Title:

Teaching Hand Surgery in Developing Countries – Study of a Successful Model in Cambodia

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ABSTRACT

The global burden of surgery is becoming increasingly prevalent in the developing world. Hand surgery presents with its own challenges, in particular, the unique skill sets needed, multidisciplinary nature and heterogeneity of cases. The aim of this essay is to explore the feasibility of teaching hand surgery in developing countries within a meaningful and sustainable framework, using a curriculum that was implemented at the Children Surgical Centre in Cambodia. From 2013-2016, a three-year hand surgery curriculum was designed following visits, analysis of data and local surgeon's skillsets. These were further refined by the use of the Pareto's analysis and selected competency procedures to develop entrustable professional activities (EPAs). Following seven visits, local surgeons were assessed for EPAs in the management of three domains for adult and paediatric hand patients: congenital hand differences, trauma deformities and nerve injuries, including brachial plexus reconstruction. Essential elements of this diagonal model include the need for measurable outcomes, clear curriculum goals, long-term partnerships and information technology support. The inclusion of these non-negotiable elements should make this a reproducible model in other developing countries.

INTRODUCTION

The Lancet Commission on Global Health recently estimates that five billion of the world's population are unable to reach surgical services when measured in terms of timeliness, surgical capacity, safety and affordability(1). In the midst of such damning statistics, hand surgery presents with its own unique challenges. As compared to life-and-death situations, hand disabilities are often overlooked as insignificant in comparison with conditions treated by *de facto* specialties like general or even orthopaedic surgery. The practice of hand surgery requires specialist skillsets that are not universally available even in developed countries(2). The impact of hand disabilities have only been recognised in recent years with the use of utilities such as quality-adjusted-life-years (QALY) rather than life expectancy, highlighting the socioeconomic impact of hand injuries on a person's livelihood(3). Despite these evidences, the development of hand surgery remains lacking in developing countries. The question remains: how does one engage in meaningful, sustainable hand surgery education in such countries, and is it even possible? This essay documents our journey through a 3-year pilot project in Cambodia.

The Children's Surgical Centre, Cambodia

In 1975, the Khmer Rouge implemented a radical social reform resulting in the loss of over two million lives. At liberation time in 1979, only 32 of the original 530 doctors were alive(4). While recent macro-economic improvements has allowed the substantial reduction of communicable diseases, e.g., HIV, the rates of non-communicable diseases continue to increase(5). Identifying this unmet need, the Children's Surgical Centre (CSC) was founded in 1998. Initially designed to be a small project treating adult and paediatric landmine victims, the growing community needs catalysed its transformation into a medium-size surgical centre offering 500 free operations annually. To keep up with demands, a key strategy remains the "training of local surgeons…focusing on the development of sustainable surgical services for Cambodians"

(www.csc.org). This vision and strategy provided the motivation for a group of hand surgeons from the United Kingdom and Singapore to visit CSC with the aim of developing a curriculum in hand surgery.

METHODS

One of the main priorities in developing a sustainable service was maintaining a strict focus on teaching local surgeons and not simply performing surgery. For this reason, a hand surgery curriculum was designed immediately after the first visit, based on a three-stage process (Fig 1).

The first stage is the 'Define' stage; to find out what the true community needs are through 'what comes in the door' as referred by local surgeons. After the first days, it became apparent that the upper limb work in CSC would revolve around congenital and acquired deformities, mainly of traumatic origin. Meticulous cataloguing of consultations and surgeries performed form the bedrock of data analysis. In addition, local surgeons were asked to audit their last 600 consecutive cases performed in CSC before our visits in order to establish disease pattern (Fig 2).

The second stage is the Design stage. Based on the community needs, a curriculum was designed to cover three main domains: (1) congenital hand differences, (2) deformity correction and (3) nerve reconstruction. To meet learning needs, relevant workshops and workplace-based assessments (WBAs) e.g., direct observation of procedural skills (DOPS) and case-based discussions (CBDs) were planned as part of a provisional 3-year curriculum (Table 1).

The third and final stage is to Deliver the curriculum. This was by far the most challenging aspect, as efforts would be futile if there was a failure for transfer of relevant skillsets in a meaningful and sustainable way. For this reason, the final yardstick of success was shifted from simply achieving competencies to "pass it on". In other words: "Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime"; or to go further: "Teach a man to teach others to fish and you feed a community". Pedagogical methods were refined to allow meaningful communication in their own Khmer language with other local surgeons, while information technology (IT) skills were taught to allow the storage of resources for sustainability (Fig 4b).

RESULTS

From 2013 to 2016, a group of three hand surgeons and a physiotherapist visited CSC seven times to implement the curriculum. Each visit was five-days long, with four days spent operating and the fifth conducting workshops.

Impact of Visit as Measured by Case Mix

Figures 2 and 3 show the distribution of cases performed by local surgeons (before our visits) and visiting surgeons respectively. From the two data sets, disparities can be easily identified; while the number of congenital cases remains relatively unchanged (around 20%), differences exist particularly in the burn and nerve categories. Previously, burn contracture surgeries comprised over half of those performed by local surgeons but made up only 22% during the subsequent visits. This data reflected the epidemiological findings that South-East Asia has the highest burns rates in the world(5) and also the pre-existing ability of local surgeons to release straightforward contractures and skin grafting. Conversely, nerve surgery previously makes up a small proportion but constituted over 40% of cases subsequently. In particular, brachial plexus surgery was non-existent and the standard method of treating a pan-plexal injury was shoulder fusion and arm amputation.

Designing The Hand Surgery Curriculum

With more data, the hand surgery curriculum was designed, as shown in Fig 6. Structured around three main modules, the curriculum was further divided into eight sub-modules including basic science and congenital hand modules, three sub-modules for ‘Nerve’ and three for ‘Deformity’.

Five skills workshops were designed and conducted using simulation models (Fig 4a,b). Most of these were delivered using a ‘flipped-classroom concept’: lectures were preloaded on a website and viewed by participants beforehand so that workshop time could be more productively spent on discussion rather than lectures. In addition, an IT workshop was conducted to teach local surgeons

how to upload lectures in their own Khmer language to a CSC YouTube channel for sustainability (Fig 4c). Finally, a donated GoPro camera allowed creation of index operation videos, similarly in Khmer, for storage on the channel (Fig 4d).

Secondary Refinements of the Curriculum

To ensure sustainability, a conscious decision was made to teach only procedures that could be reliably performed by local surgeons and passed on. After examining resources, it was felt that microvascular free-flap reconstruction was unsuitable at this stage for CSC. Instead, surgeons were trained to be competent in using the pedicled groin, reversed-radial forearm and crossed-finger flaps as a suitable repertoire to cover the majority of upper limb defects (Fig 5a,b).

For more varied conditions like congenital hand differences, the Pareto analysis was a useful way to organise teaching needs so as to maximise pedagogical efficiency. The technique, commonly known as the "80/20" rule involves identifying 80% of the case types, followed by the channelling of resources to meet these needs. For example, it was found that 80% of cases were polydactyly, syndactyly and radial aplasia. These patients were selected as teaching cases using DOPS and CBDs to ensure the best long-term outcomes were obtained. It may be argued that neglecting the remaining 20% was undesirable or even unethical but with limited resources, this practice allows some form of 'triaging' and enables the needs of the majority to be met in a more sustainable manner (Fig 6).

Designing a New Service for Brachial Plexus Reconstruction

Even the most casual observer would notice that the primary form of transport in Cambodia is the motorcycle. It is not uncommon to see whole families on a single vehicle, weaving in and out of the haphazard traffic. Tragically, this results in high incidences of plexus injuries and perhaps even

more so, patients are often met with futile glances by healthcare professionals and turned away to a life without hope of useful integration into society. From our first visit, it became apparent that this was one patient group that could not be ignored if we were to stay true to our mission of meeting their community needs. Plexus reconstruction could transform the lives of patients and potentially even Cambodia as a whole, as it was so rarely performed. A series of steps were implemented immediately:

1. A Micro-neural workshop
2. Identifying surgeons to teach these skills
3. Establishing a few nerve transfer operations as competency-based procedures

The aim of plexus reconstruction was to turn a useless limb into an assisting limb. With limited resources, the complexities of surgery were simplified to a few reliable workhorse nerve transfers (Table 2). The selected surgeons received targeted training and were soon able to operate independently, with minimal supervision. The motivation for mastering such a complex subject like plexus reconstruction have surely stemmed from their desire to help their own (Fig 7).

DISCUSSION

A recent survey by Lawrence et al.(6) revealed that if opportunities arise, 83% of healthcare professionals would commit themselves annually towards organised altruistic work. While it remains clear there is no lack of volunteers in the medical profession, what is perhaps less clear is what volunteerism actually entails. 89% of participants felt "altruism" must be the mark of true medical professionalism. Through the channels of volunteerism, how do these principles of 'professionalism' actually work in developing countries?

Dupuis, in an invited editorial article, described his concerns after observing foreign surgeons were 'training their residents using the poor kids of Southeast Asia" while ignoring the existing local surgeons in humanitarian missions(7). He vigorously advocated abandoning the 'body-count' method (number of cases/trip) as outcome measures and for fund-raising purposes, concluding that "twenty operations performed perfectly for the purpose of teaching are better than 100 amateurish ones performed by volunteer plastic surgeons".

What contributes to sustainability? Patel et al(8) was correct in acknowledging that surgical missions were traditionally quite similar to other humanitarian efforts and delivered via a 'vertical' model of healthcare. This model is disease-specific and aims to maximise resources in meeting urgent needs, such as eradication of infectious diseases. However, the initiatives tend to operate in parallel with and outside existing healthcare infrastructures. Within the surgical context, such models may involve a team 'parachuting' in to operate (often bringing residents to 'meet service needs') and then leaving without improving the surgical capacity in any sustainable way.

In contrast, a 'horizontal' model focuses on long-term investments in healthcare infrastructures, in particular primary care, and expansions of publicly-funded healthcare administrations. In the

surgical context, proponents of the horizontal model highlight the benefits of building a platform for long-term growth but opponents disapprove of the longer time-frame needed and its dependency on governmental 'red-tape' to get things done. Surgeons are not the best primary care administrators, and a practical point remains that donors are less inclined to give to long-term projects with little immediate yield, as compared to vertical models which are relatively media-popular because of its urgent appeal.

What is the middle ground? A 'diagonal' model has been proposed(8) that combines the immediate results of a vertical model with the long-term benefits of a horizontal one, with the final aim of enriching surgical capacities of local hospitals. While vertical systems work in parallel outside the existing infrastructure, a diagonal one tries to work within it through a continual emphasis on teaching, partnership and the use of surgical capacity as outcome measures. In other words, whether the surgeons are achieving EPAs and passing it on, is seen as more important than body counts. This model has recently been incorporated into the philosophy of several groups, including Operation Smile(9); initially, heavy reliance was placed on international teams to provide care but by 2012 two-thirds of cases were being performed by local surgeons(10).

There are a few key essentials for a diagonal model to work (Fig 8). Firstly, it must have some vertical elements, i.e., visible, immediate impact that can be measured. By virtue of its nature, surgery has the power to accomplish this, as compared to, e.g., eradication of a communicable disease. Cleft surgery can transform a face while hand surgery can transform a deformed hand; these visible improvements are necessary to encourage local surgeons and pragmatically also to appease donors. The only exception is perhaps nerve reconstruction, where results can only be seen after months and this is where the second essential requirement comes in: long-term partnerships. As compared to short-term vertical interventions, a diagonal system focuses on sending the same

team regularly and repeatedly to establish a long-term presence and build partnerships based on trust and commitment. Partnerships are especially needed when results are not immediate: on our second or third visit in CSC, the number of plexus referrals stopped (Fig 7). It was only after a year when results became apparent that word spread among the provinces and other hospitals, leading to increased referrals. It was also during this time that local surgeons began to take plexus training seriously, once the enormity of the problem was realised but more importantly the potential of surgery; surgery that can be mastered one day and taught to others.

Another important element is the effective use of IT(11). The 'iPATH' network that has been employed in CSC since 2012 allows a 'store-and-forward' system, where case histories are loaded onto a secure server and accessed only by invited world experts. By removing unnecessary 'middle-man' steps, the use of such improved IT allows local surgeons to be supported through continued and easy access to advice(12).

Overall, there remains a paucity of literature about effective guidelines for surgical missions(13) and perhaps even less so for enriching surgical capacity(14). From existing publications, however, these key diagonal elements such as clear curriculum goals, long-term partnership and effective use of IT would seem to give the maximal impact in hand surgery education (Fig 8). In a recent survey, local surgeons were asked to rate their confidence level in three surgical domains, before and after visits, as well as teaching others. The positive responses seen in Table 1 would indicate we are on the right path.

The Future

As technology advances, we anticipate the use of IT, in particular, mobile technology to play an important role. Globally, 35% possess a smartphone with high penetrance even in developing countries. The use of 'Apps' can enhance the usability of existing technologies like iPATH and usher in new educational initiatives like TouchSurgery, where surgeons can simultaneously learn and practice surgery on their smartphones (www.touchsurgery.com). Another exciting initiative is the use of augmented reality, allowing surgeons to 'assist' in operations from afar using footages digitally enhanced for live interactions (www.proximie.com). In developing countries where cost of operating microscopes remain prohibitively expensive, the development of instruments which use digital rather than optical magnification allows a much more cost-effective (and portable) way of performing microsurgery (www.digitalsurgicals). Finally, the use of 3-dimensional printing technology allows realistic models to be manufactured for teaching, especially in developing countries where access to prosections or sophisticated plastinated specimens remain limited (Fig 9).

As hand surgeons, we can play our part in reducing the global surgical burden and it is hoped that this paper has provided a feasible model that can produce results within a three-year timeline, and be reproducible in other countries.

(2497 words)

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TABLE AND FIGURE LEGENDS

FIGURES

Fig 1: The three-stage process in developing a hand surgery curriculum: Define the community needs, Design the curriculum around these needs and then Deliver the curriculum using suitable pedagogical methods. Each of these stages require specific tasks that lead to the development of Entrustable Professional Activities (EPAs). The final aim is to achieve independent practice and to teach others.

Fig 2: Pie chart showing distribution of the last 600 consecutive hand and upper limb cases operated on at the Children Surgical Centre (CSC) before visits by the international hand surgeons.

Fig 3: Pie chart showing distribution of 151 cases performed by the visiting hand surgeons over seven visits from 2013-2016. There was a significant increase in the number of nerve reconstructions, and the creation of a new category that was previously non-existent: brachial plexus reconstruction.

Fig 4a-d: (a) Micro-neural workshop using pig's trotter models and repair of digital nerves. The course utilised existing microscopes at CSC (for ophthalmic surgery) and a flipped classroom concept. Competency was achieved within a day for the majority of candidates. The winners of the course were 'selected' to be the micro-neural surgeons and to receive further targeted training to perform nerve coaptations. (b) Tendon workshop using pig's trotter models. (c) Information technology workshop to teach local surgeons how to record lectures in the Khmer language and upload these to their own YouTube channel for enriching surgical capacity. (d) The use of a GoPro camera for recording surgeries and uploading these as edited clips for the educational resource library on the YouTube channel. (https://www.youtube.com/user/CSCcambodia)

Fig 5a, b: Operations of a suitable level of complexity were chosen as competency-based procedures: the pedicled groin flap, reversed radial forearm flap and crossed-finger flap were chosen to allow cover of the majority of hand defects. (a) This 24-year-old lady's hand was run over by a car and initially treated with skin grafts, with very little resultant function. Following our visits, the local surgeons reconstructed the hand with the pedicled-groin flap thus allowing her to regain function and return to her original employment. (b) Snake bites and other venomous injuries were commonplace and previously received inadequate treatment with skin grafts. The local surgeons reconstructed this wrist with the reversed radial forearm flap.

Fig 6: Pareto's analysis of patients presenting with congenital hand differences. This follows the 80:20 principle, where resources are channelled into meeting 80% of the cases, which were consistently polydactyly, syndactyly and radial aplasia. Local surgeons were taken through workplace-based assessments to ensure that the best long-term patient outcomes were obtained.

Fig 7: Chart showing number of brachial plexus reconstructions performed or supervised from 2013-2016. Before results were visible, there were few or no patients referred during the second or third trip. With visible results, referrals increased from the provinces and other hospitals. The number of cases performed by the local surgeons themselves also increased with subsequent trips.

Fig 8: *Adapted from Patel et al. "An Opportunity for Diagonal Development in Global Surgery: Cleft Lip and Palate Care in Resource-Limited Settings. Plastic Surgery International 2012.* A recommended model of delivering and teaching hand surgery in a developing country is the diagonal system, which focused on achieving immediate targets without neglecting the long-term goal of enriching surgical capacity. Combined with the three-stage process of curriculum

development, success of the diagonal model depends on setting clear curriculum goals, long-term partnerships and the aid of information technology.

Fig 9: The use of 3-dimensional (3-D) printed models of dissections in hand anatomy teaching. Cadaveric hand dissections were scanned and printed using 3-D printers. These models can be easily transported and used for teaching in developing countries.

TABLES

Table 1: Designing a provisional Hand Surgery Curriculum with modules, desired workshops and WBAs. Further competency-based procedures were planned as the curriculum develops and required skill sets are identified. WBAs: Workplace-based assessments, DOPS: direct observation of procedural skills; CBDs: case-based discussions.

Table 2: The Hand Surgery Curriculum, as it stands in May 2016. The curriculum was first designed in May 2013 and then modified several times to fit the educational and training needs with the use of Pareto analyses and selection of required competency-based procedures. A timeline was assigned to each module and a provisional completion date set at 3 years to review progress.

Table 3a-c: Responses from survey conducted following 7 visits by hand surgeons. A total of 15 surgeons were surveyed for the three main domains (a-c) and asked the following question:
On a scale of 1-5 (5 being most confident): 'How confident do you feel about performing these procedures independently or with minimal supervision (either in person or via live technology)?'
Each response was recorded with reference to 'Before our visits' and 'After our visits'. They were then asked the second question: 'How confident do you feel now about teaching these procedures to other local surgeons in Cambodia?'