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REVIEW

Systematic review of laparoscopic surgery in low- and middle-income countries: benefits, challenges, and strategies

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Abstract

Background Laparoscopy may prove feasible to address surgical needs in limited-resource settings. However, no aggregate data exist regarding the role of laparoscopy in low- and middle-income countries (LMICs). This study was designed to describe the issues facing laparoscopy in LMICs and to aggregate reported solutions.

Methods A search was conducted using Medline, African Index Medicus, the Directory of Open Access Journals, and the LILACS/BIREME/SCIELO database. Included studies were in English, published after 1992, and reported safety, cost, or outcomes of laparoscopy in LMICs. Studies pertaining to arthroscopy, ENT, flexible endoscopy, hysteroscopy, cystoscopy, computer-assisted surgery, pediatrics, transplantation, and bariatrics were excluded. Qualitative synthesis was performed by extracting results that fell into three categories: advantages of, challenges to, and adaptations made to implement laparoscopy in LMICs. PRISMA guidelines for systematic reviews were followed.

Results A total of 1101 abstracts were reviewed, and 58 articles were included describing laparoscopy in 25 LMICs. Laparoscopy is particularly advantageous in LMICs, where there is often poor sanitation, limited diagnostic imaging, fewer hospital beds, higher rates of hemorrhage, rising rates of trauma, and single income households. Lack of trained personnel and equipment were frequently cited challenges. Adaptive strategies included mechanical insufflation with room air, syringe suction, homemade endoloops, hand-assisted techniques, extracorporeal knot tying, innovative use of cheaper instruments, and reuse of disposable instruments. Inexpensive laboratory-based trainers and telemedicine are effective for training.

Conclusions LMICs face many surgical challenges that require innovation. Laparoscopic surgery may be safe, effective, feasible, and cost-effective in LMICs, although it often remains limited in its accessibility, acceptability, and quality. This study may not capture articles written in languages other than English or in journals not indexed by the included databases. Surgeons, policymakers, and manufacturers should focus on plans for sustainability, training and retention of providers, and regulation of efforts to develop laparoscopy in LMICs.

Keywords Global Surgery · Laparoscopy · LMIC · Low-resource settings · Training/courses

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Surgical conditions are an acknowledged and often neglected global health problem disproportionately affecting the world's poorest people [1]. Perioperative mortality is as high as 5–10 % in low-income countries (LICs) compared to 0.4–0.8 % in high-income countries, with the majority related to infections, anesthesia complications, and

hemorrhage. Inadequate infrastructure, equipment, medications, organizational management, and infection control contribute to these difficulties [2].

In developed countries, many surgical conditions are preferentially treated with minimally invasive surgery (MIS), including laparoscopy. MIS provides several advantages over open surgery, including decreased infection, decreased blood loss, reduced postoperative pain, improved bed utilization, and rapid return to work [3, 4]. These distinct advantages of laparoscopy over open operations may be even more pronounced in developing countries, where access to clean water and sanitary living conditions can be limited [5] and blood banks are scarce. In addition, modern diagnostic imaging is often not available in low- and middle-income countries (LMICs), and diagnostic laparoscopy may be both clinically and economically effective [6, 7]. For example, in a district hospital in Nigeria, the unnecessary laparotomy rate was found to be 14 % among patients with acute abdomen, resulting in 6 unnecessary deaths as well as other significant morbidity [6]. Diagnostic laparoscopy may be more cost-effective as well; the equipment cost ratio of laparoscopy/ultrasonography/CT/MRI has been estimated at 1:500:2500:4500 [7].

Laparoscopy equipment may be accessible in some LMICs as a result of laparoscopic tubal ligation campaigns that occurred in the 1970s and 1980s [8] and subsequent donations from charitable organizations. Surgeons in resource-limited settings have shown that the procedures can be affordable and patient costs can be similar to laparotomy [9, 10]. Udwadia described doing his first 3200 diagnostic laparoscopies using a single laparoscopic set and reusable instruments from 1972 to 1990. Equipment costs per case were $0.75. His next 1084 cases of laparoscopic cholecystectomies had a total cost per patient of $20 [9]. There is an abundance of literature reporting adaptations that can decrease costs and surmount other barriers to allow for more widespread utilization of laparoscopy in LMICs [7, 11].

However, some suggest that laparoscopic surgery may not be appropriate for developing countries, arguing that it is expensive, requires specialized training and technical support, and distracts attention from urgent basic needs [12]. Traditional open surgery is often considered to be safer, and in limited-resource settings, mortality can be a greater priority than both decreased morbidity and improved cosmesis.

There are no validated models that can determine the safety and feasibility of laparoscopic surgery in resource-limited settings. The purpose of this paper is to aggregate the literature, including feasibility, risks and benefits, and required adjustments. Additionally, we suggest recommendations to ensure patient safety and sustainability.

Materials and methods

This study follows the guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [13]. A database inquiry was initiated in Medline, LILACS/BIREME/SCIELO, DOAJ, and African Index Medicus for studies analyzing safety, cost, and outcome aspects of minimal invasive surgery in LMICs after 1992. Studies in English were included, but not studies pertaining to arthroscopy, ENT, flexible endoscopy, hysteroscopy, cystoscopy, computer-assisted surgery, children under 18, organ transplantation, stem cell transplantation, or bariatric surgery. Complete search terms were as follows: ("Laparoscopy" or "Thoracoscopy" or "Minimally invasive surgery or surgical procedures") + (LMIC code) + ("Safety" or "Costs and cost analysis" or "Treatment outcome" or "Mortality" or "Length of stay") − ("Endoscopy" or "Flexible endoscopy" or "Colonoscopy" or "Hysteroscopy" or "Cystoscopy" or "Computer assisted surgery" or "Eye*" or "Ocular*" or "Ophtal*" or "Nose" or "Nasal" or "Throat" or "Child*" or "Infan*" or "Adolesc*" or "Teen*" or "Pediatr*" or "Paediatr*" or "Transplant*" or "Bariatric*").

Additional articles were discovered by manually reviewing references from pertinent studies. Studies not focusing on minimal invasive surgery, studies conducted in developed countries, case reports, and editorials were excluded, as were studies for which online full-text was not available through the authors' institutions. Studies reporting advanced laparoscopic techniques were also excluded, as they likely represented well-established laparoscopy programs with abundant resources.

Results

The process of identification, abstract screening, full-text eligibility assessment, and inclusion is presented in Fig. 1. Fifty-eight articles were found describing laparoscopic surgery experiences in 25 different LMICs (Table 1).

A number of studies highlighted advantages of laparoscopy, delineated in Table 2. These benefits could be broadly classified as clinical, economic, or systemic. Many advantages paralleled those found in developed countries, while others were specific to limited-resource settings. For instance, in settings where there is no clean water in the patient's home, open incisions carry significantly higher risk of infection [5]. Because infectious diseases can cause diverse symptoms that can be challenging to diagnose with basic laboratory and radiology facilities, laparoscopy is ideal for the diagnosis of peritoneal tuberculosis [7, 14–16], the treatment of biliary ascariasis [17], and many gynecologic conditions [18–20].

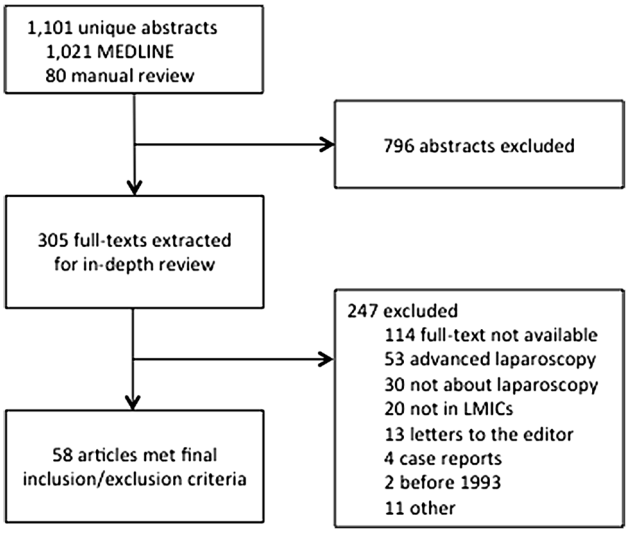

Fig. 1 Study selection

In terms of economic benefits, many studies found laparoscopy to be cost-effective [10, 21–23], and one author noted that investing in laparoscopy equipment is much cheaper than investing in CT or MRI technology [7]. Others point out that early return to work can be important in LMICs since families likely depend on day-to-day earnings and have little savings [5, 24, 25]. Similarly, the value of decreased bed utilization may be more important in LMICs since unmet surgical need is greater and inpatient capacity is smaller [26].

There were a number of challenges identified facing the development of laparoscopic surgery, shown in Table 3. Two authors cited the lack of safe clinical guidelines as a challenge particularly relevant in LMICs [26, 27]. The most common challenge named was related to the cost of laparoscopy. Some argued that high purchase costs impose the need for laparoscopic equipment to be donated [10, 28], and others posited that in the setting of widespread unemployment and low wages, early discharge was not as beneficial as others had concluded [10, 29, 30]. In countries that had health insurance, beneficiaries were likely to be provided with coverage for open operations, but not laparoscopy, resulting in high out-of-pocket costs [21]. Systemic challenges included the limited availability of trained staff [23, 31, 32] and training opportunities [15, 19, 21, 27, 28, 30, 32–36], as well as a dearth of resources to maintain equipment [19, 37] and handle challenging complications [15].

A number of adaptive measures have been undertaken to work around limitations in developing countries, as shown in Table 4. Equipment and technique alternatives include mechanical insufflation with room air [38, 39], syringe suction, homemade endoloops [9], hand-assisted techniques, extracorporeal knot tying [40], innovative uses of cheaper instruments [9, 11], and the reuse of disposable trocars and graspers [9, 12, 37, 40–43]. Spinal and local anesthesia may be safe and possibly advantageous alternatives to resource-intensive general anesthesia [9, 44–47]. Training systems using lectures, workshops, laboratory-based trainers, animal models, and telemedicine are integral in teaching skills outside of the operating room [22, 48–52].

Discussion

There are many benefits to laparoscopy that have been realized in developed countries for several decades [3, 4]. However, while laparoscopy has not yet become widely available across LMICs, it offers a number of advantages for these settings in particular. While laparoscopy is often criticized as being an expensive surgical technology, it may be highly cost-effective considering its diagnostic applications. It has been estimated that ultrasound equipment costs 500 times as much as laparoscopy equipment, while CT imaging costs 2500 times more and MRI costs 4500 times more [7]. As cars and motorcycles become more prevalent in developing countries, trauma is rising concomitantly. Diagnostic laparoscopy could reduce unnecessary laparotomies [25, 53]. Laparoscopy is also highly useful as a diagnostic tool when there is suspicion for extra-pulmonary tuberculosis and other infectious diseases [7].

In resource-poor settings, reduced postoperative hospitalization may be far more important than in high-income countries. Inpatient beds are often in limited supply since they may be required for pre-operative patients who are often pre-admitted because they must travel great distances to reach surgical care [26], patients who are unable to pay the bill, or postoperative patients that have no other suitable place to recover. Furthermore, families often have only one wage-earner, and a loss of income during a lengthy hospitalization can be devastating to the entire family [24, 25]. For laborers and merchants, there is no such concept as sick leave—i.e., no work means no pay—and they often live hand-to-mouth with little in the way of savings or investments. Additionally, in patriarchal societies, there may not be another family member who can work in place of the sick individual [5]. Many hospitals require family members to assist with nursing care, which adds to family hardship by disrupting both childcare and earning potential. However, shortened hospitalization can be risky if homes are not equipped with basic necessities such as clean water. Laparoscopic surgery is attractive because it can decrease hospitalization without the additional infection risk borne by a larger incision [5].

Anesthesia-related mortality is often higher in LMICs than high-income countries. One study reported a general anesthesia mortality rate of 1 in 504 at a central hospital in

Table 1 Included articles

Reference #	First author	Year Pub.	Country	Laparoscopy
[5]	Basha	1995	Yemen	LC
[7]	Udwadia	2004	India	DL
[9]	Udwadia	2001	India	DL
[10]	Bendinelli	2002	Senegal	Diverse
[11]	Gnanaraj	2010	India	DL
[12]	Adisa	2013	Nigeria	Diverse
[14]	Krishnan	2008	India	DL
[15]	Manning	2009	Afghanistan	LC
[16]	Malik	2011	Pakistan	DL
[17]	Astudillo	2008	Ecuador	Ascariasis Tx
[18]	Darwish	2003	Egypt	Gyn
[19]	Raiga	1999	Cameroon	Gyn
[20]	Sewta	2011	India	Gyn
[21]	Teerawattananon	2005	Thailand	LC
[22]	Straub	2011	Mongolia	LC
[23]	Dobbyne	2011	Tanzania	Diverse
[24]	Vellani	2009	Pakistan	LA
[25]	Mir	2009	India	LO
[26]	Bal	2003	India	DCLC
[27]	Brekalo	2007	Bosnia	DCLC
[28]	Bekele	2012	Ethiopia	LC
[29]	Clegg-Lamptey	2010	Ghana	LC
[30]	Tintara	1995	Thailand	Gyn
[31]	Khan	2010	Pakistan	LC
[32]	Piukala	2006	Tonga	LC
[33]	Hussain	2008	Yemen	LC
[34]	Parkar	2003	Kenya	Gyn
[35]	Mehraj	2011	Pakistan	LC
[36]	Mufti	2007	Pakistan	LC
[37]	Asbun	1996	Nicaragua, Bolivia	LC
[38]	Nande	2002	India	LC
[39]	Tintara	1998	Thailand	Gyn and DL
[40]	Adisa	2012	Nigeria	LA
[41]	Mir	2008	India	LC
[42]	Price	2013	Mongolia	Diverse
[43]	Mir	2007	India	LC
[44]	Bessa	2010	Egypt	LC
[45]	Hamad	2003	Egypt	LC
[46]	Yuksek	2008	Turkey	LC
[47]	Singh	2010	Nepal	DCLC
[48]	Merrell	1999	Zimbabwe, Ecuador	LC
[49]	Beard	2014	Tanzania	Diverse
[50]	Mir	2008	India	LC
[51]	Okrainec	2009	Botswana	Diverse
[52]	Okrainec	2010	Botswana	Diverse
[53]	Yahya	2008	Libya	DL
[56]	Chauhan	2006	India	DCLC
[57]	Garg	2009	India	LA

Table 1 continued

Reference #	First author	Year Pub.	Country	Laparoscopy
[58]	Mohamed	2013	Egypt	LA
[59]	Utpal	2005	India	LA
[60]	Ali	2010	Pakistan	LA
[61]	Mucio	1994	Mexico	LC
[62]	Malla	2010	Nepal	LC
[63]	Patel	2003	Kenya	LA
[64]	Sharma	1998	India	LC
[65]	Vijayaraghavan	2006	India	Diverse
[66]	Agarwal	2007	India	LC
[67]	Sinha	2009	India	LC

Diverse indicates many different basic laparoscopic procedures

Pub published, *LC* laparoscopic cholecystectomy, *DL* diagnostic laparoscopy, *Tx* treatment, *Gyn* gynecologic laparoscopy, *LA* laparoscopic appendectomy, *LO* laparoscopic orchiectomy, *DCLC* day care laparoscopic cholecystectomy

Table 2 Advantages of laparoscopy

Clinical	Shortened hospital stay; Decreased convalescence and pain; Faster return to work [9, 15, 17, 19, 22, 28, 30, 35, 40, 41, 51, 57–60]
	Improved clinical outcomes [9, 17, 19, 23, 24]; specifically:
	1. Smaller wound [28, 35] (particularly important in the setting of unclean water in the patient's home)[a] [5]
	2. Fewer infections [19, 22, 51, 57, 58]
	3. Fewer long-term complications, including hernias and adhesions [19, 25, 35, 40, 57, 61, 62]
	4. Less immunosuppression [51]
	5. Less abdominal drainage [58]
	Fewer unnecessary appendectomies [40]
	When imaging is limited[a] [7], laparoscopy reduces unnecessary laparotomy [25] and can be diagnostic for:
	1. Tuberculosis[a] [7, 14–16]
	2. Intra-abdominal malignancies [15]
	3. Pelvic inflammatory disease [20]
	4. Traumatic injuries [53]
	And both diagnostic and therapeutic for:
	1. Ascariasis in the biliary tree[a] [17]
	2. Gynecologic conditions and procedures, such as: paratubal and paraovarian cysts, ectopic pregnancy, hysterectomy, and tubal ligation [18–20]
Economic	Equipment cost ratio for laparoscopy/ultrasound/CT/MRI is 1:500:2500:4500[a] [7]
	More cost-effective for hospitals than open surgery [9, 10, 19, 21–23] due to:
	1. Minimal use of analgesics, antibiotics, medical supplies [9, 30]
	2. Early discharge [21, 30]
	Better for patients due to lower hospital bill [24] and quicker return to work [5, 21, 24, 25, 42] (particularly important given unequal distribution of labor)[a]
Systemic	Beds in short-supply are made available due to quicker discharge[a] [12, 26, 56]; therefore, elective surgery wait times decrease[a] [47]
	Laparoscopic training facilitates courses for basic and emergency surgical services [42]
	Gives surgeons a sense of professional accomplishment and motivation [42]
	Generates faith in the health system [42][a]

[a] Issues that may be specific to low-resource settings

Malawi, and another reported 1 in 133 deaths at a teaching hospital in Togo [54, 55]. Laparoscopy can be performed with spinal or local anesthesia instead of general by using gasless abdominal tenting, balloon laparoscopy, or creating a pneumoperitoneum with room air; all of these techniques were described in the included studies.

Table 3 Challenges facing laparoscopy

Clinical	High rate of conversion to open [14, 31]
	Higher incidence of major complications [15]
	Absence of safe guidelines[a] [26, 27]
	Increased time to perform laparoscopic operations [30, 57, 58, 60] (though decreases with experience) [40]
	No clear clinical advantage of laparoscopic appendectomy over open [60]
	Trained laparoscopic surgeon not always available [63][a]
Economic	Cost-prohibitive given hospital billing procedures[a] [5], absence of health insurance[a] [12], or insurance that only pays for open surgery[a] [21]
	Early return to work is not a priority when salaries are low[a] [10, 29, 30]
	High start-up costs [19, 21, 30, 32, 34, 41, 43, 64] often necessitate donated equipment[a] [10, 28]
	Laparoscopy costs at least the same [24] and often more than open operations [21, 28, 29, 33], although standardized discharge protocols could reduce the cost [60]
	Early discharge is not significantly cost-saving to hospitals[a] [26, 29]
	Higher costs for anesthesia due to increased OR time [30]
	Economic benefit may only apply to high-income patients [30]
Systemic	Limited availability of trained staff[a] [23, 31, 32] and high-quality training opportunities[a] [15, 19, 21, 27, 28, 30, 32–36] leads to inability to handle complications [15]
	Limited resources[a], equipment[a] [15, 31, 32, 35–37], and maintenance availability[a] [19, 37]
	After discharge, patients have poor access to telephones[a] [26, 56] and medical resources[a] [26, 47, 56]
	People mistrust the "new" [38] and may not perceive benefits due to lack of education, poor health literacy, and presence of nonscientific beliefs[a] [26, 28, 56]
	Chemical sterilization of laparoscopic equipment can lead to atypical mycobacteria infections [65]

[a] May be country- or hospital-specific issues

Certainly, there are major clinical, economic, and infrastructure-related limitations to utilizing laparoscopy in LMICs. Hospitals must overcome these infrastructure limitations and resource-allocation issues, and deal with safety and ethical concerns as well, if they hope to begin laparoscopic surgical care. In the absence of guidelines for resource-poor settings, safety is of utmost concern [26]. Staff training requires a significant investment of time and money, and there is often limited availability of individuals to serve as trainers [31–33].

While some studies have cited the cost-effectiveness of laparoscopy, others argue the opposite. It has been claimed by some that the lower costs of inpatient care [29] and surgery [26] in developing countries mean that prioritizing early discharge does not yield significant cost-savings. Others have argued that the costs of providing day surgeries in developing countries are higher than in developed settings [56]. High-cost equipment is often not available and hospitals may require donations [10, 31, 32], which may not include all the necessary components. Furthermore, it can be difficult to quickly secure repairs and replacements for high-price donated items. In the absence of a robust insurance system, these additional costs may be prohibitive to patients [5, 12]. The assertion that early discharge is an important priority for patients has also been contended. Studies conducted in Senegal have concluded that low salaries diminish the importance of an early return to work [10, 29].

There are sociocultural barriers to advancing laparoscopy in LMICs as well. People often mistrust the new technology [33] and may not perceive the benefits [56]. Lack of education, poor health literacy, and the presence of nonscientific beliefs are all contributing factors [26, 56]. As is the case with any surgery, barriers to follow-up care are abundant. Patients often have poor access to health facilities due to poverty, poor transportation infrastructure, and large distances in rural settings [26, 47, 56]. In the case of complications and emergencies, patients may not have access to any mode of communication with a health professional, much less an ability to reach a hospital [26, 56]. Furthermore, local providers who are unfamiliar with laparoscopy may not be able to appropriately assess and address complications.

A number of promising strategies have been described to overcome these barriers. When infrastructure, equipment, and training supplies remain cost-prohibitive, tactics such as using a cystoscope as a laparoscope, foregoing insufflation, or using sunlight instead of a fiberoptic light source have been described, although the safety of these techniques has not been robustly studied. A number of alternative low-cost solutions can be made as replacement

Table 4 Adaptive strategies

Infrastructure	Discharged patients asked to telephone the hospital rather than vice versa [26]
	Local soft drink manufacturers may supply affordable CO2 [42]
Equipment	Use reusable ports and instruments (though trocars need to be sharpened and disposable rubber replaced) [9, 12, 37, 40–43], using glutaraldehyde sterilization [10] or tube drapes that can be washed and autoclaved [11]
	1. Instruments can be reused for up to 18 years [9, 42]
	2. Reusable instruments save USD$300 per case [25]
	To reduce the cost of clips:
	1. Replace clips with: intracorporeal ligatures [42, 43], vicryl sutures [41], or polyglactin sutures [25]
	2. Sterilize clip applicators and reload clips [12, 42]
	3. Use low-cost laparoscopic ligatures manufactured in India [22]
	Make alternative Endopouches from low-cost condoms [42, 43], nasogastric tube covers [25, 41], 10-mm port itself [12, 40], or gloves [42]
	Make endoloops using catgut [9]
	Make cholangiography catheters with infant feeding tubes [9]
	Substitute expensive equipment:
	1. Use sunlight as a light source [7, 66]
	2. Use a sigmoidoscope air pump [9], or a locally manufactured air pump [38, 66] to create a pneumoperitoneum
	3. Use a simple hook dissector to skeletonize tubular structures [9]
	4. Use ovum forceps to make a lithotripter and stone evacuator [9]
	5. Use a cystoscope as a laparoscope [11]
	6. Replace a Harmonic scalpel with clips and diathermy [12]
	7. Make tripolar forceps with a blade in between bipolar cautery [40]
Technique	Perform gasless laparoscopy: using towel clips or wire loops to tent the abdominal skin [38, 39]; or using a laparolift, laparofan, or electric power actuator and abdominal wall retractor [39]
	Use a Gazayerli endoscopic retractor with insufflation [39]
	Perform extracorporeal ligation instead of endoloops [40]
	Perform solo laparoscopic female sterilization using 1 port and a laparocator with a camera [20]
	Use local anesthesia [9, 39]
	Use of spinal anesthesia is safe [39, 44–46], feasible with adaptations [9, 44–46, 67], and advantageous [44–46]
Training	Cheap skills labs can be created with inexpensive box trainers and laptops [41–43, 49, 50]
	Short training courses can be cheap, easy, and effective [22, 37] but may require more than 3 days [51]
	If reliable internet is accessible, FLS can be taught via telesimulation [23, 48, 52], even intra-operatively [48]

for endopouches for appendectomies or cholecystectomies, and a number of instruments can be reused.

Limitations

The techniques and modifications described here are only the tip of the iceberg. Surgeons in LMICs face significant barriers to publication in general, and to publishing reports about technical adaptations, in particular. Though we utilized African Index Medicus and LILACS-BIREME to maximize the probability of including LMIC publications, there are likely many journals that were not identified—especially those published in languages other than English. Furthermore, there may be a publication bias toward advancing laparoscopy in LMICs rather than challenging its utility. Nonetheless, we did identify several articles that presented significant obstacles, and in fact, contradicted advantages reported elsewhere. These contradictions represent differences in the costing methodology, as well as the economic circumstances of individual hospitals and countries. The LMIC category encompasses a wide range of economies with a wide spectrum of resource availability and infrastructure, even within a given country.

Recommendations

Laparoscopy should be considered an important component of surgical care that can be developed in low-resource settings.

1. Long-term planning for sustainability

    - Involvement of all stakeholders, including patients, local surgeons, anesthetists, and nurses, Ministries of Health, donors, academic institutions, and

industry is needed to assess pertinent risks and benefits within a given socioeconomic context.
- Collaborative research should help identify and propagate solutions to common challenges.
- Regional equipment production and maintenance facilities must be established to ensure cost-effectiveness. Collaborations between industry, donors, and governments can facilitate the generation of local employment opportunities.

2. Training and retention of providers

- Basic laparoscopic training should be incorporated in major teaching hospitals. Promoting training in advanced procedures may help to retain health care providers or and attract others who have left.
- Training should also be offered to operative nurses, anesthesia providers, and biomedical professionals as well as surgeons.
- Training programs can include surgical simulation using low cost, locally made trainers, internet-based surgical videos, exchange programs, telemedicine, and intraoperative practice.

3. Regulation

- Perioperative outcome data are needed to develop quality and safety measures.
- Ministries of Health and donors can collaborate to develop national programs to monitor and improve surgical quality.
- Existing surgical societies (e.g., COSECSA, WACS, PAACS) can provide mentorship and advice regarding guidelines and essential equipment and instrumentation.

Summary and future directions

Developing countries face challenges that require greater efforts in innovation. Laparoscopic surgery may be safe, effective, feasible, and cost-effective in LMICs, although it often remains limited in its accessibility, acceptability, and quality. Surgeons, policy makers, and manufacturers must work together to overcome limitations and optimize implementation where appropriate.

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References

1. Ozgediz D, Riviello R (2008) The 'other' neglected diseases in global public health: surgical conditions in sub-Saharan Africa. PLoS Med. doi:10.1371/journal.pmed.0050121
2. Gawande AA (2009) WHO guidelines for safe surgery: safe surgery saves lives. World Health Organization, Geneva
3. Nguyen NT, Goldman C, Rosenquist CJ, Arango A, Cole CJ, Lee SJ, Wolfe BM (2001) Laparoscopic versus open gastric bypass: a randomized study of outcomes, quality of life, and costs. Ann Surg 234:279–289 (discussion 289–291)
4. Murphy AA, Nager CW, Wujek JJ, Kettel LM, Torp VA, Chin HG (1992) Operative laparoscopy versus laparotomy for the management of ectopic pregnancy: a prospective trial. Fertil Steril 57:1180–1185
5. Basha YY, El-Muttarid NS, Sief M, Shamoun SE, Rypins EB (1995) The first 100 laparoscopic cholecystectomies in the Republic of Yemen. J Laparoendosc Surg 5:163–167
6. Ogbonna BC, Obekpa PO, Momoh JT, Obafunwa JO, Nwana EJ (1992) Laparoscopy in developing countries in the management of patients with an acute abdomen. Br J Surg 79:964–966
7. Udwadia TE (2004) Diagnostic laparoscopy. Surg Endosc 18: 6–10
8. Ryder RM, Vaughan MC (1999) Laparoscopic tubal sterilization. Methods, effectiveness, and sequelae. Obstet Gynecol Clin North Am 26:83–97
9. Udwadia TE (2001) One world, one people, one surgery. Surg Endosc 15:337–343
10. Bendinelli C, Leal T, Moncade F, Dieng M, Toure CT, Miccoli P (2002) Endoscopic surgery in Senegal. Benefits, costs and limits. Surg Endosc 16:1488–1492
11. Gnanaraj J (2010) Diagnostic laparoscopies in rural areas: a different use for the cystoscope. Trop Doct 40:156
12. Adisa AO, Lawal OO, Arowolo OA, Alatise OI (2013) Local adaptations aid establishment of laparoscopic surgery in a semi-urban Nigerian hospital. Surg Endosc 27:390–393
13. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group (2010) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg Lond Engl 8: 336–341
14. Krishnan P, Vayoth SO, Dhar P, Surendran S, Ponnambathayil S (2008) Laparoscopy in suspected abdominal tuberculosis is useful as an early diagnostic method. ANZ J Surg 78:987–989
15. Manning RG, Aziz AQ (2009) Should laparoscopic cholecystectomy be practiced in the developing world? the experience of the first training program in Afghanistan. Ann Surg 249: 794–798
16. Malik AM, Talpur KAH, Soomro AG, Qureshi JN (2011) Yield of diagnostic laparoscopy in abdominal tuberculosis: is it worth attempting? Surg Laparosc Endosc Percutan Tech 21:191–193
17. Astudillo JA, Sporn E, Serrano B, Astudillo R (2008) Ascariasis in the hepatobiliary system: laparoscopic management. J Am Coll Surg 207:527–532
18. Darwish AM, Amin AF, Mohammad SA (2003) Laparoscopic management of paratubal and paraovarian cysts. J Soc Laparoendosc Surg 7:101–106
19. Raiga J, Kasia JM, Bruhat MA (1999) Laparoscopic surgery in the Cameroon. Int J Gynaecol Obstet 65:65–66
20. Sewta RS (2011) Laparoscopic female sterilisation by a single port through monitor–a better alternative. J Indian Med Assoc 109:262, 263, 266
21. Teerawattananon Y, Mugford M (2005) Is it worth offering a routine laparoscopic cholecystectomy in developing countries? a Thailand case study. Cost Eff Resour Alloc 3:10

22. Straub CM, Price RR, Matthews D, Handrahan DL, Sergelen D (2011) Expanding laparoscopic cholecystectomy to rural Mongolia. World J Surg 35:751–759
23. Dobbyne C, Horgan LF (2011) Through the keyhole. J Vis Commun Med 34:98–100
24. Vellani Y, Bhatti S, Shamsi G, Parpio Y, Ali TS (2009) Evaluation of laparoscopic appendectomy vs. open appendectomy: a retrospective study at Aga Khan University Hospital, Karachi, Pakistan. J Pak Med Assoc 59:605–608
25. Mir IS, Mohsin M, Kirmani O, Cheachek BA, Alam I, Wani M (2009) Is laparoscospic orchidectomy the treatment of choice in adults with impalpable testis in rural hospitals in the developing world? Trop Doct 39:12–15
26. Bal S, Reddy LGS, Parshad R, Guleria R, Kashyap L (2003) Feasibility and safety of day care laparoscopic cholecystectomy in a developing country. Postgrad Med J 79:284–288
27. Brekalo Z, Innocenti P, Duzel G, Liddo G, Ballone E, Simunovic VJ (2006) Ten years of laparoscopic cholecystectomy: a comparison between a developed and a less developed country. Wien Klin Wochenschr 119:722–728
28. Bekele S, Biluts H (2012) Laparascopic cholecstectomy at Myungsung Christian Medical Center, Ethiopia: a five-years experience. Ethiop Med J 50:251–257
29. Clegg-Lamptey JN, Amponsah G (2010) Laparoscopic cholecystectomy at the Korle Bu Teaching Hospital, Accra, Ghana: an initial report. West Afr J Med 29:113–116
30. Tintara H, Leetanaporn R (1995) Cost-benefit analysis of laparoscopic adnexectomy. Int J Gynaecol Obstet 50:21–25
31. Khan N, Naeem M, Bangash A, Sadiq M, Hamid H (2010) Laparoscopic cholecystectomy: an experience at Lady Reading Hospital, Peshawar. J Ayub Med Coll Abbottabad 22:46–51
32. Piukala S (2006) Laparoscopic cholecystectomy: complications and experiences in Tonga. Pac Health Dialog 13:107–110
33. Hussain A, Mahmood HK, Dulku K (2008) Laparoscopic cholecystectomy can be safely performed in a resource-limited setting: the first 49 laparoscopic cholecystectomies in Yemen. J Soc Laparoendosc Surg 12:71–76
34. Parkar RB, Thagana NG, Baraza R, Otieno D (2003) Experience with laparoscopic surgery at the Aga Khan Hospital, Nairobi. East Afr Med J 80:44–50
35. Mehraj A, Naqvi MA, Feroz SH, Ur Rasheed H (2011) Laparoscopic cholecystectomy: an audit of 500 patients. J Ayub Med Coll Abbottabad 23:88–90
36. Mufti TS, Ahmad S, Naveed D, Akbar M, Zafar A (2007) Laparoscopic cholecystectomy: an early experience at Ayub Teaching Hospital Abbottabad. J Ayub Med Coll Abbottabad 19:42–44
37. Asbun HJ, Berguer R, Altamirano R, Castellanos H (1996) Successfully establishing laparoscopic surgery programs in developing countries. Clinical results and lessons learned. Surg Endosc 10:1000–1003
38. Nande AG, Shrikhande SV, Rathod V, Adyanthaya K, Shrikhande VN (2002) Modified technique of gasless laparoscopic cholecystectomy in a developing country: a 5-year experience. Dig Surg 19:366–371 (discussion 372)
39. Tintara H, Leetanaporn R, Getpook C, Suntharasaj T (1998) Simplified abdominal wall-lifting device for gasless laparoscopy. Int J Gynaecol Obstet 61:165–170
40. Adisa AO, Alatise OI, Arowolo OA, Lawal OO (2012) Laparoscopic appendectomy in a Nigerian teaching hospital. J Soc Laparoendosc Surg 16:576–580
41. Mir IS, Mohsin M, Majid T, Wani K, Hasan M, Kirmani O, Naqshbandi J, Maqbool M (2008) Laparoscopic cholecystectomy in a small rural hospital in Kashmir Valley, India. Trop Doct 38:213–216
42. Price R, Sergelen O, Unursaikhan C (2013) Improving surgical care in Mongolia: a model for sustainable development. World J Surg 37:1492–1499
43. Mir IS, Mohsin M, Kirmani O, Majid T, Wani K, Hassan M, Naqshbandi J, Maqbool M (2007) Is intra-operative cholangiography necessary during laparoscopic cholecystectomy? a multicentre rural experience from a developing world country. World J Gastroenterol 13:4493–4497
44. Bessa SS, El-Sayes IA, El-Saiedi MK, Abdel-Baki NA, Abdel-Maksoud MM (2010) Laparoscopic cholecystectomy under spinal versus general anesthesia: a prospective, randomized study. J Laparoendosc Adv Surg Tech A 20:515–520
45. Hamad MA, El-Khattary OAI (2003) Laparoscopic cholecystectomy under spinal anesthesia with nitrous oxide pneumoperitoneum: a feasibility study. Surg Endosc 17:1426–1428
46. Yuksek YN, Akat AZ, Gozalan U, Daglar G, Pala Y, Canturk M, Tutuncu T, Kama NA (2008) Laparoscopic cholecystectomy under spinal anesthesia. Am J Surg 195:533–536
47. Singh DR, Joshi MR, Koirala U, Shrestha BR, Shrestha S, Gautam B (2010) Early experience of day care surgery in Nepal. J Nepal Med Assoc 49:191–194
48. Merrell R, Rosser J (1999) Integration of quality programs by telemedicine in surgical services. Stud Health Technol Inform 64:108–114
49. Beard JH, Akoko L, Mwanga A, Mkony C, O'Sullivan P (2014) Manual laparoscopic skills development using a low-cost trainer box in Tanzania. J Surg Educ 71:85–90
50. Mir IS, Mohsin M, Malik A, Shah AQ, Majid T (2008) A structured training module using an inexpensive endotrainer for improving the performance of trainee surgeons. Trop Doct 38:217–218
51. Okrainec A, Smith L, Azzie G (2009) Surgical simulation in Africa: the feasibility and impact of a 3-day fundamentals of laparoscopic surgery course. Surg Endosc 23:2493–2498
52. Okrainec A, Henao O, Azzie G (2010) Telesimulation: an effective method for teaching the fundamentals of laparoscopic surgery in resource-restricted countries. Surg Endosc 24:417–422
53. Yahya A, Shuweiref H, Thoboot A, Ekheil M, Ali AA (2008) Laparoscopic repair of penetrating injury of the diaphragm: an experience from a district hospital. Libyan J Med 3:138–139
54. Hansen D, Gausi SC, Merikebu M (2000) Anaesthesia in Malawi: complications and deaths. Trop Doct 30:146–149
55. Ouro-Bang'na Maman AF, Tomta K, Ahouangbévi S, Chobli M (2005) Deaths associated with anaesthesia in Togo, West Africa. Trop Doct 35:220–222
56. Chauhan A, Mehrotra M, Bhatia PK, Baj B, Gupta AK (2006) Day care laparoscopic cholecystectomy: a feasibility study in a public health service hospital in a developing country. World J Surg 30:1690–1695 (discussion 1696–1697)
57. Garg CP, Vaidya BB, Chengalath MM (2009) Efficacy of laparoscopy in complicated appendicitis. Int J Surg Lond Engl 7:250–252
58. Mohamed AA, Mahran KM (2013) Laparoscopic appendectomy in complicated appendicitis: is it safe? J Minimal Access Surg 9:55–58
59. Utpal D (2005) Laparoscopic versus open appendectomy in West Bengal, India. Chin J Dig Dis 6:165–169
60. Ali R, Khan MR, Pishori T, Tayeb M (2010) Laparoscopic appendectomy for acute appendicitis: is this a feasible option for developing countries? Saudi J Gastroenterol 16:25–29
61. Mucio M, Felemovicius J, De la Concha F, Cabello R, Zamora A (1994) The Mexican experience with laparoscopic cholecystectomy and common bile duct exploration. A multicentric trial. Surg Endosc 8:306–309

62. Malla BR, Shrestha RKM (2010) Laparoscopic cholecystectomy complication and conversion rate. Kathmandu Univ Med J 8: 367–3369
63. Patel SC, Jumba GF, Akmal S (2003) Laparoscopic appendicectomy at the Aga Khan Hospital, Nairobi. East Afr Med J 80:447–451
64. Sharma AK, Rangan HK, Choubey RP (1998) Mini-lap cholecystectomy: a viable alternative to laparoscopic cholecystectomy for the Third World? ANZ J Surg 68:774–777
65. Vijayaraghavan R, Chandrashekhar R, Sujatha Y, Belagavi CS (2006) Hospital outbreak of atypical mycobacterial infection of port sites after laparoscopic surgery. J Hosp Infect 64:344–347
66. Agarwal BB, Agarwal B, Gupta M, Agarwal S, Mahajan K (2007) Anatomical footprint for safe laparoscopic cholecystectomy without using any energy source: a modified technique. Surg Endosc 21:2154–2158
67. Sinha R, Gurwara AK, Gupta SC (2009) Laparoscopic cholecystectomy under spinal anesthesia: a study of 3492 patients. J Laparoendosc Adv Surg Tech A 19:323–327