Regional anesthesia training model for resource-limited settings: a prospective single-center observational study with pre–post evaluations

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ABSTRACT

Background and objectives Educational initiatives are a sustainable means to address provider shortages in resource-limited settings (RLS), yet few regional anesthesia curricula for RLS have been described. We sought to design a reproducible training model for RLS called Global Regional Anesthesia Curricular Engagement (GRACE), implement GRACE at an RLS hospital in Ghana, and measure training and practice-based outcomes associated with GRACE implementation.

Methods Fourteen of 15 physician anesthesiologists from the study location and three from an outside orthopedic specialty hospital consented to be trainees and trainers, respectively, for this prospective single-center observational study with pre–post evaluations. We conducted an initial needs assessment to determine current clinical practices, participants' learning preferences, and available resources. Needs assessment findings, expert panel recommendations, and investigator consensus were then used to generate a site-specific curriculum that was implemented during two 3-week periods. We evaluated trainee satisfaction and changes in knowledge, clinical skill, and peripheral nerve block (PNB) utilization using the Kirkpatrick method.

Results The curriculum consisted of didactic lectures, simulations, and clinical instruction to teach ultrasound-guided PNB for limb injuries. Pre–post evaluations showed trainees were satisfied with GRACE, median knowledge examination score improved from 62.5% (15/24) to 91.7% (22/24) ($p<0.001$), clinical examination pass rate increased from 28.6% (4/14) to 85.7% (12/14) ($p<0.01$), and total PNB performed in 3 months grew from 48 to 118.

Conclusions GRACE applied in an RLS hospital led to the design, implementation, and measurement of a regional anesthesia curriculum tailored to institutional specifications that was associated with positive Kirkpatrick outcomes.

INTRODUCTION

The current state of anesthesia and surgery care in resource-limited settings (RLS) was detailed in a landmark study commissioned by *The Lancet*.[1] A key message from the report was that more than five billion individuals, most of whom reside in RLS, do not have access to safe, high-quality anesthesia. Reduced anesthesia capacity in RLS, especially of well-trained providers,[2] contributes to high rates of perioperative complications[3] and inadequate pain management.[4] Findings from previous research at Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ghana, exemplify these disparities.[5] Providers reported patients died or were injured as a result of oxygen supply failures, faulty ventilators, and underequipped post-anesthesia and intensive care units. Unreliable access to opioids made postoperative pain management challenging. Whereas service-based missions were previously a popular strategy to address health inequities like these, sustainable educational initiatives are now considered a preferred approach.[6]

In RLS hospitals like KATH, where vital signs monitors, difficult airway equipment, and analgesic medications may be unobtainable, regional anesthesia can limit general anesthesia exposures and curb acute pain in a variety of clinical scenarios.[7] At KATH, a large number of orthopedic limb conditions are managed surgically[8] and are amenable to regional anesthesia services. Spinal anesthesia is done for lower extremity operations, but peripheral nerve blocks (PNB) are deployed inconsistently. Although ultrasound machines and local anesthetics are available, many providers are not trained in PNB techniques. To fill this education gap, KATH collaborated with Hospital for Special Surgery in New York, USA, to teach regional anesthesia to KATH physicians.

Regional anesthesia courses in high-income countries are described in the literature,[9 10] but few regional anesthesia[11] or other subspecialty[12] programs are designed specifically for RLS, where patient populations differ and critical perioperative infrastructure, equipment, and medications are lacking. Additionally, previous curricula do not routinely use recognized evaluative framework (Kirkpatrick,[13] RE-AIM,[14] etc) to gauge program success and inform improvements. We therefore sought to create a transferrable model for RLS that would provide targeted education guided by a needs assessment to ascertain local conditions and capabilities, detail steps to translate needs into a tailored curriculum, and estimate program success using standardized pre–post evaluations.

The specific study objectives were to design an educational model that can address a range of regional anesthesia training needs in any RLS, implement the model at KATH, and measure training and practice-based outcomes associated

with implementation. The model was called Global Regional Anesthesia Curricular Engagement (GRACE). We hypothesized a priori that implementation of GRACE would be associated with high trainee satisfaction, improved examination scores, and greater volume and variety of PNB performed at KATH as evaluated by the Kirkpatrick method.[13]

METHODS

The study location was KATH, a 1200-bed tertiary referral hospital in the West African nation of Ghana, which performs roughly 10,000 surgeries annually.[5] Institutional review boards at KATH and Hospital for Special Surgery approved this prospective single-center observational study with pre–post evaluations. All physician anesthesiologists at KATH, including those in postgraduate training or with prior regional anesthesia experience, were invited to participate. The sole exclusion criterion was an anticipated inability to attend at least half of curricular activities. Written informed consent was obtained from all KATH trainee participants. Paper records were stored in a locked file cabinet and electronic records saved on password-protected devices accessible only by investigators. No protected health information was recorded.

Needs assessment

We developed and conducted a 4-week needs assessment at KATH in October 2017. Needs assessment objectives were to discern the current state of regional anesthesia practice, determine participants' wishes for the curriculum, and ascertain what expertise and resources trainers could offer.

Perioperative records review: Because trainers were orthopedic anesthesiologists, we considered only limb cases amenable to PNB. Investigators aimed to document numbers of operations, types of anesthesia used, and patient demographics, diagnoses, comorbidities, and outcomes. Accident and Emergency Center theater logbooks were the data source. Individual patient charts were not included because many were missing or organized where data extraction was prohibitively difficult. Data for cases during a 3-month period (August 2017 to October 2017) were recorded in an electronic spreadsheet. We used these data to classify operations by case type: acute trauma, fractures, severe fractures (open fractures, traumatic amputations, or femur/pelvic fractures), bone involvement (surgery involving bone tissue), pediatric (0 to 8 years of age), and subspecialty (arthroplasty, arthroscopy, or oncology).

Anonymous surveys of GRACE trainees and trainers: The trainee survey (online supplemental digital content 1) assessed self-reported clinical expertise, prior training, and desires for the new curriculum. The trainer survey (online supplemental digital content 2) assessed self-reported educational expertise, time allotted for teaching, and resources to be brought to the training site.

Direct observations of perioperative care: The observations data capture form (online supplemental digital content 3) was used to document available resources and practice norms. Observations took place in all areas where relevant regional anesthesia procedures occured. PNB for limb surgeries were done in the Accident and Emergency Center, where four of the hospital's theaters are located.

Curriculum design and implementation

Needs assessment results were summarized for an expert panel of five physician anesthesiologists with experience working in RLS and considered to be authorities in regional anesthesia education. After summary review, panel members were interviewed by the same investigator and asked: (1) What blocks should be taught? (2) What topics should be taught? and (3) What general recommendations do you have for teaching regional anesthesia at KATH? Expert recommendations and the needs assessment summary were then used to generate a curriculum. One investigator prepared and circulated a draft curriculum to co-investigators. We reached consensus after three revision rounds. The final curriculum was implemented during two 3-week periods at KATH in January 2018 and June/July 2018.

Kirkpatrick evaluations

We used the four-part Kirkpatrick method[13] to evaluate GRACE implementation. The Kirkpatrick method was originally made to assess industrial training program influence on workers but has also been used with anesthesia and surgery training.[15 16] The Kirkpatrick method aims to measure outcomes in four domains: (1) *Reaction*, (2) *Learning*, (3) *Behavior,* and (4) *Results*.

Trainee *Reaction* was measured with a post-GRACE satisfaction survey (online supplemental digital content 4). The survey included 10 statements about the KATH curriculum where trainees indicated their level of agreement on a four-point Likert scale and two open-ended items prompting trainees to suggest ways to improve the curriculum.

Changes in *Learning* were measured with pre–post-GRACE knowledge examinations (online supplemental digital content 5). The knowledge examination originally contained 25 multiple-choice questions corresponding to curriculum content. One question was excluded from analysis due to a mistake labeling the ultrasound image, thus only 24 items were graded. For question #17, we determined two answer choices should be scored correct. These errors are repaired in Supplemental Digital Content 5, allowing readers to access a working test.

Changes in *Behavior* were measured with pre–post-GRACE clinical examinations derived from the *Regional Anaesthesia Procedural Skills Assessment Tool*, comprising a checklist and global rating scale.[17] While Chuan *et al* validated this tool on patients,[17] we asked trainees to demonstrate ultrasound scanning on volunteers and needling on a gel block manikin to minimize patient risk. Participants were tested on the sciatic nerve block in the popliteal fossa because few had experience with this PNB, and the block was integral to the KATH curriculum. Satisfaction survey and examination responses were confidential and accessed only by the grading investigator.

Results were measured by totaling the number and variety of PNB performed 3 months before and after GRACE. Theater logbooks were used to count the total number of PNB performed and the percentage of upper extremity surgeries done using PNB as the primary anesthetic. The pre-GRACE period corresponded to the needs assessment (August to October 2017). The post-GRACE period was 3 months after training concluded (mid-July to mid-October 2018). Because PNB were not performed for postoperative analgesia before the study, a PNB logbook was created to capture post-GRACE blocks.

Statistical analysis

Quantitative needs assessment results are presented as counts and percentages. Satisfaction survey results are reported as counts and percentages of categorical responses, and written comments are summarized as text. Knowledge and clinical examination continuous results are presented as medians and IQRs, and Wilcoxon signed-rank test was used to compare pre-GRACE and post-GRACE time points. Binary outcomes for the checklist

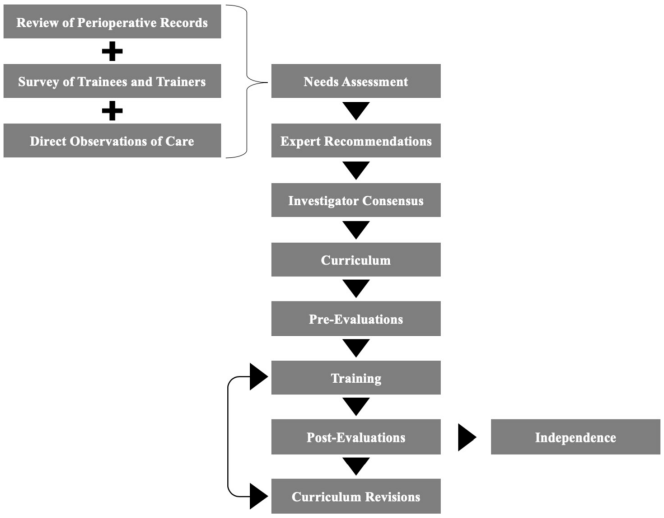

Figure 1 Global Regional Anesthesia Curricular Engagement (GRACE) schematic.

pass/fail item are reported as percentages, and McNemar's test was used to compare pre-GRACE and post-GRACE time points. The pre-GRACE and post-GRACE total number of PNB and proportion of upper extremity surgeries performed under PNB are presented as counts and percentages. All statistical tests were two-tailed. A value of $p<0.05$ was considered statistically significant. Statistical analyses were performed with SAS V.9.4 (SAS Institute). Sample size was based on the number of trainees and patients available during the study period.

Following the study, the curriculum was revised in response to formal Kirkpatrick evaluations and informal feedback during training. The overarching purpose of GRACE is to foster an independent regional anesthesia service staffed by local experts who provide sustained education to their colleagues and students without external support. Once independence is achieved, the GRACE initiative is complete. The GRACE schematic is pictured in figure 1.

RESULTS

Fourteen of 15 KATH physician anesthesiologists consented to participate as trainees (one was on leave during the training period). There were four residents, six specialists (junior attendings), and four consultants (senior attendings). One Hospital for Special Surgery attending and two fellows consented to participate as trainers.

Needs assessment

Accident and Emergency Center theater logbooks revealed 594 cases performed in 3 months; 119 non-extremity surgeries were not considered. We could not determine if the operation was performed on a limb for 40 cases because entries were illegible or blank; thus 435 surgeries were recorded. Most extremity cases were done by orthopedic and plastic surgeons. Average patient age was 33 years, and 65% of patients were male. Upper limb surgeries numbered 109, lower limb 301, and 25 could not be further classified. We assumed data were missing or illegible at random. Forty-four per cent of upper extremity operations were performed under PNB, and 74% of lower extremity operations were done with spinal anesthesia. Case numbers by type were: acute trauma – 263; fractures – 199; severe fractures – 124; bone involvement – 320; pediatric – 58; arthroplasty – 17; arthroscopy – 0; and oncology – 12. Three of 435 patients (0.7%) died in the theater or post-anesthesia recovery unit but causes of death were not reported.

All KATH participants completed the trainee needs assessment survey. All indicated regional anesthesia was relevant to their practice, but described insufficient expertise. Previous instruction took the form of textbook study, review of The New York School of Regional Anesthesia and YouTube online materials, clinical training, and participation in a KATH course recently presented by visiting German physicians.[11] Only four participants read peer-reviewed journals. Simulation training was uncommon but desired. More than half were comfortable performing spinal anesthesia and single-shot ultrasound-guided brachial plexus blocks, but few were proficient with lower extremity PNB. Most wanted more training for all types of PNB. All respondents felt GRACE should target physician anesthesiologists. All trainer participants completed the trainer needs assessment survey. They were comfortable teaching ultrasound-guided PNB and neuraxial techniques for limb surgeries, but not truncal blocks for thoracoabdominal operations or PNB approaches without ultrasound.

Direct observations of care yielded details about existing resources (table 1) and practice norms.

Practice observations revealed: spinal anesthesia was performed for lower extremity surgeries by physician anesthesiologists and nurse anesthetists, but PNB were done by physicians alone; ultrasound-guided interscalene and supraclavicular brachial plexus blocks were the primary PNB employed; analgesic PNB were uncommon; pediatric regional anesthesia was infrequent; procedural elements like informed consent, safety checks, and thorough PNB documentation were not always followed; sedation was not routinely expected or given; and there was no dedicated regional anesthesia service. The greatest limitation for using PNB was a lack of trained providers.

Curriculum design and implementation

Blocks and topics recommended by three or more expert panel members were included in the curriculum. Expert suggestions included: the curriculum should be concise enough to deliver in the allotted time frame; training should target what trainees wish to learn and trainers are qualified to teach; trainees should log their blocks and set concrete goals; and trainers should check in with trainees between visits to assess progress and discuss interesting cases.

Clinical experiences at KATH led to several mid-program changes. The axillary brachial plexus block was dropped because supraclavicular and infraclavicular approaches were sufficient for surgeries of the distal arm. Intercostobrachial nerves block was introduced to cover incisions along the medial elbow and upper arm in awake patients. The fascia iliaca block was abandoned in favor of separate femoral and lateral femoral cutaneous nerve blocks that could be accomplished with less local anesthetic and thereby conserve supplies. Also, the anterior proximal thigh approach to the sciatic nerve[18] was used for patients who were too uncomfortable to turn lateral or prone. The final GRACE PNB and educational topics for KATH are listed in box 1.

GRACE training included KATH-specific didactic lectures, simulations, and clinical instruction. These particular modalities and content were included based on needs assessment results and expert panel recommendations. Most teaching occurred Monday through Friday, though additional opportunities were available weekends. The KATH clinical schedule was adjusted so several trainees could participate in GRACE activities. The goal

Table 1 KATH regional anesthesia equipment and medications

	Available	Unavailable
Equipment		
Ultrasound	Two Sonosite M-Turbo machines with large-footprint linear HFL38x and curvilinear C60x transducers	Small-footprint curvilinear transducer (eg, Sonosite C11x)
Peripheral nerve stimulator	Two Braun Stimuplex HNS 12; 2 Braun Stimuplex DIG RC (donated to KATH for GRACE)	
PNB needles	Stimulating needles (limited supply); angiocatheter needles (with catheter removed); long-bevel needles (typically of limited length); 25G 9 cm spinal needles	Non-stimulating needles designed for PNB
PNB catheter equipment		Not stocked by KATH, but some anesthesiologists had a limited personal supply; infusion pumps
Other block supplies	Topical disinfectant; sterile gloves; ultrasound gel; syringes; extension tubing; normal saline/water for dilution; tape; gauze; ECG stickers	Sterile ultrasound transducer covers; occlusive dressings
Monitors	Continuous 3-lead ECG; pulse oximeter; non-invasive blood pressure monitors. (not routinely employed for PNB)	Capnograph
Resuscitation	Supplemental oxygen; basic airway equipment; defibrillator	Video laryngoscope
Medications		
Local anesthetic	Bupivacaine 0.5%; lidocaine 2%. (shortages occurred)	Mepivacaine; ropivacaine
PNB additives	Intravenous dexamethasone, epinephrine	Preservative-free dexamethasone
Procedural sedation	Fentanyl; midazolam; ketamine; propofol	
Analgesics	Intravenous morphine and fentanyl; intravenous and PO acetaminophen and NSAIDs; PO tramadol	PO μ-agonists (eg, oxycodone, hydrocodone, hydromorphone); antiepileptics/antidepressants; dexmedetomidine
Resuscitation	Midazolam; 20% fat emulsion (Intralipid) (donated to KATH for GRACE); atropine; glycopyrrolate; epinephrine; induction agents	Phenylephrine; norepinephrine

GRACE, Global Regional Anesthesia Curricular Engagement; KATH, Komfo Anokye Teaching Hospital; NSAIDs, non-steroidal antiinflammatory drugs; PNB, peripheral nerve block; PO, per os.

was for trainees to attend all didactic lectures and at least half of simulation and clinical opportunities.

Trainers delivered 45 min morning didactic lectures during the first week of each 3-week training period. Lectures included oral presentations accompanied by computer-generated projections.

Box 1 Peripheral nerve blocks and educational content of the GRACE curriculum at KATH

Peripheral nerve blocks
- Interscalene brachial plexus (US)
- Supraclavicular brachial plexus (US)
- Infraclavicular brachial plexus (US)
- Intercostobrachial nerves (SA)
- Femoral nerve (US+NS)
- Lateral femoral cutaneous nerve (US)
- Adductor canal (US)
- Popliteal sciatic nerve (US+NS)
- Sub/transgluteal sciatic nerve (US+NS)
- Anterior sciatic nerve (US+NS)

Educational content
- Informed consent
- Monitors
- The 'time out'
- Ultrasound
- Nerve stimulator
- Pharmacology
- Complications
- Postoperative analgesia
- Individual block considerations

GRACE, Global Regional Anesthesia Curricular Engagement; KATH, Komfo Anokye Teaching Hospital; NS, nerve stimulator-guided; SA, surface anatomy-based; US, ultrasound-guided.

After lectures, trainees were given 15 min to practice skills learned that day on an ultrasound volunteer in the classroom. Lectures were repeated during the second training period to reinforce learning and allow trainees to make up missed sessions. Simulations took place during clinical downtime, and two ultrasound modules were developed for deliberate practice.[19] A Blue Phantom gel block manikin (CAE Healthcare, USA) was used to impart needling skills. The manikin contained an artificial vessel and nerves approximating anatomical relationships. Additionally, trainees scanned volunteers for relevant PNB anatomy. For the comfort of volunteers, 'intimate' blocks (ie, femoral, lateral femoral cutaneous, and proximal thigh sciatic nerve approaches) requiring undergarment removal were not attempted in a group setting. Participants were required to attend lectures and simulations relevant to PNB before performing them on patients. For intimate PNB, trainees were required to proficiently scan patients before inserting the needle.

The majority of educational time was spent caring for patients. Each day, a KATH participant identified PNB candidates. Patients were informed about GRACE and those who consented were blocked. All blocks were done with vital signs monitoring (ie, continuous 3-lead electrocardiograph, pulse oximeter, and non-invasive blood pressure cuff), and resuscitation equipment was nearby. Trainees were encouraged to follow their patients into theaters and through the recovery period to see how their blocks faired. Trainees always blocked patients in the presence of trainers, and KATH residents were always overseen by KATH attendings. We looked for PNB complications and failed blocks, but none were observed during the study period.

After each 3-week training period, trainers stayed in touch with trainees via a WhatsApp group text that all participants accessed on their mobile devices. This forum allowed trainees to ask questions of trainers remotely, discuss difficult and interesting cases, and propose program improvements.

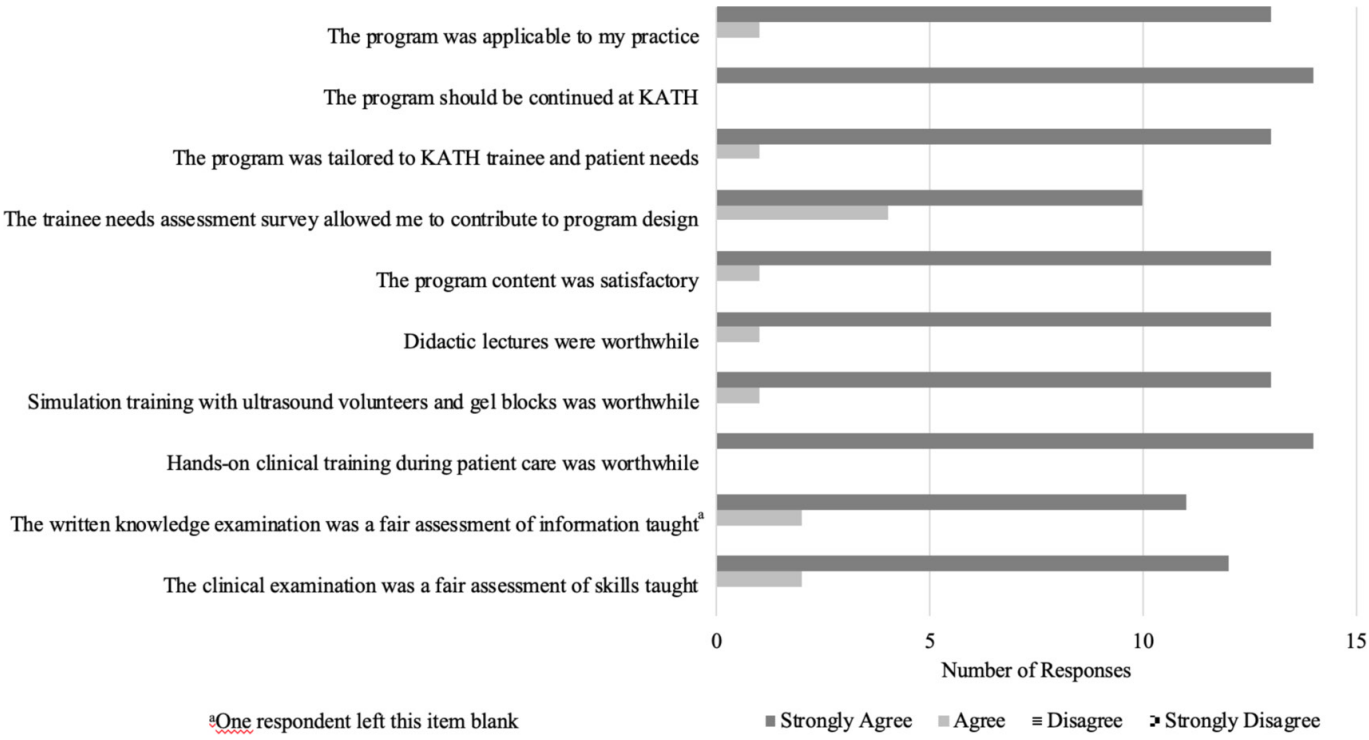

Figure 2 Post-GRACE trainee satisfaction survey results (n=14). GRACE, Global Regional Anesthesia Curricular Engagement; KATH, Komfo Anokye Teaching Hospital.

Kirkpatrick evaluations

Satisfaction survey responses are compiled in figure 2. Free-text suggestions included: offer one-on-one tutoring; extend training duration; teach truncal blocks; explore remote video conferencing for didactic lectures; award course-completion certificates; adjust the KATH clinical schedule to allow greater participation; prepare KATH experts to maintain training between GRACE programs; and task hospital management to invest in regional anesthesia supplies. Knowledge and clinical examination results are summarized in figure 3, and PNB numbers are shown in figure 4. The median increase in percentage of correct responses for the knowledge examination was 18.8% (4.5/24) (IQR 16.6%, $p<0.001$). For the clinical examination checklist, the median increase in percentage of tasks completed

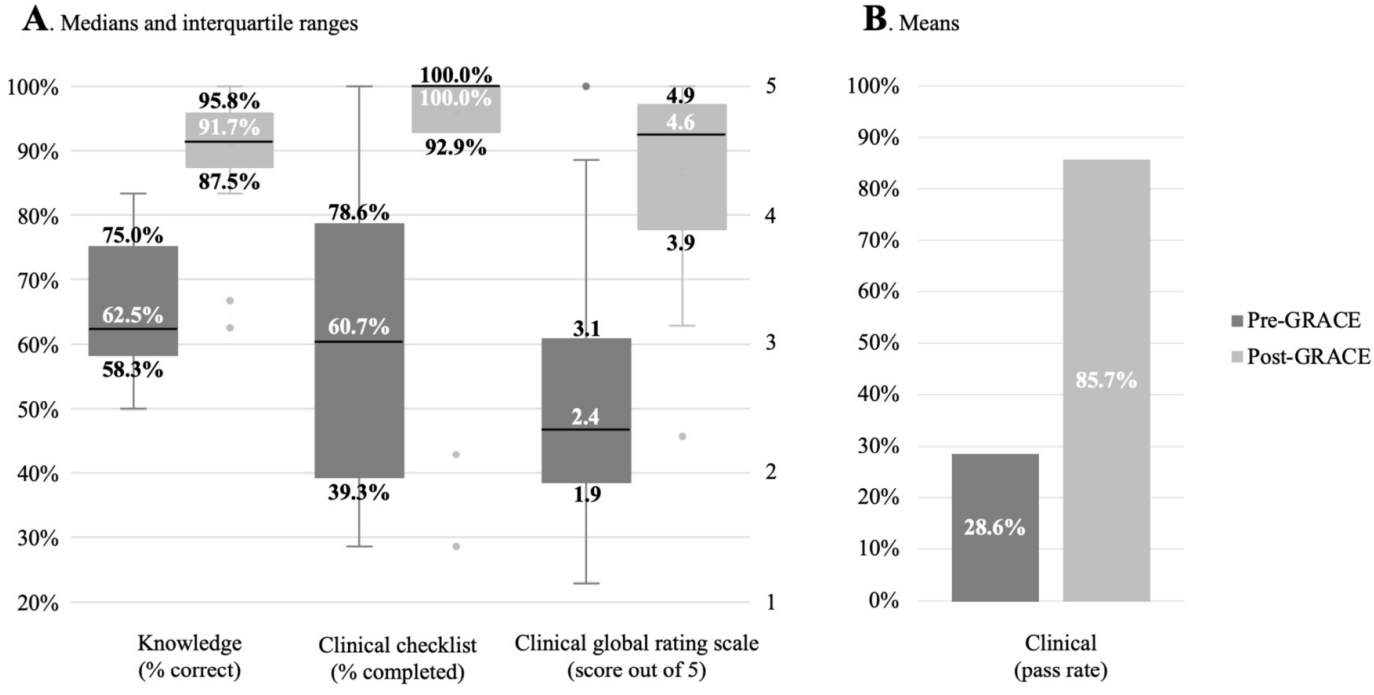

Figure 3 Pre-GRACE and post-GRACE trainee knowledge and clinical examination results (n=14). GRACE, Global Regional Anesthesia Curricular Engagement.

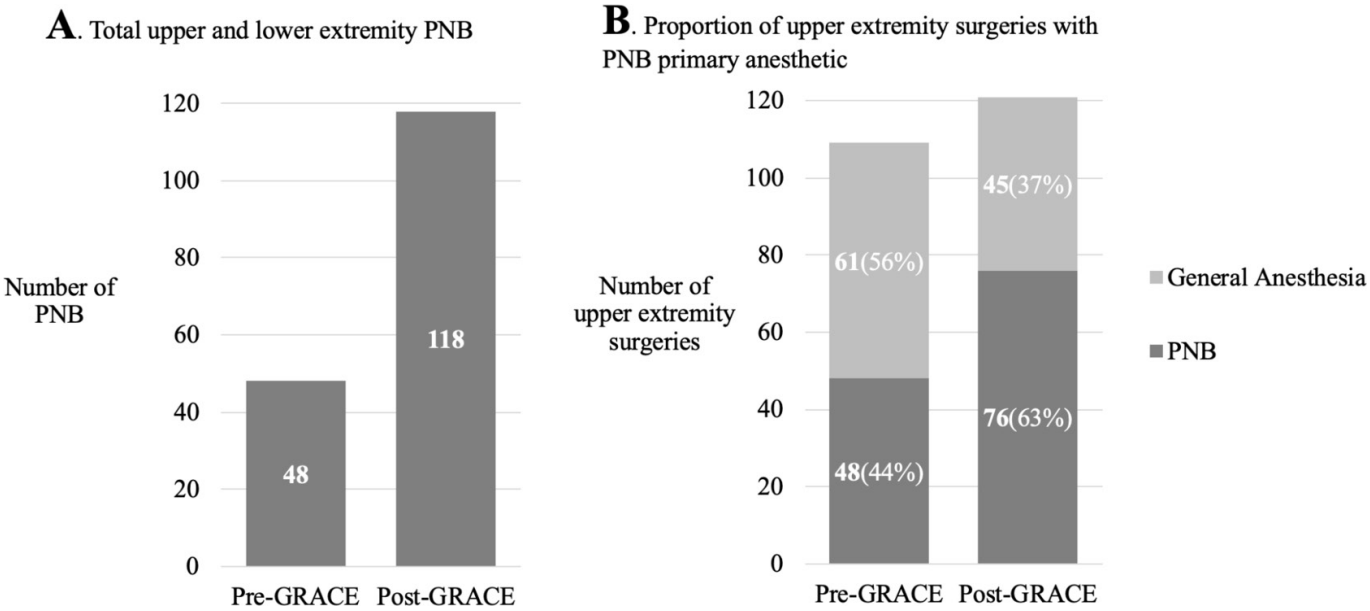

Figure 4 Pre-GRACE and post-GRACE peripheral nerve block (PNB) numbers for 3 months before and after curriculum implementation. GRACE, Global Regional Anesthesia Curricular Engagement.

successfully was 25.0% (3.5/14) (IQR 42.9%, p<0.01). For the clinical examination global rating scale, the median increase in average score was 1.9/5 (IQR 2.0, p<0.001). The percentage of examinees who passed the clinical exam was 28.6% (4/14) pre-GRACE and 85.7% (12/14) post-GRACE (p<0.01). Before GRACE, virtually all PNB were interscalene and supraclavicular brachial plexus blocks. After GRACE, infraclavicular brachial plexus, intercostobrachial, femoral, lateral femoral cutaneous, adductor canal, popliteal sciatic, trans/subgluteal sciatic, and anterior sciatic nerve blocks were practiced as well.

DISCUSSION

More than five billion people in RLS lack access to high-quality anesthesia,[1] and greater research in RLS is essential to delineate obstacles to care and investigate solutions.[20] Initiatives that train providers have become the standard for sustainable RLS interventions,[6] and we designed a teaching program for physicians at an RLS teaching hospital with a regional anesthesia education gap. GRACE is unique from previous curricula in that it can adapt to varied RLS and respond to feedback, which is made possible by the use of a needs assessment to delineate local conditions, consensus process to transform needs into relevant training, and pre–post evaluations that estimate program success and inform curriculum improvements. Our data support the hypotheses that GRACE at KATH would be associated with high trainee satisfaction, improved examination scores, and increased PNB utilization.

From needs assessment to curriculum

Needs assessment results permitted shaping a curriculum to the unique KATH patient population and resources. In general, we matched what patients and trainees required with what trainers could provide. Theater logbooks revealed a large number of extremity surgeries performed for young, predominantly male trauma patients. The curriculum therefore focused on limb PNB for injuries. Although PNB in trauma populations is controversial, arguments against this practice are weak.[21] Because general anesthesia can be especially dangerous and opioids inconsistently available in RLS,[5] we believe the benefits of PNB under these circumstances often outweigh the risks. Lower extremity surgeries outnumbered upper extremity cases three to one, so most clinical instruction involved lower limb PNB analgesia in conjunction with spinal anesthesia. Less than half of upper extremity operations were done with a PNB as the primary anesthetic, which supported our use of PNB as an alternative to general anesthesia. The perioperative mortality rate of 0.7% for extremity operations found in the logbooks was similar to the rate for all KATH surgical services (0.7%) previously reported by our group.[5] Unfortunately, the available records did not allow us to determine causes of death or establish if there was an association between mortality and anesthesia modality. Further information about patients and their outcomes would have been ideal to support the use of regional anesthesia at KATH.

Trainee surveys disclosed KATH physicians felt their current training was inadequate and they desired additional education. Most providers were competent performing spinal anesthesia but welcomed help with other techniques. Trainer surveys found visiting trainers were orthopedic anesthesiologists experienced primarily with peripheral and neuraxial blocks for limb operations. Future programs can consider a more broadly practicing group of trainers, proficient with blocks for head, neck, thoracic, and abdominopelvic surgeries. Regional anesthesiologists increasingly practice point-of-care ultrasonography, and these diagnostic techniques can be taught as well. Survey responses affirmed trainers were available to teach in Ghana for 6 weeks per year. Based on KATH experiences, we recommend collaborative training programs offer at least two 2-week training opportunities annually to reinforce learning and sustain key relationships. Although trainers reported their intention to bring supplies to KATH, we caution outside donations should not hinder local abilities to upscale capacity.

From direct observations of care, we learned two ultrasound machines were available and maintained by KATH. In recent years, ultrasound technology has become more affordable and portable, and its use in RLS has consequently become more common and feasible.[22] Though ultrasounds were present, the greatest observed barrier to regional anesthesia use at KATH was a lack of trained providers. With respect to epidurals and

peripheral nerve catheters, we identified KATH patients that would benefit from these techniques, but the equipment to perform and infrastructure to safely maintain delivery were not in place.

Lessons learned

In the KATH clinical environment, we learned anecdotally about the utility of our blocks. For example, the infraclavicular brachial plexus block required a relatively large volume of local anesthetic, which depleted scarce KATH resources more quickly than the supraclavicular approach. For femur fractures, femoral nerve blocks alone usually provided adequate analgesia. Trans/subgluteal sciatic blocks well served patients with lower extremity injuries who had bandages or splints obstructing the popliteal fossa. For hip fracture analgesia, femoral and lateral femoral cutaneous nerve blocks produced satisfactory results. Recent data supporting hip fracture PNB like the suprainguinal fascia iliaca[23] and pericapsular nerve group[24] blocks are promising, and we wish to consider these for KATH once their benefits and safety are substantiated in clinical trials.

GRACE education was implemented without major barriers, but two organizational issues hinder widespread adoption of PNB at KATH. First, the small workforce prevents continuous availability of providers competent in regional anesthesia. While motivated GRACE participants block patients on their non-clinical time, a full-time regional anesthesia service is necessary to provide patients equitable access to PNB. Given the number of doctors entering the KATH anesthesia residency program has recently increased, a regional anesthesia service may soon be possible. Second, supplies of needles and local anesthetics have not increased in step with the greater number of lower extremity PNB performed, and many patients cannot pay for them out-of-pocket. Even though PNB are cheaper than general anesthesia, they are more expensive than systemic opioid analgesia at KATH. Greater reporting of analgesic PNB benefits is needed to persuade hospital leadership and patients that these supplies are worth the cost.

Study limitations

Kirkpatrick results were positive but should be interpreted in an exploratory way. First, while the Kirkpatrick method is well suited for pointed interventions like GRACE that assess predefined and measurable outcomes,[15 16] these evaluations may be suboptimal for complex curricula, hierarchical interpretation of results can be misguided, only expected outcomes are considered, and the educational process may not be thoroughly explored.[25] Second, our satisfaction survey and examinations were not validated in our population. While we used a validated clinical examination,[17] we tested trainees on ultrasound volunteers and manikins rather than patients to maximize safety. Validation strategies for needs assessments,[26] satisfaction surveys,[27] and examinations[17 28] have been described in the literature and should be considered where possible. Tool validation is ideal but may be difficult for programs like GRACE that require evaluations change each time training is applied at a new location. Third, we could not fully measure the program's impact on patients. Unfortunately, such an evaluation is challenging in the absence of medical records that report detailed patient characteristics and outcomes. Fourth, sources of unrecognized bias common to before-after studies should be entertained (eg, selection, history, test–retest, maturation, observer, Hawthorne, and publication bias).[29] To reduce bias in our study, we implemented evaluative tools prospectively, with pre-measurements and post-measurements made in close succession by the same investigator, using consistent scoring and reporting criteria. Use of a control group would have been helpful to demonstrate program benefits but was not pursued at the request of KATH trainees who wished not to exclude or delay education to anyone. The paucity of training programs employing pre–post evaluations in comparative trials, even in high-income countries,[10] suggests experiments with this level of rigor may be impractical in RLS.

The GRACE model, while intended to adapt to various RLS settings, may not be suitable for every surgical center. Our trainers work only at locations that have licensed anesthesia providers, sufficient surgical volume, a maintained ultrasound machine, local anesthetics, and resuscitation supplies. Travel expenses for trainers visiting RLS should be considered as well. Our group spent US$3000 to US$5000 per trainer per trip for this research, which is a substantial investment for individuals and institutions interested in supporting similar humanitarian work.

Despite the inherent limitations of our approach, we believe the GRACE model is meaningful and actionable. Although it is time consuming to perform a needs assessment, convene an expert panel and consensus process, and make pre–post comparisons, site-specific education and evaluative characteristics ensure curricula are relevant to RLS, respond to feedback, and confirm efforts and investments are worthwhile. While the results of our study at KATH were promising, future research is needed to determine if improvements are sustainable and whether the GRACE model can succeed in various locations.

CONCLUSIONS

A model to teach regional anesthesia in RLS called GRACE was designed, implemented, and measured at an RLS teaching hospital, and results suggest it was tailored to local specifications, welcomed by trainees, improved knowledge and clinical skill, and promoted PNB utilization.

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