally, direct observation of equipment and supplies was performed. We did not systematically assess the availability of care for musculoskeletal infections or congenital, degenerative, oncologic, or sports medicine conditions. However, the lack of availability of basic resources required for essential orthopaedic care as defined by the World Bank is concerning, and demands redress prior to or in tandem with capacity improvements for the care of other musculoskeletal conditions¹¹. Lastly, the use of only population-level spatial access gaps to target hospitals for improvement neglects other important considerations, such as reducing nonspatial barriers to orthopaedic care (e.g., affordability and acceptability), prioritizing health equity (e.g., improving access to care for particularly marginalized or high-risk populations), and matching care availability with the geospatial distribution of disease^{38,39}. Despite the aforementioned limitations, these findings allow us to make reasonable conclusions about orthopaedic trauma care capacity, population-level spatial access to orthopaedic care in Ghana, and ways that they might be improved.

In conclusion, these findings demonstrate critical deficiencies in orthopaedic trauma care capacity and the resultant impact on population-level spatial access to care in Ghana. Although orthopaedic care should be funded and organized across the health-care system, we have identified facilities with the greatest impact on spatial access to orthopaedic care as rational targets for capacity-building interventions, such as training and making hardware available or subsidized. Access to care also can be improved by establishing protocols for the early recognition, stabilization, and timely transfer of patients with complex conditions

to facilities capable of definitive care. Importantly, orthopaedic care capacity improvements must occur in parallel with training and quality-assurance initiatives to have the greatest impact on well-being and population health. While these data are particularly useful for Ghana, this study might also serve as a model for other countries that are in need of or planning strategic orthopaedic care capacity improvements. ■

Barclay T. Stewart, MD, MScPH^{1,2,3,4}
Adam Gyedu, MD, MPH^{2,3}
Gavin Tansley, MD⁵
Dominic Yeboah, MD, MPH^{2,3}
Forster Amponsah-Manu, MD⁶
Charles Mock, MD, PhD^{1,7}
Wilfred Labi-Addo, MD^{8,9}
Robert Quansah, MD, PhD^{2,3}

¹Departments of Surgery (B.T.S. and C.M.) and Global Health (C.M.), University of Washington, Seattle, Washington

²School of Public Health (B.T.S.) and Department of Surgery (A.G., D.Y., and R.Q.), School of Medical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

³Department of Surgery, Komfo Anokye Teaching Hospital, Kumasi, Ghana

⁴Department of Interdisciplinary Health Sciences, Stellenbosch University, Cape Town, South Africa

⁵Department of Surgery, Dalhousie University, Halifax, Nova Scotia, Canada

⁶Department of Surgery, Eastern Regional Hospital, Koforidua, Ghana

⁷Harborview Injury Prevention & Research Center, Seattle, Washington

⁸Eastern Regional Health Directorate, Ghana Health Service, Ministry of Health, Koforidua, Ghana

⁹St. Joseph Orthopaedic Hospital, Korforidua, Ghana

E-mail address for B.T. Stewart: stewartb@uw.edu

References

- Collaborators GBD; GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015 Jan 10;385(9963):117-71. Epub 2014 Dec 18.
- Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, Abraham J, Adair T, Aggarwal R, Ahn SY, Alvarado M, Anderson HR, Anderson LM, Andrews KG, Atkinson C, Baddour LM, Barker-Collo S, Bartels DH, Bell ML, Benjamin EJ, Bennett D, Bhalla K, Bikbov B, Bin Abdulhak A, Birbeck G, Blyth F, Bolliger I, Boufous S, Bucello C, Burch M, Burney P, Carapetis J, Chen H, Chou D, Chugh SS, Coffeng LE, Colan SD, Colquhoun S, Colson KE, Condon J, Connor MD, Cooper LT, Corriere M, Cortinovis M, de Vaccaro KC, Couser W, Cowie BC, Criqui MH, Cross M, Dabhadkar KC, Dahodwala N, De Leo D, Degenhardt L, Delossantos A, Denenberg J, Des Jarlais DC, Dharmaratne SD, Dorsey ER, Driscoll T, Duber H, Ebel B, Erwin PJ, Espindola P, Ezzati M, Feigin V, Flaxman AD, Forouzanfar MH, Fowkes FG, Franklin R, Fransen M, Freeman MK, Gabriel SE, Gakidou E, Gaspari F, Gillum RF, Gonzalez-Medina D, Halasa YA, Haring D, Harrison JE, Havmoeller R, Hay RJ, Hoen B, Hotez PJ, Hoy D, Jacobsen KH, James SL, Jasrasaria R, Jayaraman S, Johns N, Karthikeyan G, Kassebaum N, Keren A, Khoo JP, Knowlton LM, Kobusingye O, Koranteng A, Krishnamurthi R, Lipnick M, Lipshultz SE, Ohno SL, Mabweijano J, MacIntyre MF, Mallinger L, March L, Marks GB, Marks R, Matsumori A, Matzopoulos R, Mayosi BM, McAnulty JH, McDermott MM, McGrath J, Mensah GA, Merriman TR, Michaud C, Miller M, Miller TR, Mock C, Mocumbi AO, Mokdad AA, Moran A, Mulholland K, Nair MN, Naldi L, Narayan KM, Nasserli K, Norman P, O'Donnell M, Omer SB, Ortblad K, Osborne R, Ozgediz D, Pahari B, Pandian JD, Rivero AP, Padilla RP, Perez-Ruiz F, Perico N, Phillips D, Pierce K, Pope CA 3rd, Porrini E, Pourmalek F, Raju M, Ranganathan D, Rehm JT, Rein DB, Remuzzi G, Rivara FP, Roberts T, De León FR, Rosenfeld LC, Rushton L, Sacco RL, Salomon JA, Sampson U, Sanman E, Schwebel DC, Segui-Gomez M, Shepard DS, Singh D, Singleton J, Sliwa K, Smith E, Steer A, Taylor JA, Thomas B, Teyjeh IM, Towbin JA, Truelsen T, Undurraga EA, Venketasubramanian N, Vijayakumar L, Vos T, Wagner GR, Wang M, Wang W, Watt K, Weinstock MA, Weintraub R, Wilkinson JD, Woolf AD, Wulf S, Yeh PH, Yip P, Zabetian A, Zheng ZJ, Lopez AD, Murray CJ, AlMazroa MA, Memish ZA. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012 Dec 15;380(9859):2095-128.
- Groen RS, Samai M, Stewart KA, Cassidy LD, Kamara TB, Yambasu SE, Kingham TP, Kushner AL. Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet*. 2012 Sep 22;380(9847):1082-7. Epub 2012 Aug 14.
- Gosselin RA, Heitto M, Zirkle L. Cost-effectiveness of replacing skeletal traction by interlocked intramedullary nailing for femoral shaft fractures in a provincial trauma hospital in Cambodia. *Int Orthop*. 2009 Oct;33(5):1445-8. Epub 2009 May 13.
- Ariès MJ, Joosten H, Wegdam HH, van der Geest S. Fracture treatment by bonesetters in central Ghana: patients explain their choices and experiences. *Trop Med Int Health*. 2007 Apr;12(4):564-74.
- World Health Organization; Mock C, Julliard C, Brundage S, Goosen J, Joshupura M. Guidelines for trauma quality improvement programmes. 2009. http://apps.who.int/iris/bitstream/10665/44061/1/9789241597746_eng.pdf. Accessed 2016 May 2.
- Institute of Health Metrics and Evaluation. Data visualizations. Global burden of disease cause patterns. 2013. <https://vizhub.healthdata.org/gbd-compare/>. Accessed 2015 May 27.
- Mock CN, Abantanga F, Cummings P, Koepsell TD. Incidence and outcome of injury in Ghana: a community-based survey. *Bull World Health Organ*. 1999;77(12):955-64.
- Gyedu A, Nakua EK, Otupiri E, Mock C, Donkor P, Ebel B. Incidence, characteristics and risk factors for household and neighborhood injury among young children in semiurban Ghana: a population-based household survey. *Inj Prev*. 2015 Apr;21(e1):e71-9.
- Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg*. 2015 Oct;39(10):2428-40.
- Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT; DCP3 Essential Surgery Author Group. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015 May 30;385(9983):2209-19. Epub 2015 Feb 5.
- CIA world factbook – the best country factbook available online. United States of America Central Intelligence Agency. <http://www.cia-worldfactbook.us/africa/ghana.html>. Accessed 2015 Apr 12.
- Ghana health sector. Accra, Ghana: Ghana Health Service, 2010. http://www.ghanahelthservice.org/downloads/GHS_2010_Annual%20Report_Final.pdf.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, Fleischer-Djoletto C, Moresky R, McCord CW, Cherian M, Abdullah F. Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health*. 2010 Sep;15(9):1109-15. Epub 2010 Jul 14.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, McCord CW, Abdullah F. Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med*. 2011 Apr;86(4):529-33.
- World Health Organization; Mock C, Lormand J, Goosen J, Joshupura M, Peden M. Guidelines for essential trauma care. 2004. http://www.who.int/violence_injury_prevention/publications/services/en/guidelines_traumacare.pdf. Accessed 2016 May 2.
- Achampong EK. The state of information and communication technology and health informatics in Ghana. *Online J Public Health Inform*. 2012;4(2). Epub 2012 Sep 14.
- WorldPop. 2015. <http://www.worldpop.org.uk>. Accessed 2015 Jul 30.
- OpenStreetMap. 2015. <http://www.openstreetmap.org>. Accessed 2015 Jul 30.
- Centre for Remote Sensing and Geographic Information Services. 2015. <http://cersgis.org/home.html>. Accessed 2015 Jul 30.
- Damsere-Derry J, Afukaar FK, Donkor P, Mock C. Assessment of vehicle speeds on different categories of roadways in Ghana. *Int J Inj Contr Saf Promot*. 2008 Jun;15(2):83-91.

- 22.** Derry JD, Afukaar FK, Donkor P, Mock C. Study of vehicle speeds on a major highway in Ghana: implication for monitoring and control. *Traffic Inj Prev.* 2007 Jun;8(2):142-6.
- 23.** Delamater PL, Messina JP, Shortridge AM, Grady SC. Measuring geographic access to health care: raster and network-based methods. *Int J Health Geogr.* 2012;11(1):15. Epub 2012 May 15.
- 24.** Huerta Munoz U, Källestål C. Geographical accessibility and spatial coverage modeling of the primary health care network in the Western Province of Rwanda. *Int J Health Geogr.* 2012;11:40. Epub 2012 Sep 17.
- 25.** Polo G, Acosta CM, Ferreira F, Dias RA. Location-allocation and accessibility models for improving the spatial planning of public health services. *PLoS One.* 2015;10(3):e0119190. Epub 2015 Mar 16.
- 26.** Yang DH, Goerge R, Mullner R. Comparing GIS-based methods of measuring spatial accessibility to health services. *J Med Syst.* 2006 Feb;30(1):23-32.
- 27.** Shah MT, Bhattarai S, Lamichhane N, Joshi A, LaBarre P, Joshipura M, Mock C. Assessment of the availability of technology for trauma care in Nepal. *Injury.* 2015 Sep;46(9):1712-9. Epub 2015 Jun 16.
- 28.** Groen RS, Kamara TB, Dixon-Cole R, Kwon S, Kingham TP, Kushner AL. A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone. *World J Surg.* 2012 Aug;36(8):1970-7.
- 29.** Quansah R, Mock C, Abantanga F. Status of trauma care in Ghana. *Ghana Med J.* 2004;38(4):149-52.
- 30.** Stewart BT, Quansah R, Gyedu A, Boakye G, Abantanga F, Ankomah J, Donkor P, Mock C. Serial assessment of trauma care capacity in Ghana in 2004 and 2014. *JAMA Surg.* 2016 Feb 1;151(2):164-71.
- 31.** Cotton M, Henry JA, Hasek L. Value innovation: an important aspect of global surgical care. *Global Health.* 2014;10:1. Epub 2014 Jan 6.
- 32.** Zirkle LG Jr. Injuries in developing countries—how can we help? The role of orthopaedic surgeons. *Clin Orthop Relat Res.* 2008 Oct;466(10):2443-50. Epub 2008 Aug 7.
- 33.** Opondo E, Wanzala P, Makokha A. Cost effectiveness of using surgery versus skeletal traction in management of femoral shaft fractures at Thika level 5 hospital, Kenya. *Pan Afr Med J.* 2013;15:42. Epub 2013 Jun 6.
- 34.** Phillips J, Zirkle LG, Gosselin RA. Achieving locked intramedullary fixation of long bone fractures: technology for the developing world. *Int Orthop.* 2012 Oct;36(10):2007-13. Epub 2012 Jul 31.
- 35.** Young S, Lie SA, Hallan G, Zirkle LG, Engesaeter LB, Havelin LI. Low infection rates after 34,361 intramedullary nail operations in 55 low- and middle-income countries: validation of the Surgical Implant Generation Network (SIGN) online surgical database. *Acta Orthop.* 2011 Dec;82(6):737-43. Epub 2011 Nov 9.
- 36.** LeBrun DG, Chackungal S, Chao TE, Knowlton LM, Linden AF, Notrica MR, Solis CV, McQueen KA. Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries. *Surgery.* 2014 Mar;155(3):365-73. Epub 2013 Oct 11.
- 37.** Patel PB, Hoyler M, Maine R, Hughes CD, Hagander L, Meara JG. An opportunity for diagonal development in global surgery: cleft lip and palate care in resource-limited settings. *Plast Surg Int.* 2012;2012:892437. Epub 2012 Dec 20.
- 38.** Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg.* 2015 Nov;39(11):2613-21.
- 39.** Asante AD, Zwi AB, Ho MT. Equity in resource allocation for health: a comparative study of the Ashanti and Northern Regions of Ghana. *Health Policy.* 2006 Oct;78(2-3):135-48. Epub 2006 May 15.