

Innovation in income-poor environments

F. C. Oppong

Colorectal Unit, Derriford Hospital, Plymouth PL6 8DH, UK

Correspondence to: Mr F. C. Oppong (e-mail: chrisoppong@gmail.com)

Background: At the core of surgical development in any economic environment lies innovation. Innovation in high-income countries (HICs) often derives from research, whereas innovation in low- and middle-income countries (LMICs) may be spontaneous owing to a desperate drive to meet a local need. The local needs are substantial because of the unequal access to healthcare in LMICs.

Methods: The experience of the author in working in LMICs through Operation Hernia, a medical charity, provides a backdrop for this review. Other published innovative devices and models are discussed.

Results: Innovation in income-poor countries has provided cost-effective but efficient solutions to local health needs. Some innovations have been enhanced and adopted worldwide.

Conclusion: HICs can learn more from innovative strategies adopted in LMICs.

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Introduction

Innovation is the bedrock of surgical development, in both income-poor and -rich countries. It is vital not only to the development of surgery, but in many ways it is fundamental to its very survival. Any progressive institution will have promotion of innovation at its core¹. Innovation is a novel idea, process, technology or device that is introduced to meet a need or improve on an existing facility.

The benefits of innovation to any health system are enormous. Innovation raises care standards and so transforms the quality of care. To underline the crucial role innovation plays in improving the quality and delivery of care in the UK National Health Service (NHS), the Department of Health published a policy document *Innovation Health and Wealth, Accelerating Adoption and Diffusion in the NHS*¹ to promote a culture of research and innovation in the NHS. The Royal College of Surgeons of England responded by publishing its own documents to incentivize research and innovation, and to promote its adoption as an indispensable part of surgical practice: *From Theory to Theatre: Overcoming Barriers to Innovation in Surgery*² and *From Innovation to Adoption: Successfully Spreading Surgical Innovation*³.

If there is a requirement to promote surgical development in income-poor countries, it will be through innovation. The lack of skill, appropriate technology, financial resources and their judicious management often results in paralysis in the provision of healthcare. This paper celebrates stakeholders who have not despaired in the face of limited resources, but have been motivated to be

innovative to provide much-needed care to patients. They have tested and introduced novel systems and processes, adapted existing products or created new products to replace unavailable and often more expensive alternatives, to meet local needs. Income-poor environments have also benefited from innovative systems and devices that have originated from income-rich countries.

The essence of innovation in income-poor countries should be viewed in the light of the increasing emphasis on global surgery, which until recently has been excluded from the global health agenda. Around 11 per cent of the global burden of disease can be remedied by a surgical intervention⁴. The World Health Organization (WHO) has recognized the fact that provision of essential surgical care is critical in achieving the Millennium Development Goals⁵, set by the United Nations in 2000, to be fulfilled by 2015. In spite of this recognition there remains a staggering inequality of access to safe and essential surgical care worldwide. Of the estimated 234 million surgical operations undertaken worldwide annually, the world's richest one-third receives 74 per cent, whereas the poorest one-third benefits from less than 4 per cent of these procedures. Two billion of the world's population have no access to basic surgical care.

The literature contains many recommendations for improving access to essential surgical care in resource-poor countries. The following is a list from the Lancet Commission on Global Surgery⁶: training more surgeons and trying to incentivize them to stay in underserved

regions; surgical missions; and strengthening national health systems through sustainable, global partnerships between surgeons, hospitals and institutions. To this list should be added: hard-wiring innovation into the training of health workers and administrators to incentivize innovative ideas, systems and technology appropriate to surgical development in resource-poor countries.

Variation in motivation

There is a difference in the motivating factor that drives innovation in low- and middle-income countries (LMICs) and high-income countries (HICs). Both are driven by the need for improved patient care and reduced cost. Innovators in HICs are largely motivated by the need to facilitate or improve outcome and also to generate profit, whereas innovators in low-income countries are driven by lack of resources and the quest for survival⁷.

Variation in innovation

The economic inequalities between LMICs and HICs dictate the type of innovative solution that is created in the different settings. Most innovative ideas in low-income countries could be classified as evolutionary. This is because they are often a creative adaptation of an existing product that is delivering quality healthcare in better-resourced environments. The adaptation allows a product to deliver effective, affordable and sustainable solutions to local surgical needs. Innovation in HICs would, mostly, be regarded as revolutionary because it is often a new surgical device or technology. Innovation is needed to advance aspects of care either by improving on the performance of an available device or system, or to replace it with a superior product to achieve enhanced value or outcome.

Appropriate innovation in income-poor settings

The single most important characteristic of an innovation appropriate for income-poor settings is its ability to meet a specific need. Any device should be affordable, easily replaceable and cost-effective to use. A frequent visitor to surgical theatres and wards in income-poor countries will not fail to notice the number of white elephants stored in corners gathering an ever-increasing layer of dust. These were once valuable devices or systems, either imported or donated from a resource-rich country, that were expensive to run or maintain. Another characteristic of a successful innovation is to ensure that the product uses technology that can be serviced by local technicians, using available

and affordable resources. This is sustainable innovation that is more relevant to income-poor environments.

Mosquito net as mesh for repair of inguinal hernias

An example of innovation that satisfies the criteria discussed above is the use of sterilized polypropylene mosquito net by Operation Hernia to repair inguinal hernias in income-poor countries in Africa, South America and Asia. Operation Hernia is a UK-registered charity that was founded by two consultant surgeons⁸. They were assisted by the European Hernia Society and a local charity, Plymouth–Takoradi Link. The first humanitarian mission organized by Operation Hernia in 2005 visited a port city, Takoradi, in the western region of Ghana⁹. The objectives of Operation Hernia are: to relieve suffering by repairing hernias using mesh; to train local doctors in mesh hernia repair and then to get them to transfer their skills to other surgeons; and to engage in relevant research about hernias in low-income countries. The project has expanded to 15 countries. Since 2005, Operation Hernia has sent out over 100 humanitarian missions (56 to Ghana). Surgeons have volunteered from 18 countries in Europe, including the UK, USA, Australia and Africa. Over 8000 hernias have been repaired since 2005.

The credentials of Operation Hernia, as a leader in innovation that benefits low-income environments, were underlined by the charity winning a prize at the World Innovation Summit for Health, held in Doha, Qatar, in 2013¹⁰.

In the early years of the organization, hernias were repaired with brand meshes. When mosquito nets were introduced they were initially used concurrently with brand meshes. Over the past 5 years, however, Operation Hernia has used mostly mosquito nets on the missions. They are affordable, safe and cost-effective^{11,12}. These values have been underpinned by research.

Origin of mosquito net meshes

Dr Ravindranath Rangnath Tongaonkar, a surgeon in India, popularized the use of polypropylene mosquito nets for repair of inguinal hernia in India¹³. However, he was not the innovator of this product, and credits this achievement to a rural surgeon in India, Dr Brahmma Reddy, who introduced him to the technique in 1996. Mosquito nets are composed of a copolymer of polypropylene. Tongaonkar, Reddy and colleagues¹³ published their joint experience in 2003 in the *Indian Journal of Surgery*. The features of mosquito net mesh that make it an appropriate technology for LMICs are as follows.

Structure

Sanders and colleagues¹⁴ used vibrational spectroscopy and scanning electron microscopy to study the macromolecular structure and ultrastructure of mosquito nets. They also performed uniaxial and tensile burst strength tests, and concluded that the mosquito net is equivalent to commercially produced meshes.

Affordability

Studies conducted by Operation Hernia in Ghana and Ecuador proved that mosquito net mesh repair is cost-effective; the mesh is several times cheaper than brand mesh, and is easily affordable by LMICs. This was confirmed by Sørensen and Rosenberg¹⁵ in a recent systematic review. The cost of an individual 10 × 15-cm mesh is estimated at US \$0.0072–0.014 (€0.006–0.011; exchange rate 4 November 2014)¹⁶. In another study¹⁷ the cost of mosquito net was estimated at '1/1000 the price of commercial mesh'.

Safety

The morbidity associated with mosquito net mesh repair (wound infection, mesh rejection, chronic wound pain) is comparable to results obtained with brand mesh. Operation Hernia audited 1748 patients operated on in Ghana, Nigeria and Ivory Coast from 2005 to 2010. The wound complication rate was 0.6 per cent (10 of 1748)¹⁸. In earlier studies the wound infection rate was less than 2 per cent (2 of 106)¹⁶, and 4.7 per cent of 539 patients¹³. Research suggests that the *in vitro* risk of infection of mosquito net is not significantly different from that of commercially available mesh¹⁹.

Long-term results

Long-term follow-up results were published in 2014²⁰. The authors audited 713 consecutive inguinal hernia repairs in 651 patients. No recurrences or instances of mesh rejection were reported. In the 10-year retrospective study, only two patients (0.3 per cent) had chronic groin pain.

Sterilization

Sterilization of mosquito net is by autoclaving. Mosquito net mesh manufactured in India can be sterilized safely at lower temperatures (121°C) than those usually demanded by advanced healthcare systems (134°C)²¹.

Verdict on mosquito net

Mosquito net for hernia repair provides LMICs with what is described as a 'fabulously clever, inexpensive and

context-appropriate'²² alternative to commercially produced mesh for hernia repair. This has proven the worth of Operation Hernia setting up a hernia centre at Takoradi Hospital, in Africa⁸.

Lifebox oximeter

Among other innovations that have been designed specifically to improve surgical safety in LMICs is the Lifebox (LB) oximeter (Lifebox® Foundation; <http://www.lifebox.org>). The perioperative monitoring of patients is now regarded as a standard of care for patients undergoing general anaesthesia²³. All operating theatres in the developed world use oximeters. HIC theatres have complex and expensive oximeters that are beyond the budget of many LMICs. Not surprisingly, in sub-Saharan Africa 70 per cent²⁴ of operating theatres have no oximeters; 70 000 operating theatres in Africa and Latin America also have none. The use of oximeters, combined with the WHO Surgical Safety Checklist²⁵, is estimated to make surgical operations nearly 50 per cent safer. A study²⁶ has confirmed the accuracy of LB oximeters. LB oximeters are an inexpensive and robust alternative device that LMICs can afford. They cost US \$250 (€200), compared with at least \$1000 (€800) for a standard device used in HICs. Other affordable oximeters are coming to the market. The WHO recognizes the essential contribution of the LB oximeter to reducing anaesthetic morbidity in LMICs²⁷. Lifebox Foundation is a global health charity that is working to make surgery safer in low-income countries.

Bogota abdominal bags

A Bogota bag is a simple, cheap but very ingenious device that originated in Bogotá, Colombia²⁸. It is a sterile plastic bag used to provide temporary abdominal closure (laparostomy) in emergency laparotomy where closure of the abdomen is either impossible or unsafe owing to the risk of compartment syndrome, often after damage limitation surgery. This technique was adopted worldwide and modified to include a suction mechanism^{29,30}. In most hospitals a 3-litre glycine bladder irrigation bag is cut open and used to cover the laparostomy. It allows direct inspection of bowel in patients with ischaemia, facilitates relaparotomy, improves drainage of excess fluid from the abdomen and reduces tissue oedema. This facilitates eventual fascial closure. Alternative vacuum dressings, which no doubt are more expensive but potentially more efficient, are now produced commercially³¹. Management of laparostomies with a vacuum device has become standard in this situation, and has resulted in a higher rate of fascial closure, reducing the risk of large, unsightly, incisional hernias³².

Task shifting

Task shifting is an innovative model of healthcare delivery that originated in income-poor countries. Reference has been made to the striking inequality in access to essential surgical services in the world. The inequality is in part due to lack of health facilities, equipment, medication and financial resources in LMICs. The most significant challenge to bridging the gap, however, is the acute human resource crisis that LMICs face³³. The lack of doctors, nurses and other skilled health workers will prevent any attempt at improving access to essential surgical services. The WHO Global Atlas of Health Workforce compares the doctors per 10 000 population ratio of developed countries and LMICs. The developed world enjoys ratios of between 24 in the USA, 27 in the UK and 49 in Austria, whereas LMICs endure ratios of between 6 in India, 1 in Ghana and 0.6 in Zimbabwe³³. Resolution of this crisis calls for an innovative model to increase the availability of specialized skills in healthcare, without compromising efficacy and safety. The conventional model is to train more doctors and other healthcare workers. This approach has not been successful because of failure to retain the skilled workforce, especially the doctors³⁴. The strategy that LMICs have used for several years in an attempt to resolve the crisis is task shifting. The WHO describes task shifting as the rational redistribution of tasks among health workforce teams³⁵. In practice, it involves transferring defined healthcare tasks, traditionally performed by a highly skilled workforce, to less skilled, but appropriately trained individuals³⁶. Two areas in which task shifting has been successful in LMICs are nurse anaesthetists and non-physician clinicians (NPCs).

Nurse anaesthetists have played an important role in delivering essential surgical services in most LMICs for years. In 1996, it was estimated that nurse anaesthetists provided a vital service in 107 of the world's 200 countries. They are trained to a high standard to administer general and spinal anaesthetics. Soyannwo and George³⁷ reported that nurse anaesthetists in Gambia administered anaesthesia for 94 per cent of obstetrics and gynaecology operations, with minimal complications. The experience of Operation Hernia in Ghana and Rwanda supports these statistics. In Ghana in 2013, there were 14 nurse anaesthetists in the eight hospitals visited. In hospitals where there was no Operation Hernia anaesthetist, the nurse anaesthetists administered all the general anaesthesia and spinal anaesthesia, which they were particularly skilled at.

NPCs have been trained to perform major surgical operations safely in LMICs. Beard and colleagues³⁸ published an audit of the outcomes of non-obstetric operations done by NPCs in Tanzania in 2012. The operations included

hernia repair, prostatectomy, exploratory laparotomy and hydrocelectomy. NPCs performed 56 per cent of the operations. The postoperative mortality rate was 1.7 and 1.5 per cent for NPCs and trained surgeons respectively. There was no difference in outcome between the NPCs and the doctors. Wilhelm and co-workers³⁹ reported similar results in patients who had surgery for strangulated hernia. The study concluded that this innovative model may be a way to address the global surgical workforce crisis.

Other examples of task shifting in LMICs are training of traditional surgeons to perform circumcision, and training NPCs to treat fractures and joint dislocations in Ghana. The significant issue that will need to be addressed is continuing education and training of the NPCs.

Other significant innovations in LMICs include the ligation of intersphincteric fistula tract operation for anal fistula (LIFT), with a 94 per cent healing rate⁴⁰. Others⁴¹ reported a similar success rate of 69 per cent. The Desarda technique is a non-mesh repair for hernia developed by an Indian surgeon. The reported results are similar to those of mesh repair but without the cost of a mesh^{42,43}. This is becoming increasingly popular because of long-term groin pain complicating standard mesh repair.

Discussion

One common characteristic of the innovations discussed above is that the driver for each is acute need in a resource-poor environment. The innovators were individuals who were determined to think beyond the conventional to discover and create sustainable solutions to local health needs. All these innovations have provided quality products that are affordable in LMICs. Some of the innovations discovered in LMICs have been adopted³¹, enhanced and used in high-income settings to improve healthcare. Prospective controlled trials of mosquito mesh and brand mesh are ongoing. A product that has hitherto been used only in LMICs may be adopted by health systems in HICs to reduce health costs, without sacrificing quality.

It has been shown to be possible to provide an inexpensive but highly effective technology to solve health problems. Nurse anaesthetists may be trained to administer anaesthesia in selected patients in HICs. This will follow established trends in endoscopy, ultrasonography and gastrointestinal physiology. If nurses in LMICs can be trained to perform major surgery with outcomes as good as those of their physician counterparts, it should be possible to train nurses in HICs to carry out minor and possibly intermediate surgical procedures. It could be a very cost-effective strategy to increase capacity in health systems in HICs, such as the UK. Without research and innovation, surgical development in both LMICs and HICs is

hindered. Strategies to incentivize innovation should be adopted in the education and training of all health workers.

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OPERATION HERNIA

www.operationhernia.org.uk



Established in 2005 to offer humanitarian repair of hernias and to train local doctors. Also provides invaluable training to UK and EU trainees



Innovation is crucial in meeting surgical needs in low-income countries



Operation Hernia has popularised Indian (Mosquito Net) mesh for repair of hernias



The mesh is affordable, safe, has equivalent properties
Good outcome published



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