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E-learning Supporting Surgical Training in Low-Resource Settings

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Abstract

Purpose of Review Surgical training is most needed in low-resource settings (LRSs) worldwide. Technological advances provide new tools to expand and enhance surgical training in these settings. Accessible technologies such as e-learning can achieve an immediate impact on training.

Recent Findings LRS trainees regard both e-learning resources specifically designed for their context, and those designed for other contexts, as valuable. However, LRS trainees have some specific learning needs which are best addressed through LRS learner-centred content. Challenges to creating valuable educational experiences include infrastructural deficiencies, difficulties in finding and accessing resources, variable quality of material, incompleteness, repetition, and a lack of context- and curricula-focused material.

Summary Future efforts should focus on improving the findability, quality, and contextual appropriateness of educational resources, while emphasizing sustainability and local ownership. The appropriateness, acceptability, and impact of available e-learning resources in LRSs should be evaluated.

Keywords Surgical training · Surgery · E-learning · Technology · LMIC · Low resource

Introduction

There is an enormous unmet need for surgical care worldwide, felt most acutely in low- and middle-income countries [1]. Lack of access to safe, affordable surgical care causes immense disability, suffering, and death. This is a complex, multifactorial problem, but a key issue is an insufficient surgical care workforce in low-resource settings. A significant limitation on the expansion of surgical training is a dearth of trainers, which directly impacts the efficacy of the trainee–trainer relationship—the cornerstone of the classical apprenticeship model of surgical training.

Advances in technology provide new tools to expand and enhance the training of surgeons in low-resource settings. New technologies allow access to learning material, peer interaction, supervision, feedback, and learning opportunities at a distance. This can reduce the trainee's dependence on a trainer as the font of all surgical instruction, and by doing so, allow for an expansion of quality-assured training, and even potentially reduce the time required to train a surgeon.

To expand quality surgical training in low-resource settings, the opportunity that technology presents must be grasped. This review will first describe how technology is helping to enhance and expand surgical training worldwide. It will then focus on cognitive e-learning in low-resource settings, outlining the current situation, challenges, and suggested avenues for progress.

This review uses the terms high-resource setting (HRS) and low-resource setting (LRS) when referring to the context in which surgical training takes place. The local context is more important than the overall wealth of the country in which training takes place, thus in line with recent recommendations [2], the terms high-income country (HIC) and low- and middle-income country (LMIC) are used sparingly.

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Technology in Surgical Training

Understanding the basis of learning is key to identifying the role of technology in supporting surgical training. Bloom divided learning into cognitive (knowledge), psychomotor (skills), and affective (attitude) domains [3]. Gallagher et al. posit that, given our limited capacity to pay attention to many things at once, learning in one domain reduces the need to concentrate on that domain, allowing for greater acquisition in the others [4]. Therefore, for example, a trainee coming to the operating theatre who has a sound understanding of the procedural steps and the basic science related to the procedure at hand will be able to concentrate more on the technical skill required to perform the procedure. Similarly, having practised the psychomotor skills on a simulator will allow the trainee to devote more attention to the non-technical aspects of the surgery, such as decision-making.

Some educational technology primarily supports learning in the cognitive domain—all static didactic resources and most e-learning courses could be described in this way. Other technologies aim to promote psychomotor skills acquisition—such as low-fidelity simulators. Communication and telepresence tools can be used for learning in either domain. Increasingly sophisticated immersive simulation technology aims to combine learning in the cognitive and psychomotor domains, though the challenge of providing realistic haptic feedback (the "sense" of touch, force, self-movement, and body position) in a virtual world remains.

Didactic Resources and Training Tools

Digital versions of textbooks, journals, surgical atlases, and other reference material would be familiar to previous generations of trainees, while commonly used new media formats such as podcasts, social media, and video sharing platforms now offer a vast and diverse array of surgical training content. Messaging apps provide a platform for case-based discussions [5]. Electronic training logbooks can provide trainees with feedback on their operative experience through a scoring system or by showing how their experience compares with their peer cohort [6].

Cognitive, Interactive E-learning

While there are many definitions of e-learning and related terms [7], it can simply be considered as "the delivery of educational content through web-based methods" [8]. In this review, this definition is narrowed by adding the requirement that the content is accessible without the use of any other equipment such as a headset or physical simulator, and that the live online presence of a trainer is not required. Most resources discussed are asynchronous—meaning the learner works through the material in their own time—contain at least some degree of interaction and generally support learning in the cognitive domain. Many surgical e-learning platforms, courses, and resources exist—some e-learning content is intended to provide a complete learning experience in the chosen topic, while other content is designed as an adjunct to a short course or training programme or as preparation for an examination.

Mechanical Simulation

Technological advances have led to increasingly sophisticated physical surgical task simulators, while innovative low-cost simulation systems are making high-fidelity simulation more widely available [9].

The Global Surgical Training Challenge, for example, spurred the creation of an ecosystem of low-cost, open-access, easily reproducible simulation training modules for LRSs [10], in many cases combining cutting-edge technology with widely available materials such as socks [11] and cigarettes [12] to produce realistic training experiences. The Surgical Education Learners Forum [13] and Wellcome Leap SAVE [14] programmes aim to further develop this paradigm. The rapid creation of reliable, low-cost anatomical models is now possible with 3D printing. Exact patient anatomical replicas can be created in advance of complex surgery to aid trainees and surgeons to design optimal plans.

Immersive Simulation

Interactive simulated surgery can take place on a two-dimensional screen [15]. Attempts to create a more immersive surgical training experience include 360° videos displayed on a two-dimensional screen [16], and immersive virtual reality where the user is placed in an entirely simulated world [17]. Augmented and mixed realities and advanced visualization tools for complex anatomical structures are being used to support surgical training and practice, overlaying imagery on top of physical simulators, or indeed on the actual surgical field [18]. In augmented reality, images are overlaid on the user's view of the physical world [19], while in mixed reality, overlaid images interact with the physical world [20]. Both modalities offer the possibility of realistic haptic feedback.

Communication and Telepresence

Widely used videoconferencing tools are routinely used to deliver lectures and tutorials online, and full academic surgical degree programmes can be completed entirely online [21]. Live surgery can be streamed and telepresence—"the subjective experience of being in one place or environment,

even when one is physically situated in another" [22]—aims to deepen the experience, to virtually bring trainees into an expert's operating theatre, or vice versa [23–25]. Live interaction allows for teaching and supervision. Video recordings of these surgeries have been accumulated to create enormous digital libraries of surgical imaging for future applications and potential implementation of artificial intelligence techniques. Video analytics and instrument motion capture can already provide feedback on skills performance [26–28].

Integrating Technology into Training

These technologies complement, rather than replace, the learning experience that takes place in the hospital environment. An effective use of technology is to achieve a "blend" of individual, self-directed, technology-enhanced learning and live, in-person learning. Blended learning in medical education is found to have "consistently better effects on knowledge outcomes when compared with traditional learning" [29]. A common and proven blend is the "flipped classroom" model, where trainees are introduced to concepts online, practise and receive feedback in-person, and extend and test their learning online [30].

No single tool, resource, or modality is the answer to all trainee learning needs. Trainees and training programmes face the challenge of choosing appropriate tools for different learning needs, and a combination of different technologies may often be appropriate. For example, a trainee will often progress from a cognitive e-learning module, in which they learn about a procedure, to a task simulator, on which they practice the technical skills required to perform the procedure.

The remainder of this review will focus on e-learning in surgical training. Numerous studies have shown e-learning to be "a valuable tool for surgical education" [31]. While noting the transformative potential of some of the more advanced technologies listed here, the "Future of Surgery" report [32••] suggests that "technologies that are cheaper and easier to transport, such as those that can be used with smartphones, will, however, have the biggest immediate impact".

LRS Trainees Have Different Needs

E-Learning is accepted as a useful training tool by trainees in LRSs [33••]. Both resources designed specifically for LRS trainees and those designed with HRS trainees in mind are regarded as valuable by LRS trainees [34]. Both LRS and HRS trainees are highly heterogeneous groups; nevertheless, we can draw some general differences between these two training contexts. These differences mean that simply providing access for LRS trainees to a HRS e-learning programme is an incomplete response; contextualisation is key.

Different Content Needs for a Different Context

Pathologies, diagnostic strategies, laboratory capabilities, pre-hospital services, and treatments, as well as the availability of drugs and other resources vary in different contexts—and an ideal training programme should prepare trainees for the local realities they will face in practice. In the Sub-Saharan African context, Parker et al. note that HRS surgical textbooks have historically been the primary source of content, but point out a number of issues, such as "textbooks exclude disease processes frequently or exclusively seen in [Sub-Saharan Africa], like typhoid intestinal perforations, hydatid disease, and rheumatic heart disease" and "images… do not represent physical examination findings as they appear on darker skin tones" [35•]. Conversely, LRS learners may spend significant time and energy learning about pathologies, treatments, and tools that are not available or applicable in their context. We can reasonably expect that a lack of context-specific material is having a negative effort on surgical training in LRSs, but have little evidence as yet for this.

Different Role for Surgeons

Surgeons in LRSs often have a broader scope of practice than their HRS counterparts, often providing surgical care in other specialties, yet "rarely, if ever, are these specialties covered adequately in… curricula from high-resource areas" [35•].

Different Cadres of Surgical Provider

The composition of the surgical team differs in different settings. In some LRS contexts, non-specialist and non-physician surgical providers supply the majority of surgical care [36]. As surgery is very rarely performed by these cadres in HRSs, surgical training material designed specifically for the learning needs of these cadres is not widely available.

Different Role for E-learning

In many HRSs, part of the appeal of e-learning, simulation, and other technological solutions is as a perceived substitute for the decreased exposure to surgery brought about by working time directives and other reforms [37]. This is a much less critical issue in many LRSs, where trainees often have more operative exposure than HRS counterparts [38] and take on roles of greater responsibility [39].

E-learning may support other needs in LRSs, which are less pressing in HRSs. With a lower density of surgeons and

trainees in LRSs [1], issues related to professional isolation and the lack of a critical mass of trainers and trainees can partly be alleviated through e-learning. E-learning can also provide standardization of the delivery of cognitive learning across large geographies, and the opportunity for trainees in smaller centres to gain exposure to topics not routinely encountered in their training site.

LRS training institutions may adopt different strategies to make high-quality e-learning material available to their trainees; they may adopt or adapt training material created in the HRS context, or create local context-driven original content. The relative impact of implementing these different educational strategies is not clear. While we know that learning needs differ in different contexts, it is not yet clear in which parts of surgical training curricula context-specific material provides significant added value over non-context-specific material, and in which areas non-context-specific material is perfectly appropriate. All of these strategies can be assumed to add value, and a decision to adopt, adapt, or create should be the result of a careful needs assessment, should be a pragmatic one, and unfortunately must be based on the availability of funding and other local resources.

Open-Access HRS Resources

LRS surgical trainees' e-learning needs can be addressed not only through content specifically designed for their settings, but also through making appropriate content available through an open-access model—even where the content is not specifically designed with LRSs in mind. The Free, Open-Access Medical education (FOAM or FOAMed) [40] movement aims to make medical education resources freely accessible, and in doing so reduce educational disparities between different settings [41].

Open-access platforms, where both content and access are setting-agnostic, are an important resource. Platforms may be entirely free and open access, such as "AO Surgery Reference" [42], or may provide a free basic offering with paid premium offerings, such as "Orthobullets" [43].

Some platforms provide free access to LRS learners to (mainly HRS authored) content, to which counterparts in HRSs, or more commonly their training institutions, must pay for access. DeckerMed provides free access to its surgical training platform to African trainees [44]. The Research-4Life Initiative [45] provides LMIC institutions with access to journal articles and other academic content.

The above two modalities are likely to provide the majority of the e-learning content accessed in LRSs. In the case of neurosurgery training, for example, a study identified resources suitable for use in LMICs, and recommended 13 resources, all of which are hosted in HRSs [46].

LRS-Specific Content

There is a clear perceived benefit to developing LRS-specific learning resources, to address the learning needs described above, though of course no two LRS contexts are the same. Many excellent LRS-specific resources exist, only a fraction of which can be named in this review. These resources are created by LRS, HRS, and global bodies.

Many LRS training institutions manage their own learning management systems—accessible to their trainees and faculty. The College of Surgeons of East, Central and Southern Africa (COSECSA) manages the "School for Surgeons" platform [34], developed in collaboration with the Royal College of Surgeons in Ireland [47]. The existence of an established LRS platform, with large enrolled cohorts of learners who are now familiar with e-learning, has created fertile conditions for the production of content specific for such platforms such as COSECSA's "Surgical Foundations in Basic Science" course [35•, 48].

Other LRS institutions take a different approach by making their resources available open access, such as the University of Cape Town's "Developing World ENT" platform [49].

International organizations often take the lead in building platforms and courses specifically for the LRS environment, such as the "Trauma and Disaster Team Response Course Open Program" [50]. The "Essential Surgical Skills" course [51] is one of the few explicitly targeting non-physician clinician surgical providers.

In practice, resources are often collaboratively produced between HRS and LRS authors and institutions, such as the "COSECSA-ReSurge Plastic Surgery Modular Course" [52]. Creation of such resources can provide an opportunity for "South–South" cooperation—COSECSA and the West African College of Surgeons collaborate on the "Pan-African Paediatric Surgery E-Learning Programme", supported by HRS institutions [53].

Global bodies both create and curate content. Some original surgically related content is hosted on OpenWHO [54], with WHO Academy operative care content forthcoming [55]. The United Nations Global Surgery Learning Hub "SURGhub" [56] curates and makes available high-quality pre-existing e-learning courses suitable for LRSs—both contents created in LRSs and in HRSs.

Challenges for LRS Surgical E-learning

Many of the challenges facing LRS surgical trainees, and those who train and create content for them, are common to surgical trainees worldwide. Trainees are universally

time poor, may have significant clinical responsibilities, and may not always find the perfect environment to concentrate and study. The generally high drop-out rate of e-learning courses is a long-recognized phenomenon [57], with variable learner motivation a factor in medical education [58•]. In considering the particular challenges facing LRS surgical trainees, it is useful to also draw examples from other medical specialties, particularly Emergency Medicine (EM) which has been an early adopter of open-access online learning for both HRSs and LRSs, and has produced a more extensive literature.

Getting Online

Given the near ubiquity of mobile Internet, a complete lack of access to the internet is likely to now be rare for members of the surgical team, and those in training. However, "suboptimal" access to computers, poor internet connectivity, and the high cost of this connectivity remain critical limiting steps for many LRS trainees [59].

Findability

Major difficulties in this regard are the sheer volume of resources and information, the way that resources are organized, and difficulties with search. A review of EM e-learning resources finds that "resources are scattered across an enormous number of sites" [60]. The "decentralized explosion of FOAM resources is a double-edged sword, as consumers of FOAM are faced with a potentially unworkable abundance of options" [61]. Learning material tends to be grouped into courses aimed at a particular cadre or specialty, yet many topics are of relevance to several specialties. This is particularly true for non-technical topics, such as research methodology, leadership, and communication skills. An excellent research methodology module, for example, in an orthopaedic surgery course hosted on an open-access orthopaedic surgery platform, is unlikely to be accessed by the many other surgical cadres who could benefit from it. Finally, content stored behind a login in a traditional learning management system, or within a larger course, is not accessible to search engines, if course contents are not also listed on a publicly accessible website.

Quality

Common e-learning quality deficiencies—in content aimed at both LRS and HRS learners—include a lack of peer review, no verification of reliability, lack of transparency, and potential conflicts of interest [62]. Formal attempts to measure the quality of online medical resources return a wide range of scores [63, 64] suggesting that many available resources may contain significant gaps and deficits. Issues with quality are not always obvious. Neither trainees nor trainers can reliably agree on whether different medical e-learning resources are accurate and legitimate [65].

Many resources are not employing learner-centred educational approaches. In EM, a lack of "curriculum-driven online resources in local [LMIC] languages" was found. A review of critical care e-learning resources found that one-third did not contain interactive learner experiences [66]. The situation in surgical training is likely to be similar. Paradoxically, too much interaction can be off-putting for many LRS surgical trainees, as many LMIC learners are more familiar with a teacher-centred didactic learning approach [67].

Incompleteness and Repetition

There is a surfeit of resources in some areas and, most likely, a corresponding dearth of resources in others. In the absence of detailed guidance and direction, a learner wading through online resources is likely to find a lot of repetition, yet is unlikely to comprehensively cover the subject area. A review of renal and genitourinary online content for EM trainees and practitioners assigned all content found to one of 35 subtopics, based upon an accepted curriculum. Forty-one per cent of all "high-quality" resources related to just one of these subtopics [60].

Appropriateness and Integration

As discussed previously, few resources are tailored to LRS context needs, leading to content gaps and inappropriate content [35•]. Integration of resources into training curricula is a key success factor for e-learning in the health professions [58•], yet few online resources are integrated into LRS surgical training programme curricula.

Sustainability

Producing high-quality e-learning material is labour intensive and often costly. Once the content is published, there are ongoing costs and administrative tasks, and soon the time rolls around where a revision is required. The time put into authoring an e-learning module may be equivalent to authoring a journal article, or delivering an in-person taught course. The administration of high-quality e-learning platforms costs money, even free platforms such as Moodle incur development and support costs. It is not sustainable to rely on volunteer authors, editors, and administrators.

After previous rapid growth, the total number of EM open-access online resources declined by 40% from 2014 to 2022 [68••]. Lin et al. attribute this to issues around financial sustainability, lack of academic recognition, and higher learner expectations [68••].

The Future of E-learning in LRSs

Champions of e-learning in surgical training in LRSs can take heart that broader changes in the world continue to alleviate some of the challenges described. Internet access continues to improve in most settings, and many learners are growing more accustomed to learning online, and to more interactive learning styles. However, there remains much to be done for e-learning to approach its potential in supporting surgical training in LRSs.

Improve Findability

In order for content to be found by the targeted learners, it must be searchable. At its simplest, this can mean ensuring that course content—which may be behind a login, or embedded within a larger course—is listed on a publicly accessible website, making it available to search engines. Bespoke search engines may be developed to help learners find content, and artificial intelligence may play a role.

Hosting content on collaborative and pre-existing platforms often makes it easier to find. Given the difficulties of finding content already described, a concentration of content on a smaller number of platforms may not be a negative outcome, if they are high-quality and sustainable. We can look to other specialties for excellent examples of platforms bringing together high-quality resources suitable for LRS trainees, such as Open Paediatrics [69] and Open Critical Care [70]. A new platform focused on surgical care systems named the United Nations Global Surgery Learning Hub "SURGhub" [56] was launched in June 2023, and provides access to high-quality surgical, anaesthetic, obstetric, and perioperative nurse training resources curated from throughout the world. As this new resource continues to grow, study of content available on the hub may help provide an understanding of where content gaps may exist.

While any list or mapping of surgical training e-learning resources will likely be incomplete, and certainly soon out of date, there is nevertheless value in such lists [46], both to help trainees and their training programmes find appropriate material, but also to avoid wasted effort and ensure that content is created only where it is fills an educational gap. A systematic review of available open-access resources in anaesthesia [63] provides a model study that could be usefully replicated in the surgical specialties.

Ensure Quality

The peer review process can, and should, be applied to newer forms of educational content [71]. Authorship, and the process by which content was reviewed, should be clearly displayed on e-learning content. A number of tools exist to help learners, training programmes, and content authors rate the quality of e-learning resources—such as the revised Medical Education Translational Resources: Impact and Quality (rMETRIQ) score [72] and the Medical Education Website Quality Evaluation Tool (MEWQET) [73]. Any listing of e-learning resources should ideally make a judgement on quality and should use a validated quality assessment tool to do so. Recommendation engines may be developed to direct learners to appropriate content using algorithms which consider factors such as usage, user ratings, and local expert review.

Quality issues can in part be attributed to a lack of understanding of e-learning principles. Learner behaviour in e-learning tends to be radically different from their behaviour in in-person teaching—for example learners tend to skim large chunks of online text, and multitask while watching long videos. High-quality e-learning resources make use of the habits that learners already have, rather than trying to change these habits. Examples include the use of short, focused videos with clear organization and summaries, knowledge checks, and tools that track progress through a course—assuming that users will drop in and out of the course rather than completing it in one sitting. Training of authors in e-learning best practice [74, 75] and high-quality instructional design may remedy these issues.

Close Gap Between Content, Trainees, and Training Programmes

It should be made explicit how resources relate to LRS curricula. Where new resources are produced, they should meet an identifiable training need, in at least one existing curriculum. Busy trainees use resources significantly more when they are required to do so—but this requires their training programmes to have proof that trainees successfully completed the course, either through access to the usage and performance data of their trainees, or course certificates of completion.

Many resources discussed in this review have no related academic publication, and where a publication exists, it is often a description of the resource, the need for the resource, or the process by which it was created. The impact of all e-learning resources should be evaluated and published, using an established evaluation model [76].

Key areas for research should be to better understand (a) the appropriateness of different resources to support training programmes in various LRS contexts, (b) the acceptability of these resources to trainees in various LRS contexts, and trainees' motivational factors for using or not using them, and (c) the impact of integrating different e-learning resources in training programmes.

Build for Sustainability

The creation of high-quality educational resources and maintenance of high-quality platforms require time and funding. Payment of authors and editors should be considered, both as an ethical principle and as a pragmatic approach to encourage timely, high-quality content production. Lin et al.'s conclusion with regard to EM online resources applies equally in the LRS surgical training context, "if the FOAM sites are to achieve independence and sustainability… the solution will rest upon finding successful business models" [68••].

Ultimately, it is primarily LRS training programmes that train the surgeons providing service in those regions. For long-term sustainability, capacity building of local LRS organizations is a key strategy. Many LRS surgical training institutions are in a position to build and manage e-learning platforms, author course content, develop e-learning strategies, and adopt, adapt, and create content to meet the needs of their own training programmes. Many more LRS institutions can be supported to do so.

Conclusion

A range of exciting technologies offer the promise of transforming surgical training worldwide. Accessible technologies such as e-learning can achieve an immediate impact. LRS surgical training can be supported both by e-learning resources specifically designed for these contexts and resources designed for other contexts. LRS trainees see both as valuable; however, LRS trainees have some specific learning needs which are best addressed through LRS learner-centred content.

Challenges to creating valuable educational experiences include infrastructural deficiencies, difficulties in finding and accessing resources, variable quality, incompleteness, repetition, and a lack of context- and curricula-focused material. Future efforts should focus on improving findability, quality, and contextual appropriateness of educational resources, while emphasizing sustainability and local ownership. The appropriateness, acceptability, and impact of e-learning resources in LRS surgical training should be evaluated.

The integration of high-quality, appropriate e-learning into LRS surgical training programmes has the potential to support a rapid expansion of surgical training in these contexts, ultimately leading to greater access to safe, affordable, and timely surgical care for those who need it.

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- • Of importance
- •• Of major importance

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