

Adoption of laparoscopy after utilization of low-cost simulation-based laparoscopy training

ABSTRACT: Introduction: Lack of access to traditional educational methods continues to hamper surgeons from learning laparoscopy in many low- and middle-income countries (LMIC). To address this gap, low-cost simulation platforms and assessment tools have been developed to support learning, practice, and assessment of laparoscopic psychomotor skills. While these tools show promise in enhancing skills, their impact on clinical practice remains unknown. ALL-SAFE, an open-source, low-cost laparoscopic surgery training system was piloted at several LMIC sites, including Mbingo Baptist Hospital (MBH). Previous studies indicate cognitive and psychomotor skill acquisition with ALL-SAFE, but its broader clinical impact needs further exploration. To characterize the impact of a laparoscopic training system beyond the simulation lab, characteristics of the practice of laparoscopic surgery were studied at MBH before and after the implementation of the ALL-SAFE program. **Methodology:** A retrospective chart review was conducted of operating room and in-patient medical records from before (January - December 2020) and after (January 2021- December 2023) the use of ALL-SAFE at MBH (2021). Total laparoscopic case volumes were extracted with proportions of laparoscopic and open surgeries calculated for surgical management of appendicitis and ectopic pregnancy. Additionally, a voluntary one-question survey soliciting barriers to implementation of laparoscopy was administered via email to all surgical faculty and residents at MBH. **Results:** At MBH, laparoscopic appendectomy accounted for 14.3% (1/7) of total appendectomy cases in 2020, 100% (7/7) in 2021, 76.9% (10/13) in 2022, and 55.6% (5/9) in 2023. Laparoscopic salpingectomy for management of ectopic pregnancy accounted for 22.2% (2/7) of total ectopic pregnancy cases in 2020, 60% (3/5) in 2021, 33.3% (2/6) in 2022, and 55.6% (5/9) in 2023. The survey findings indicated that the most frequently reported barriers to laparoscopy uptake included lack of protected operating room time, lack of structured curricula, and surgeon preference. Access to experienced trainers, equipment availability, equipment maintenance, and funding ranked as less significant. **Conclusion:** Higher laparoscopic utilization in the management of appendicitis and ectopic pregnancy was found in the years following the use of ALL-SAFE. An open-source, low-cost laparoscopic training system may have a role in increasing the volume of laparoscopic surgery, thereby impacting clinical care.

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Introduction

Though laparoscopy has become a common approach to treat many abdominal surgical pathologies, the practice of laparoscopy is still uncommon in low-and middle-income countries (LMICs). Among many identified barriers, access to affordable training remains one of the primary limitations in advancing minimally invasive surgery in

these settings. Commercial trainers and simulation centers are typically cost-prohibitive and inaccessible for most physicians seeking training in LMICs, impeding the progress of adopting laparoscopy as a routine approach. These limitations have spurred interest in low-cost simulators, accessible alternatives to acquiring laparoscopic surgery skill sets without the need for expensive equipment,[1-4].

Simulation-based education offers a low-stake opportunity to enhance transferable surgical skills,[5,6] while prioritizing patient safety,[7,8]. This allows the learner to apply academic knowledge, develop a skillset, receive effective feedback, and build confidence in a controlled setting,[8,9]. Low-cost and low-fidelity laparoscopic simulation tools have proven to be non-inferior to more expensive and sophisticated options in the development of laparoscopic surgical skills,[1,10]. Despite these demonstrated benefits, there is a notable lack of literature exploring the direct clinical impact of simulation-based education, especially in LMICs. While simulation training improves technical skills and reduces errors in controlled environments,[11], its translation to case volume and variety remains unclear.

ALL-SAFE (www.allsafe.education) is a free open-source laparoscopic surgery training platform that supports self-paced cognitive and psychomotor learning using case scenarios and models that can be built with readily available materials,[12,13]. Several early sites, including Mbingo Baptist Hospital (MBH) in Cameroon, were involved in the testing process. This training involved all 15 residents and 4 general surgeons. The first module was introduced in September 2020 and completed in December 2020. Between January 2021 and December 2023, four other modules were developed and tested at these sites. To characterize the impact of a laparoscopic training system beyond the simulation lab, characteristics of the practice of laparoscopic surgery were studied at MBH before and after the use of the ALL-SAFE program, and users were surveyed regarding the barriers to the adoption of laparoscopy in clinical practice.

Methodology

Study design

A retrospective chart review of operating room (OR) records and patient medical records of all operations conducted at MBH from January 1, 2020, to December 31, 2023, was performed. Patients who underwent laparoscopic surgery during the specified study period were identified, and their medical charts were systematically reviewed. The variables extracted included: diagnosis, type of procedure, and surgeon

performing procedure. Data were entered into a database in Microsoft Excel v. 2.73 (Microsoft Corporation), de-identified, and coded.

Cases were counted and frequencies and trends reported, with specific attention to appendectomy and surgical management of ectopic pregnancy, two procedures targeted by the ALL-SAFE system. Following confirmation of nonparametric distribution, the impact of the ALL-SAFE simulation-based training program on laparoscopic caseloads at Mbingo Baptist Hospital was analyzed using a Kruskal-Wallis test. Percent frequencies of laparoscopic appendectomies and salpingectomies of total laparoscopic cases were analyzed using Fisher's exact test. $P \leq 0.05$ was considered statistically significant.

In a parallel process, an optional one-question survey was administered to all members of the Mbingo General Surgery team of faculty ($n=6$) and residents ($n=15$) via an email from the ALL-SAFE program coordinator. The survey prompted participants to rank 10 barriers to implementation of laparoscopic procedures from 1 (least problematic) to 10 (most problematic). Each of the barrier ranking scores were summed and total rank scores reported by highest to lowest counts.

Ethical approval was obtained from the Cameroon Baptist Convention Health Board IRB.

Study setting and participants

Mbingo Baptist Hospital is a tertiary-level hospital in rural northwest Cameroon with a catchment that includes the local community as well as neighboring regions and countries. The general surgery service performs about 1100 major cases per year. The operating theatre has nine rooms with two adapted to accommodate a single laparoscopic tower that is shared between general surgery and pediatric surgery teams. The locale of Mbingo has been ravaged by civil war over the last seven years, resulting in travel restrictions and periodic roadblocks sometimes lasting for months. This has limited the consistent flow of patients, supplies, and medical personnel.

The general surgery residency program consists of 15 residents and 6 surgical staff, including 4 general surgeons, a head and neck surgeon, pediatric surgeon, and gynecologic oncologist. Two of the general surgeons (surgeons A and B) and the oncologist were trained in a high-income country (HIC) setting. The remainder of the faculty (nationals) were trained in sub-Saharan Africa. Visiting surgeons and faculty trained across the world periodically assist resident faculty.

Results

Before the onset of ALL-SAFE training in 2020, 30/424 (7.1%) major abdominal cases were performed laparoscopically. In subsequent years, the number of major abdominal cases performed laparoscopically was 60/395 (15.2%) in 2021, 50/408 (12.3%) in 2022, and 28/333 (8.4%) in 2023, $p = 0.12$ (Figure 1).

In 2020, laparoscopic appendectomy accounted for 1/7 (14.3%) of all appendectomies, increasing to 7/7 (100%) in 2021, 10/13 (76.9%) in 2022, and 5/9 (55.6%) in 2023, with no significant differences in incidence of appendectomy over time, $p > 0.05$. No laparoscopic appendectomies required conversion to an open procedure during the study period. Laparoscopic salpingectomy accounted for 2/7 (28.6%) total salpingectomies in 2020, 3/5 (60%) in 2021, 2/6 (33.3%) in 2022, and 5/9 (55.6%) in 2023, $p > 0.05$. All salpingectomies in 2020-2022 were completed laparoscopically. In 2023, 2/5 (40%) salpingectomies were converted to open due to hemodynamic instability. There was no difference in case rates across time, $p > 0.05$ (Figure 2).

In 2020, 76.7% (23/30) of laparoscopic cases were led by Surgeons A and B as well as visiting surgeons while nationals led 23.3% (7/30). In 2021, 93.3% (56/60) of cases were led by surgeons A, B, and visiting surgeons from HICs, while nationals led 6.7% (4/60). In 2022, 74% (37/50) of laparoscopic cases were led by Surgeon A, B, and visiting surgeons while nationals led 26% (13/50). In 2023, 35% (10/28) of laparoscopic cases were led by surgeons A, B, and visiting surgeons, while nationals led 64.3% (18/28) (Figure 3).

Sixteen respondents, including 2 surgeons and 14 residents (88.9% of the general surgery team) answered the question concerning perceived barriers

to laparoscopic surgery uptake at MBH. Respondents ranked lack of protected theatre time as the highest barrier to the practice of laparoscopy with a summed ranked score of 139 out of highest possible score of 160. This was followed by a lack of a training structure or curriculum and surgeons' preference, with scores of 103 and 96, respectively. Access to laparoscopic trainers, equipment maintenance, and funding ranked as the lowest barriers, with scores ranging from 57 to 31, respectively (Figure 4).

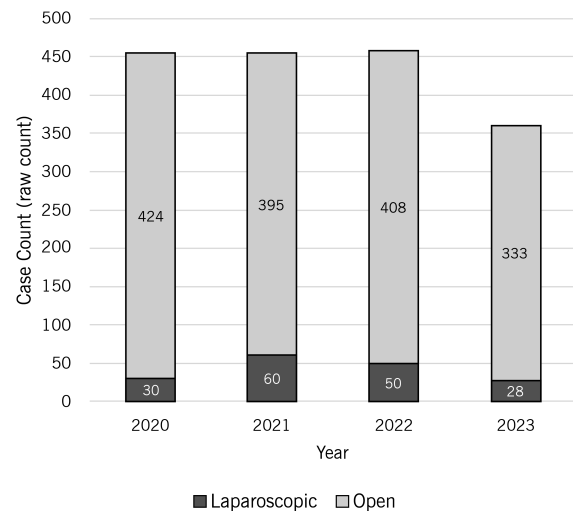


Figure 1: Laparoscopic and Open Abdominal Case Counts at MBH (2020-2023)

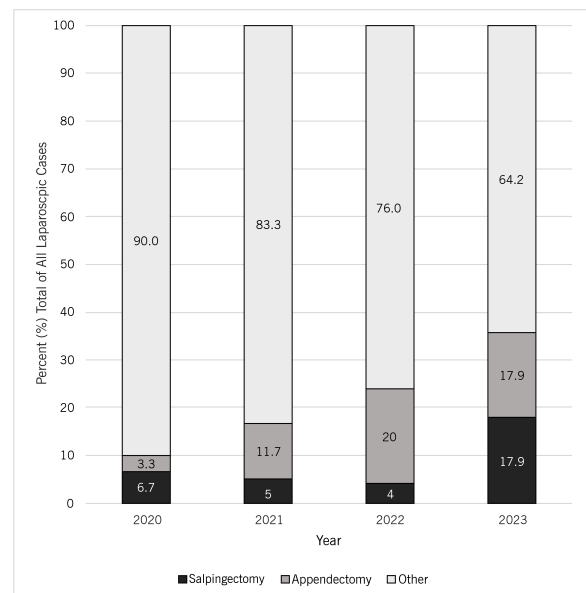


Figure 2: Laparoscopic appendectomies and salpingectomies over time as percentage of total laparoscopic surgeries, $p > 0.05$

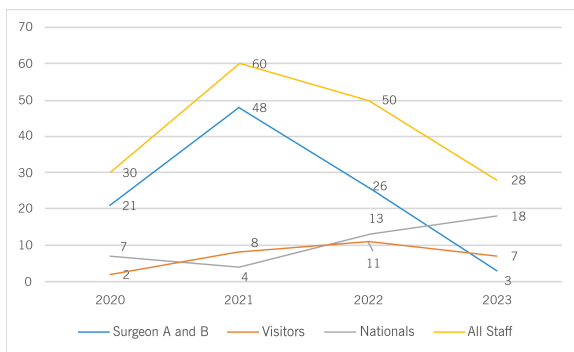


Figure 3: Distribution of Attending Surgeons for Laparoscopic Cases Over Time.

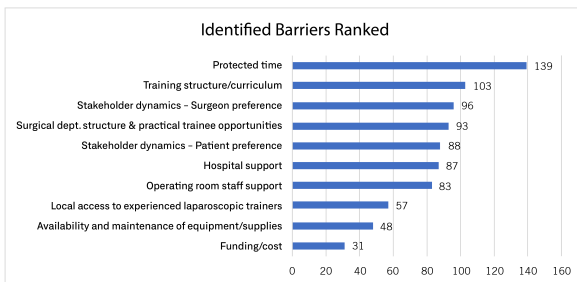


Figure 4: Ranking of barriers to uptake of laparoscopy after implementation of low-cost surgical simulation

Discussion

Higher utilization in laparoscopy was noted in the years following the use of ALL-SAFE in the management of appendicitis and ectopic pregnancy. Though laparoscopic case volume at Mbingo realized initial increasing trends, laparoscopic case volume decreased to baseline in 2023. While the initial increase in laparoscopic volume might represent a favorable endorsement of the laparoscopic surgery training platform, the subsequent decrease in laparoscopic numbers represents the reality and brings to light the challenges towards sustaining enthusiasm, advancing educational needs, and meeting continuous supply and infrastructure needs.

The decrease in laparoscopic cases in 2023 is likely due to a combination of factors including the long learning curve, the unavailability of the two main surgeons who performed laparoscopy, as well as the generally increased complexity of cases received after the multiple ghost towns and roadblocks during the civil war. During these times, there was also a need to manage the limited resources while properly selecting cases that could benefit from safe laparoscopic surgery by upcoming nationals. The decrease in total laparoscopic cases in 2023 reflects a realistic and

mature use of resources and patient selection to fit available resources.

Case trends at MBH seem to parallel trends commonly demonstrated during surgical skills progression (figure 3). As Valsamis et al describe, learning curves in surgery follow an initial rapid phase, then a phase of diminishing returns before progressing to a plateau phase. Here, new strategies are needed for continued learning, and most importantly, to avoid a decline in competency,[14]. Even though at the level of consultant, surgeons might still be on different points of the laparoscopic learning curve,[15], highlighting a need for continuous medical education, including laparoscopic simulation training. We posit that the laparoscopic trends in this study reflect the learning curve of a surgical skill, with an initial acceleration period, followed by difficulties and higher complication rates, then a stabilization of performance. The drop in total laparoscopic cases yet a progressive increase in laparoscopic cases done by nationals can also be explained by the phases of learning and progressive competence, given the long learning curve required for laparoscopy.

Furthermore, it is not uncommon in low-resource setting hospitals practicing laparoscopy to have one or a few trained surgeons who do laparoscopy (figure 3). Aghahowa et al report 119 cases done in a private hospital in Abuja Nigeria, over a 5-year period by two consultant surgeons,[16]. The practice of laparoscopy is usually on hold in their absence. The ability to continue the performance of laparoscopy even in the absence of Surgeons A and B at our center suggests a level of success in laparoscopic training.

Despite increasing adoption of laparoscopy following ALL-SAFE, significant barriers to widespread integration remain (figure 4). Given the demands of busy OR schedules and the complexity of cases, rapid patient turnover remains essential. In the initial phases, laparoscopy inherently requires longer setup and operating times compared to open surgery,[17], particularly when performed by a less experienced team. Consequently, on days with high surgical volumes, teams often prioritize procedures and techniques that facilitate quicker turnover. Also, with multiple teams sharing a single tower, competing usage and conflicting schedules are inevitable,[18]. The additional strain from a high surgical demand and

a shortage of trained staff in LMICs,[19–21] exacerbates these challenges, hindering surgeons from efficiently incorporating laparoscopy into their practice. These challenges are anticipated to continue impeding the broader adoption of laparoscopic techniques.

Finally, surgeons who have no formal laparoscopic training and possess busy work schedules may be reluctant to learn new skills,[22]. This is consistent with the report of Richstone et al, where unreceptiveness to advanced technology and preferred surgeon practice style act as barriers for diffusion of advanced surgical techniques,[23]. Continuous training initiatives are essential to gain and sustain proficiency in laparoscopic procedures. Implementation of a standard curriculum is paramount, as respondents advocated for cohesive, progressive training over disordered, sporadic modules. Tailoring curricula to build learner skill sets incrementally, scaffolded from basic to advanced levels more effectively address developmental needs, and moves away from uniform requirements that may not suit all stages of training. Emphasizing simulation-based training as a tool that promotes learning and personal growth, rather than a competition for top scores, aligns with best practice recommendations in literature,[24].

Study limitations

While our study provides valuable insights, its generalizability is constrained by its retrospective nature, single-institution design, and small sample size. Despite achieving a 90% response rate from MBH residents and faculty, it is possible our results could still misrepresent the challenges. Missing or inconsistently recorded data (e.g. complications, acuity, designating lap/open, ASA score registration, comorbidities, and surgical history), may have resulted in underestimations of laparoscopic cases and limited our ability to consider some variables in our research. Further, an unanticipated challenge, the inability to control for external environmental variables related to the civil war, was added by prolonged periods of travel restrictions and roadblocks. These external factors were beyond the scope of our control and introduced variability in patient influx, timing, and availability of materials. This may have potentially impacted the procedural workflow and outcomes but represent a reality that must be taken into consideration where applicable, in the adoption of new techniques.

Conclusion

Our study observed a trend of increased utilization of laparoscopy at MBH after the adoption of ALL-SAFE. This could indicate transferability of skills acquired through our self-paced, low-cost simulation modules to surgical practice. This expanded adoption across diverse procedures, beyond the modules covered by the platform, is encouraging and may suggest broader clinical benefits of our training approach. Further research is crucial to evaluate the clinical outcomes and benefits of low-cost simulation technologies in surgical education. Continued assessment and refinement of these tools will enhance their practical effectiveness and integration into global healthcare practices. Fostering ongoing learning and innovation in surgical training is essential for advancing patient care and outcomes globally.

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