ORIGINAL RESEARCH PAPER

General Surgery

INNOVATIVE APPROACHES IN LIMITED-RESOURCE SETTINGS: USE OF A NEBULIZER AS A SUBSTITUTE INSUFFLATOR AND A SMARTPHONE FLASHLIGHT AS A LIGHT SOURCE IN LAPAROSCOPY

KEY WORDS: laparoscopy, pneumoperitoneum, insufflator failure, light source failure, smartphone flashlight, low-resource settings, surgical innovation

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ABSTRACT

Background: Minimally invasive surgery relies on reliable pneumoperitoneum creation and high-quality illumination. Sudden equipment failure during laparoscopy can compromise patient safety and often necessitates conversion to open surgery, particularly in low-resource settings where backup systems are unavailable. **Aims:** To describe and critically evaluate two emergency intraoperative adaptations—a medical nebulizer used as a substitute insufflator and a smartphone flashlight used as an alternative endoscopic light source—employed during unexpected equipment failure. **Methods:** Two intraoperative scenarios complicated by equipment malfunction were managed using improvised techniques. Safety, feasibility, physiological parameters, intraoperative stability, and postoperative outcomes were assessed and contextualized against available literature. During laparoscopic cholecystectomy complicated by sudden insufflator failure, a standard medical nebulizer was adapted to deliver gas through a 10-mm trocar, while intra-abdominal pressure (IAP) was continuously monitored via a sphygmomanometer connected through a 5-mm port. In a separate case, failure of the endoscopic light source during cystoscopic double-J stent removal was managed by coupling a smartphone flashlight with the fiberoptic cable. **Results:** Stable pneumoperitoneum (12–15 mmHg) was achieved using the nebulizer without hemodynamic or respiratory compromise, allowing completion of laparoscopic cholecystectomy without conversion. Smartphone flashlight illumination provided sufficient brightness for safe cystoscopic visualization. No intraoperative or postoperative complications were observed in either case. **Conclusion:** Emergency improvisations using commonly available devices can safely salvage minimally invasive procedures in resource-constrained environments when applied judiciously, by experienced teams, and with vigilant monitoring. These techniques must remain restricted to emergency use and should not replace standard laparoscopic equipment.

INTRODUCTION

Laparoscopic surgery has transformed modern surgical practice by offering well-established advantages over open surgery, including reduced postoperative pain, shorter hospital stays, faster functional recovery, improved cosmetic outcomes, and lower rates of wound-related complications [1,2]. The advent of laparoscopy has enabled a significant shift towards reduced surgical trauma and has become a standard in many elective abdominal procedures, including cholecystectomy, appendectomy, and gynecological surgeries. These benefits have driven the global expansion of minimally invasive surgery across multiple specialties. However, the safety and effectiveness of laparoscopy depend fundamentally on two technological pillars: the creation and maintenance of a controlled pneumoperitoneum and the provision of adequate illumination through high-intensity fiberoptic light sources. Failure of either component during surgery can abruptly compromise visualization, disrupt physiological stability, and frequently mandates conversion to open surgery, thereby negating the advantages of minimally invasive techniques [1,2].

Conversion from laparoscopic to open surgery is not a benign event. It is associated with increased operative time, higher postoperative morbidity, prolonged hospitalization, increased healthcare costs, and reduced patient satisfaction [1,2]. In well-resourced tertiary centers, equipment redundancy, technical support, and rapid replacement minimize the impact of such failures. In contrast, rural hospitals and institutions in low- and middle-income countries (LMICs) often function with limited equipment inventories, intermittent power supply, and delayed access to technical services, rendering them particularly vulnerable to intraoperative equipment malfunction.

Challenges in Low-Resource Settings: Hospitals in LMICs face multifactorial constraints, including infrastructural limitations, constrained budgets, lack of backup devices, and dependence on aging equipment. Groen et al. highlighted that equipment-related failures contribute significantly to surgical delays, cancellations, and compromised care in LMICs [3]. The World Health Organization (WHO) estimates that nearly five billion people lack timely access to safe, affordable surgical and anaesthesia care worldwide, emphasizing the need for pragmatic, context-appropriate solutions rather than exclusive reliance on costly technologies designed for high-income settings [4].

Within this context, innovation often emerges not from technological abundance but from necessity. Surgeons working in resource-constrained environments frequently develop adaptive strategies to maintain patient safety when ideal equipment is unavailable. While such improvisations must be approached with caution, systematic documentation and critical evaluation of these experiences are essential to guide safe practice.

Physiological Basis of Pneumoperitoneum: Carbon dioxide (CO_2) pneumoperitoneum is central to laparoscopic surgery, creating an operative workspace by elevating the abdominal wall away from the viscera. Standard laparoscopic practice aims to maintain IAP between 12 and 15 mmHg, balancing adequate visualization with minimal cardiopulmonary compromise [5]. Elevated IAP influences venous return, systemic vascular resistance, pulmonary compliance, and arterial carbon dioxide levels [6,7]. Excessive pressures can precipitate adverse hemodynamic and respiratory effects, particularly in patients with limited cardiopulmonary reserve.

CO_2 is preferred because of its rapid absorption, high solubility, and low risk of gas embolism. However, evidence suggests that controlled pressure rather than the specific insufflation device or even the gas itself is the principal determinant of physiological safety. Early studies demonstrated the feasibility of room-air pneumoperitoneum without increased complication rates when IAP was carefully regulated [8]. Subsequent reports from resource-limited settings corroborated these findings, emphasizing vigilant pressure control and monitoring as the cornerstone of safety [9,10].

Illumination in Endoscopic Surgery: Adequate illumination is equally critical for safe laparoscopic and cystoscopic procedures. Modern endoscopic systems rely on xenon or LED light sources transmitted through fiberoptic cables to provide high-intensity, shadow-free lighting. Sudden light source failure can instantly compromise visualization and force premature termination of procedures. Recent reports describe emergency use of smartphone LED flashlights as alternative light sources during endoscopic procedures, particularly cystoscopy, in low-resource environments [11–13]. Although not designed for medical use, the increasing luminous output of smartphone LEDs has made them a potential emergency backup when standard systems fail.

Aim

This article aims to describe two innovative emergency intraoperative adaptations applied in a resource-restricted setting: (1) use of a medical nebulizer as an alternative insufflator to maintain pneumoperitoneum during laparoscopic cholecystectomy and (2) use of a smartphone LED flashlight coupled with a fiberoptic cable as a substitute light source during cystoscopic double-J stent removal. The safety, feasibility, physiological impact, and postoperative outcomes of these adaptations are analyzed in the context of published literature and global surgery challenges.

MATERIALS AND METHODS

This descriptive observational report details two intraoperative emergency salvage strategies undertaken in the B.D. Pandey District Hospital, Nainital, India, where resource constraints and lack of backup equipment presented significant challenges.

Case 1: Nebulizer as a Substitute Insufflator during Laparoscopic Cholecystectomy

Setup: During an elective laparoscopic cholecystectomy, the standard CO insufflator unexpectedly malfunctioned. To avoid conversion to open surgery, the surgical team repurposed a medical nebulizer designed to deliver aerosolized medications by connecting sterile insufflation tubing attached to a 10-mm laparoscopic port (Figure 1). The device was used to insufflate room air to maintain pneumoperitoneum for completion of surgery.

Pressure Monitoring: A digital sphygmomanometer system was connected through a 5-mm port to continuously monitor intra-abdominal pressure (Figure 2). This manual system compensated for the lack of automated insufflation controls. The surgical team carefully regulated gas outflow to maintain IAP between 12 and 15 mmHg based on visual assessment of abdominal distension and continuous pressure readings.

Intraoperative Monitoring: Standard anaesthesia monitoring included continuous recording of heart rate, blood pressure, oxygen saturation, end-tidal CO , and respiratory rate.

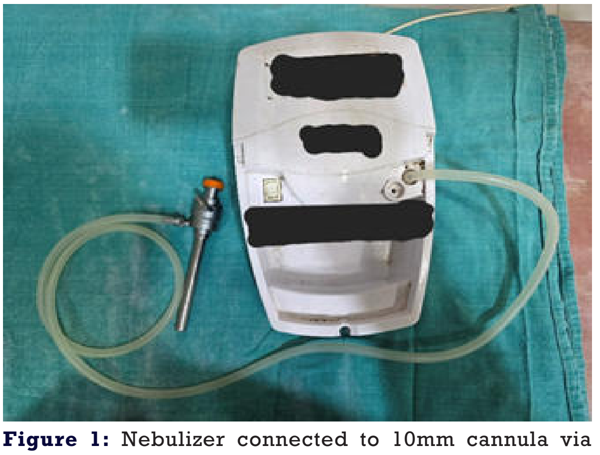

Figure 1: Nebulizer connected to 10mm cannula via insufflation tube

Figure 2: Sphygmomanometer attached to 5mm cannula

Case 2: Smartphone Flashlight as an Alternative Light Source for Cystoscopy

Setup: In a separate procedure involving cystoscopic removal of a double-J ureteral stent, the Xenon endoscopic light source failed. The fiberoptic cable was uncoupled from the defective light source and carefully aligned with overhead operating theatre lights by circulating staff for visualization but were insufficient for safe endoscopic procedure. Subsequently a high-intensity smartphone flashlight was coupled to fibreoptic cable (Figure 3). The smartphone was out of sterile field, and the flashlight was carefully positioned to maximize light output through the fiberoptic cable.

Procedure: The cystoscopy was restarted, using the smartphone flashlight for illumination, enabling safe visualization and stent removal without mucosal injury.

Precautions: The operating team ensured sterile handling of the smartphone and maintained aseptic technique. Illumination adequacy was assessed before proceeding for removal of stent.

Figure 3: *Coupling of fibreoptic cable to smartphone flashlight*

Ethical Considerations

Both innovations were applied as emergency adaptations where standard equipment was unavailable or failed, prioritizing patient safety with informed intraoperative decision-making. This improvised system was used only after careful consideration of risks and benefits. The anaesthesia team was informed, and readiness for immediate conversion to open surgery was maintained throughout. This technique was employed strictly as an emergency salvage measure by the operating surgeon and was not intended for routine use.

Ethical approval was not required as interventions served as intraoperative salvage measures during unexpected device failures.

RESULTS

Nebulizer Pneumoperitoneum System

Pneumoperitoneum Stability: Intra-abdominal pressure was successfully maintained between 12 and 15 mmHg throughout the approximately 70-minute laparoscopic cholecystectomy. Minor pressure fluctuations occurred but were manually regulated by adjusting gas outflow.

Operative Field Quality: The operative workspace was comparable to that created by conventional CO_2 insufflators, permitting clear visualization and safe dissection.

Physiologic Parameters: No significant intraoperative changes were observed in heart rate, blood pressure, oxygen saturation, or end-tidal CO_2. All remained within normal limits during the procedure, indicating adequate ventilation and cardiovascular compensation despite the alternative insufflation device.

Postoperative Course: The patient experienced an uneventful recovery with no signs of subcutaneous emphysema, gas embolism, or cardiopulmonary complications. Wound healing was normal.

Smartphone Flashlight Illumination

Illumination Adequacy: The smartphone LED flashlight provided sufficient brightness to enable clear visualization during cystoscopy. The double-J stent was safely accessed and removed without complications.

Intraoperative Safety: No mucosal injury or bleeding was noted. The procedure duration was not significantly prolonged.

Postoperative Follow-Up: There were no adverse events related to the use of the smartphone light source as there was no heating issues due to irrigation fluid used during cystoscopy.

DISCUSSION

Addressing Equipment Failures in Resource-Constrained Settings: Unexpected equipment failure during minimally invasive surgery presents significant clinical and ethical challenges, particularly in resource-constrained environments where technical support and backup systems are limited [14,15]. Emergency salvage strategies that permit completion of procedures without conversion preserve the established benefits of minimally invasive surgery while minimizing additional morbidity [1,2]. Therefore, development of safe, cost-effective, and innovative emergency adaptations that can salvage laparoscopic procedures is essential.

Pneumoperitoneum and Pressure Control: Pneumoperitoneum using CO_2 is the cornerstone of laparoscopy, facilitating visualization and intra-abdominal space creation [5]. The effect on cardiovascular and pulmonary physiology is predominantly pressure-dependent rather than gas- or equipment-dependent [5–7]. Experimental and clinical studies have established that carefully maintained IAP within 12–15 mmHg keeps physiological perturbations minimal [6,7]. Diaz et al. first demonstrated the feasibility of room-air pneumoperitoneum in laparoscopic sterilization without increased complications [8]. Subsequent studies from Nigeria and other LMICs confirmed comparable safety profiles between CO_2 and room air pneumoperitoneum when IAP is carefully regulated [9,10]. Our experience reinforces the principle that vigilant pressure monitoring is the critical determinant of safety. In our case, adapting a standard medical nebulizer as a gas insufflator allowed restoration of pneumoperitoneum during insufflator failure. The nebulizer, typically designed for aerosol delivery, offers a continuous gas flow mechanism that can be repurposed to insufflate air into the peritoneal cavity. Continuous monitoring using a connected sphygmomanometer enabled manual regulation of IAP, critical to avoiding excessive pressure-related complications such as reduced venous return, gas embolism, or pulmonary compromise [6,7,16].

Physiological and Safety Monitoring: An overriding principle in adapting novel devices for open surgery or MIS is ensuring patient safety through rigorous physiological monitoring. Laparoscopic insufflation impacts cardiopulmonary function, mandating close observation of end-tidal CO_2, hemodynamics, and oxygenation [6,7]. Torres et al. emphasized that most pneumoperitoneum-related complications are preventable through meticulous monitoring and prompt intervention [16]. O'Connor et al. described successful laparoscopic surgery in rural Africa using low-cost adaptations and careful physiological surveillance [17]. Our approach involved collaboration between the surgical and anaesthesia teams to promptly detect and manage physiological perturbations. No adverse hemodynamic events, gas embolism, or respiratory compromise were observed in the present case. The nebulizer-based system described here aligns with these reports confirming that alternative insufflators complemented with continuous pressure and physiological monitoring can be safely used as as a temporary insufflation substitute when standard equipment fails.

Smartphone Flashlight as Emergency Illumination: Backup light sources are often unavailable in low-resource theatres. Light source failure during endoscopic surgery can abruptly interrupt visualization, forcing conversion or procedure abandonment [14,15]. Modern smartphones incorporate high-intensity LED flashlights capable of delivering sufficient illumination for short endoscopic procedures, low-cost alternative for brief illumination needs in emergencies. Prior reports confirm their feasibility as backup light sources during cystoscopy and other endoscopic interventions [11–13]. Although sterility concerns exist, appropriate disinfection and sterile handling can mitigate infection risk [18]. In our case smartphone flashlight and lightsource end of fibreoptic cable was handled by circulating staff nurse.

Ethical and Safety Considerations: Improvised techniques raise important ethical considerations. Patient safety must remain paramount, and such adaptations should only be employed when the risks of abandonment or conversion outweigh the controlled risks of improvisation. Clear communication within the surgical and anaesthetic team and readiness for immediate conversion are essential.

Limitations: These techniques lack automated flow regulation, pressure alarms, and fail-safe mechanisms inherent to commercial systems [15]. Despite successful outcomes in these two cases, several limitations warrant caution. The nebulizer lacks automated flow or pressure controls and safety alarms available in dedicated insufflators, increasing risks of inadvertent over- or under-insufflation. The manual pressure monitoring via a sphygmomanometer is subject to operator variability and less precise than digital insufflator systems. Likewise, smartphone LED illumination cannot replicate the intensity and consistency of commercial xenon or LED endoscopic light sources, limiting procedure duration and usability. These techniques must, therefore, remain emergency rescue measures employed only where no alternatives exist, applied by experienced teams able to maintain vigilant monitoring and respond to potential complications promptly.

Implications for Global Surgery: The WHO advocates for contextually appropriate surgical innovations to improve access to safe surgery worldwide [4]. Low-cost innovations have demonstrated success in expanding surgical capacity, training, and resilience in LMICs [3,19,20]. Innovations like these align with global surgery goals by enabling continuation of MIS safely despite equipment failures, limiting unnecessary open conversions. Systematic reporting of such experiences contributes to evidence-based global surgery practice.

CONCLUSION

Emergency adaptation using a medical nebulizer as an alternative insufflator and a smartphone flashlight as a backup light source can safely salvage minimally invasive procedures during unexpected equipment failure in low-resource settings. When applied cautiously with stringent intraoperative patient monitoring to maintain safe intra-abdominal pressure and aseptic technique, these methods preserve surgical benefits and avoid conversion to more morbid open surgery. These methods should not replace standard equipment but may enhance surgical resilience when applied cautiously, temporarily, and under strict monitoring.

Additional Information

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Conflict Of Interest

The authors declare no conflicts of interest.

Ethical Approval

Not required due to emergency nature of interventions and observational study design.

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