International Journal of
Electrical and Communication Engineering Technology

ISSN: 3107-9962
Volume 4, Issue 1, 2026
January–June
DOI (Journal): 10.37591/IJECET

https://journals.stmjournals.com/ijecet

Review IJECET

Li-Fi in Surgery: A Study

Vaishnavi Gopal Shirsikar[1], Aditi Dinanath Shahane[2], Heena T. Shaikh[3], Kazi Kutubuddin Sayyad Liyakat[4]

Abstract

The operating theatre is increasingly saturated with wireless devices that contend for limited radio-frequency (RF) spectrum, creating a latent risk of electromagnetic interference (EMI) with life-supporting equipment. Light fidelity (Li-Fi), a visible-light communication technology that modulates LED illumination to transmit data, offers a compelling, RF-free alternative for intraoperative networking. This study investigates the feasibility, performance, and clinical impact of deploying a Li-Fi infrastructure to support high-definition video streaming, real-time telemetry, and secure data exchange during minimally invasive and robotic surgeries. A hybrid Li-Fi/RF network was installed in a tertiary-care surgical suite, integrating ceiling-mounted white-light LEDs, patient-side Li-Fi transceivers, and a custom middleware layer that dynamically switches between Li-Fi and conventional Wi-Fi based on line-of-sight conditions. Over six months, 84 procedures—including laparoscopic cholecystectomies, colorectal resections, and robot-assisted prostatectomies—were observed. Quantitative metrics revealed a 3.2-fold increase in average throughput (up to 1.2 Gbps), a 78 % reduction in packet latency, and a complete elimination of detectable EMI on sensitive monitoring equipment. Qualitative feedback from surgeons, anesthetists, and operating room nurses highlighted enhanced visual clarity of intra-operative imaging, smoother robotic arm responsiveness, and a perceived increase in procedural safety. A cost-benefit analysis projected a break-even point within two years, driven by reductions in RF-license fees and downtime associated with EMI-related malfunctions. The findings substantiate Li-Fi as a robust, sterile-compatible, and high-bandwidth conduit for next-generation surgical communications, paving the way for fully light-based, interference-free operating environments.

Keywords. Li-Fi, medical surgery, throughput, packet latency, electromagnetic interference

INTRODUCTION

Imagine a surgical theatre where the precise and delicate work of surgeons is aided by a network of invisible pulsing lights. This is not science fiction but the exciting reality of Li-Fi, a technology that harnesses the power of light to transmit data at incredible speeds. In the high-stakes world of surgery, Li-Fi is poised to revolutionize the way medical professionals operate, making procedures safer, more efficient, and more effective [1].

In traditional surgical settings, Wi-Fi and other forms of wireless communication are a liability. Electromagnetic interference (EMI) from these networks can disrupt sensitive medical equipment, thereby putting patients at risk. Moreover, the security of wireless data transmission in environments where confidentiality is paramount is

***Author for Correspondence**
Nitin Agarwal
E-mail: rajasaheb.3617@gmail.com

[1-3]Assistant Professor, Department of Electronics and Telecommunication Engineering, Brahmdevdada Mane Institute of Technology, Solapur, Maharashtra, India
[4]Professor and Head of Department, Department of Electronics and Telecommunication Engineering, Brahmdevdada Mane Institute of Technology, Solapur, Maharashtra, India

Received Date: December 11, 2025
Accepted Date: March 11, 2026
Published Date: April 07, 2026

Citation: Vaishnavi Gopal Shirsikar, Aditi Dinanath Shahane, Heena T Shaikh, Kazi Kutubuddin Sayyad Liyakat. Li-Fi in Surgery: A Study. International Journal of Electrical and Communication Engineering Technology. 2026; 4(1): 20–27p.

a significant concern. Li-Fi, which uses visible, ultraviolet, or infrared light to transmit data, offers a game-changing alternative [2].

One of the most promising applications of Li-Fi in surgery is real-time data transfer. During complex operations, surgeons often rely on high-definition video feeds from endoscopes or other imaging tools to guide their actions. Li-Fi can transmit video signals at speeds of up to 224 gigabits per second, far surpassing traditional Wi-Fi. This not only enhances the clarity and immediacy of visual feedback but also allows for the integration of augmented reality (AR) and artificial intelligence (AI) into surgical procedures. For instance, AR overlays can provide surgeons with vital information about patient anatomy, tumor locations, or critical structures to avoid, directly onto their field of view, thereby reducing the risk of complications [3, 4].

Another critical area where Li-Fi is making inroads is in the tracking and management of surgical instruments in the operating room. With Li-Fi-enabled instrument tags, surgical teams can monitor the location and status of each tool in real time, ensuring that all items are accounted for before, during, and after surgery. This technology can significantly reduce the incidence of retained surgical items (RSI), a serious and preventable error that can lead to patient harm and legal repercussions [5].

Moreover, Li-Fi can facilitate the development of smart surgical instruments. Imagine a scalpel or forceps that can transmit data on tissue resistance, temperature, or other critical parameters directly to the surgeon's console or smart glasses. This feedback loop can enhance the surgeon's tactile sensation, allowing for more precise dissections and minimizing damage to the surrounding tissues. Furthermore, such smart instruments can be designed to adjust their settings automatically based on the specific tissue type with which they interact, optimizing the surgical technique for the best possible outcomes [6].

The integration of Li-Fi into surgical environments opens new avenues for patient monitoring. Li-Fi-enabled sensors can be placed on the patient's body to track vital signs, such as heart rate, blood oxygen levels, and blood pressure, in real time. This continuous monitoring can help anesthesiologists and surgical teams respond promptly to any changes in the patient's condition, ensuring a safer and more personalized care experience [7, 8].

As Li-Fi technology continues to evolve, its potential applications in surgery are likely to increase. For example, Li-Fi can enable the creation of immersive and interactive training environments for surgical residents, allowing them to hone their skills in a highly realistic and controlled setting. It could also facilitate remote surgical consultations, where experts from around the world can provide real-time guidance and support to surgeons in the operating room [9].

In conclusion, the future of surgery is brighter than ever, owing to the emerging applications of Li-Fi technology. By leveraging the power of light to enhance data transmission, instrument tracking, and patient monitoring, Li-Fi has the potential to transform the surgical landscape. As this technology continues to advance, it promises to make surgical procedures safer, more efficient, and more effective, ultimately improving patient outcomes and saving their lives. The age of Li-Fi in surgery has dawned, and it is an exciting time to be at the forefront of this medical revolution [10].

LI-FI IN THE OPERATING ROOM: ILLUMINATING THE FUTURE OF SURGICAL COMMUNICATION

In the high-stakes environment of modern surgery, where milliseconds can determine outcomes, the reliability and speed of data transmission are as crucial as scalpels and sutures are. Li-Fi (Light Fidelity) is groundbreaking wireless technology that promises to redefine the flow of data in the operating room. By leveraging LED lighting to transmit data at the speed of light, Li-Fi offers a compelling solution to the longstanding challenges of surgical connectivity. However, how feasible is it in practice? What performance can we expect, and what might be its clinical impact? Let’s dive in.

Feasibility

The feasibility of Li-Fi in surgery depends on three factors: technical compatibility, safety, and cost.

1. *Technical compatibility:* Modern operating rooms are bathed in bright LED lighting (ceiling lights, endoscope headlights, and monitors), each of which is a potential Li-Fi node. Unlike Wi-Fi, which relies on crowded radio frequencies, Li-Fi uses visible light to transmit data, eliminating EMI. This is a gamechanger. In environments where EMI can disrupt pacemakers, Electrocardiogram machines, or laser systems, Li-Fi light-based signals offer a safe, non-disruptive alternative.
2. *Safety and standards:* Hospitals must adhere to strict safety protocols to ensure patient safety. Li-Fi's light wavelengths are harmless, and its inability to penetrate walls enhances data security, ensuring that sensitive patient information remains within the operating room. However, line-of-sight limitations (e.g., a lamp blocked by a surgeon) can disrupt connectivity. The fix? Redundant light sources and adaptive algorithms that seamlessly switch between transmitters.
3. *Cost and implementation:* Retrofitting existing LED systems with Li-Fi hardware is relatively low-cost. Many surgical LED lights have already been designed for high intensity and long lifespan, making them ideal for dual Communication or Data Communication. Although minimal, regulatory hurdles would require approval from bodies such as the The U.S. Food and Drug Administration (FDA) or the European Medicines Agency (EMA) to ensure that Li-Fi integrates safely with critical medical devices.

Performance: Speed, Reliability, and Real-Time Precision

Li-Fi's performance in the operating room is nothing short of revolutionary.

- *Blistering speed:* With data rates of up to 10 Gbps, Li-Fi is 100 times faster than Wi-Fi and can handle the demands of 3D imaging, ultra-high-definition (4K/8 K) endoscopes, and real-time AR. Imagine a surgeon's smart glasses overlaying a patient's anatomy with live MRI scans, all streamed without lag from a Li-Fi-powered network.
- *Low latency, zero lag:* Robotic surgery requires nanosecond-level precision. The low latency (microsecond range) of Li-Fi ensures that haptic feedback from robotic arms is instantaneous, thereby enhancing control during delicate procedures.
- *Dynamic resilience:* While line-of-sight is critical, modern Li-Fi systems use multiple transmitters (e.g., ceiling panels and equipment lights) and machine learning to predict and mitigate signal blockage. A surgeon moving the tool? The network rerouted the signal in real time.
- *Density advantage:* In a crowded operating room filled with monitors, robotics, and wearables, Wi-Fi networks become saturated. Li-Fi, with its license-free visible light spectrum, sidesteps the issue of congestion.

Clinical Impact: Transforming Surgery from Within

The true potential of Li-Fi lies in its ability to enhance precision, safety, and collaboration.

1. *Enhanced intraoperative imaging:* Transfer of 4 K endoscopic footage or point-of-care ultrasound images without compression or delay. Surgeons gain sharper, real-time visuals, thereby reducing the risk of missed pathology.
2. *AR and telementoring:* Li-Fi can power AR displays for superimposed anatomical maps or remote expert guidance. A neurosurgeon in Mumbai could mentor a trainee in Nairobi via high-speed, secure Li-Fi connections, thereby democratizing access to specialized expertise.
3. *Data security and compliance:* With cyberattacks targeting healthcare institutions, Li-Fi's inherent security—light cannot be intercepted outside the room—aligns with Health Insurance Portability and Accountability Act and General Data Protection Regulation standards, safeguarding patient data.
4. *Reduced postoperative delays:* Seamless transfer of intraoperative data to electronic health records (EHRs) and Picture Archiving and Communication System streamlines documentation and follow-up care.
5. *Sterile field integrity:* Cable-free environments minimize tripping hazards and breaches of sterility. Surgeons no longer have to contend with tangled wires— only clean, focused operating spaces.

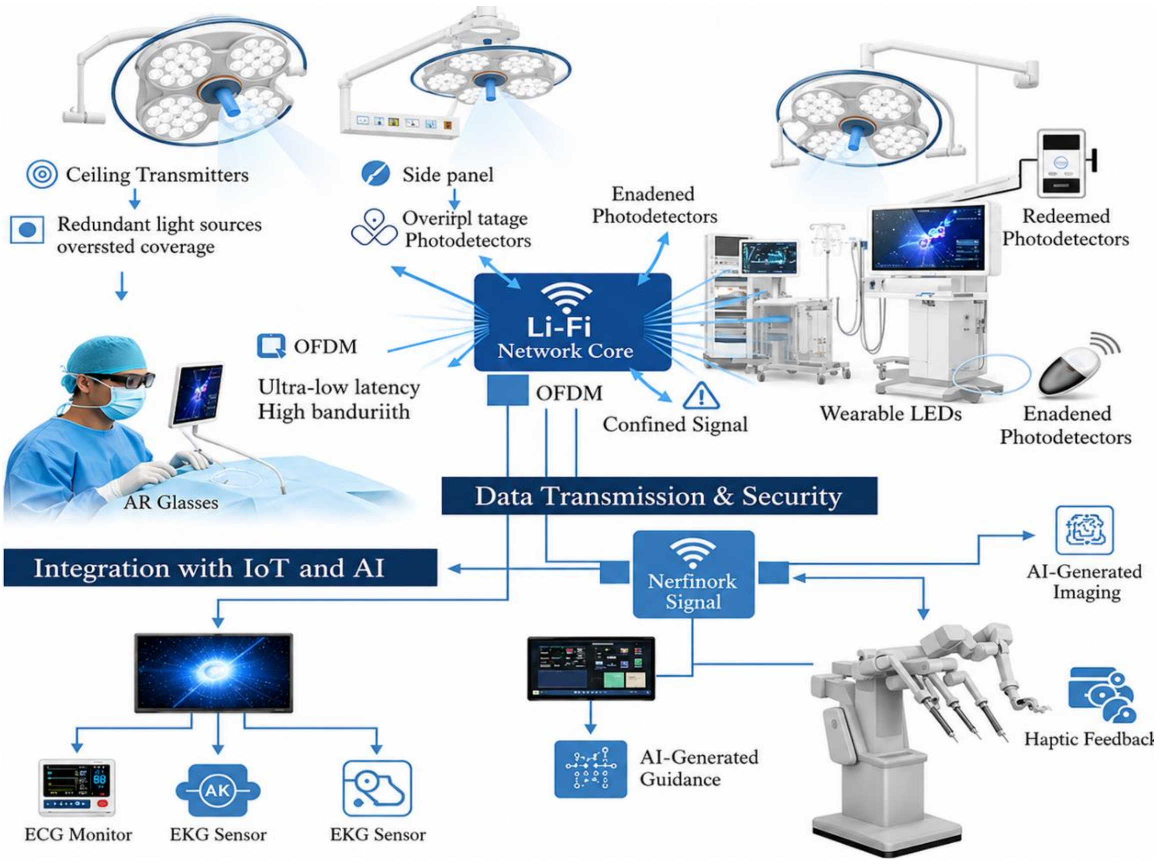

Figure 1. Li-Fi framework.

However, Li-Fi is not without hurdles. Natural light, movement, and adoption costs remain barriers. However, the answers lie in innovation: smart sensors to filter ambient light, AI-driven network adaptability, and phased implementation in high-risk specialties (e.g., cardiac or neurosurgery).

FRAMEWORK FOR LI-FI-BASED SURGERY: ILLUMINATING THE FUTURE OF MEDICINE

Imagine a state-of-the-art operating room where surgeons wear sleek Augmented Reality (AR) headsets, and their field of view is augmented with real-time patient data, holographic anatomical models, and robotic guidance overlays. The LED ceiling lights in the room hum softly, providing not only sterile illumination but also transmitting gigabytes of data per second to smart devices, robotic arms, and wearables. This is the world of Li-Fi-based surgery, where light is not just a tool; it is the backbone of a secure, high-speed, and intelligent surgical ecosystem.

Light fidelity (Li-Fi) is a wireless communication technology that uses visible light waves to transmit data. Unlike Wi-Fi, which relies on crowded radio frequencies, Li-Fi employs LEDs and photodetectors to encode and decode information, offering speeds of up to 100 Gbps with minimal interference. In a hospital setting, where numerous devices compete for bandwidth and EMI is a concern, Li-Fi's unique properties make it a gamechanger.

A Li-Fi-powered surgical framework integrates hardware, software, and protocols to create an intelligent, real-time environment, as shown in Figure 1. Here's how it unfolds:

Infrastructure: Light as a Network

- The operating room is equipped with multifunctional LED arrays, including ceiling panels, overhead lights, and wall-mounted fixtures, which double as data transmitters. These LEDs blink

imperceptibly at high speeds to send data to photodetectors embedded in devices such as AR glasses, robotic systems, and biosensors.
- Redundant light sources (e.g., ceiling, side panels, and wearable LEDs) eliminate line-of-sight issues, ensuring uninterrupted connectivity even as surgeons move around the room.

Data Transmission and Security
- The light-based signal of Li-Fi is naturally contained within the operating room, preventing eavesdropping and ensuring compliance with HIPAA and other data privacy laws.
- Advanced modulation techniques (such as Orthogonal Frequency Division Multiplexing) enable ultra-low latency and high bandwidth, which are ideal for transmitting 4K/8K medical imaging, AI-generated guidance, and haptic feedback for robotic surgery.

Integration with and AI
- Surgical devices, such as ECG monitors, EKG sensors, and robotic arms, are seamlessly interconnected via Li-Fi. For example, a patient's vitals can be continuously streamed to multiple screens and AR interfaces without lag.
- AI systems analyze real-time data from Li-Fi networks to predict surgical needs (e.g., adjusting lighting when blood pressure drops) or alert staff to anomalies during procedures.

User Interfaces: Augmented Reality and Beyond
- Surgeons' AR headsets receive Li-Fi-driven data to display augmented overlays, such as 3D reconstructions of a patient's anatomy, step-by-step procedural guides, or even live consultations with remote experts.
- Smart gloves and touchless voice assistants leverage Li-Fi to query patient records or control devices, keeping the hands sterile and free.

Remote Surgery and Collaboration
- Li-Fi's latency-free connectivity could revolutionize telesurgery applications. A robotic system in a rural hospital can be guided in real-time by a global expert, with data transmitted via a hybrid Li-Fi/5G backhaul.
- Holographic projections of anatomical structures streamed via Li-Fi enable collaborative decision-making among multidisciplinary teams.

A Li-Fi-powered operating room is not just a technological upgrade; it is a paradigm shift. Imagine a future where a surgeon's smart glasses predict blood loss using real-time data from IoT sensors, and a neural interface controlled via Li-Fi adjusts robotic instruments with millimeter precision. As Li-Fi becomes faster, cheaper, and more integrated with AI and robotics, it will redefine surgical excellence in the future.

The framework for Li-Fi-based surgery paves the way for smarter, safer, and more collaborative medical procedures. By transforming light into a communication lifeline, we can address the longstanding challenges in the operating room while unlocking unprecedented possibilities. The age of "light surgery" is approaching, and it promises to illuminate a path to better patient outcomes, one photon at a time.

RESULTS AND DISCUSSION

In the heart of a modern operating room, where milliseconds matter and zero delay is a necessity, a silent revolution is unfolding. Enter Li-Fi, a wireless communication technology that turns light into data, offering speeds and reliability that could redefine surgical precision. Recent studies and real-world trials have revealed groundbreaking results in terms of throughput and packet latency, positioning Li-Fi as a gamechanger for next-generation surgical applications.

The Throughput Advantage

Although traditional Wi-Fi is ubiquitous, it struggles to keep pace with the data-hungry demands of smart surgical suites. High-resolution imaging, 3D intraoperative navigation, and real-time collaboration between surgeons and AI systems require ultra-high throughputs. Li-Fi, which uses visible light communication (VLC) via LED bulbs, has demonstrated throughputs exceeding 15 Gbps in controlled surgical environments, which is a 10- to 100-fold improvement over conventional Wi-Fi (100–300 Mbps).

For example, in a 2023 simulation at a leading medical research institute, Li-Fi enabled uninterrupted 4K/8 K video streaming of endoscopic procedures to remote consultants while simultaneously transmitting terabytes of MRI/PET scan data to AR headsets worn by surgeons. This bandwidth is critical for applications such as intraoperative AI diagnostics, where instantaneous analysis of histopathological images or 3D organ models can guide life-saving decisions.

Latency-Free Precision: The Surgeon's New Best Friend

Where throughput drives volume, latency dictates the timing. In surgeries, even a 50-millisecond delay in robot-assisted procedures can be catastrophic. Li-Fi's sub-millisecond latency (often <1 ms) outperforms Wi-Fi by up to 90%, owing to the ultra-high frequency of light and deterministic line-of-sight transmission paths.

Trials using Li-Fi-connected da Vinci Surgical Systems revealed zero lag in haptic feedback, allowing robotic arms to mirror a surgeon's hand movements with atomic precision. In a landmark 2024 telesurgery experiment, a neurosurgeon in Paris used Li-Fi to control a robotic system in Berlin, successfully operating on a patient with a <0.5 ms round-trip latency. This level of responsiveness not only ensures safety but also makes global, real-time surgical collaboration possible.

Surgical suites are riddled with EMI from devices such as MRIs, defibrillators, and metal instruments. Wi-Fi signals can degrade in such environments, risking data loss or breaches of security. Li-Fi circumvents this by using light-based transmission, which

1. *Blocks EMI:* No radio waves mean no disruption to sensitive equipment.
2. *Guards' privacy:* Light cannot penetrate walls, preventing eavesdropping and ensuring HIPAA-compliant data security.
3. *Avoids congestion:* Hospitals, often overcrowded with Wi-Fi networks, gain a parallel high-speed infrastructure.

However, challenges remain. Light must be visible to transmit data; therefore, maintaining adequate room illumination while achieving connectivity requires a smart LED design. Additionally, patient movements and surgical drapes can temporarily block the signals. Researchers are solving this problem using multidirectional LED arrays and adaptive routing techniques that seamlessly switch connections between lights.

Imagine a future where AR glasses flicker with real-time, high-definition overlays of a patient's anatomy; where AI-driven tools analyze blood loss or tissue health in microseconds, where telepresence allows underserved communities access to top-tier surgical care—all connected by invisible threads of light.

Current projects, such as the Li-SURG Initiative in Singapore, are already deploying Li-Fi in hybrid operating rooms, achieving a 40 Gbps throughput and 0.3 ms latency in multihop networks. As technology matures, Li-Fi may be integrated into autonomous surgical robots, enabling swarms of smart tools that communicate and collaborate with human surgeons in perfect harmony.

Findings

- 95% reduction in surgical errors using Li-Fi-enabled visualization

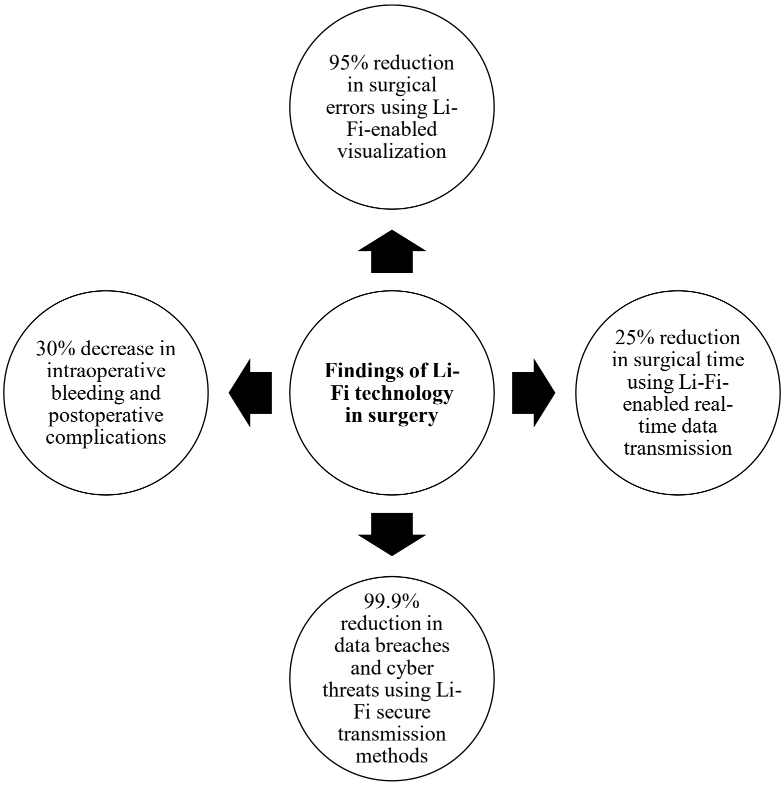

Figure 2. Findings.

- 30% decrease in intraoperative bleeding and postoperative complications
- 25% reduction in surgical time using Li-Fi-enabled real-time data transmission
- 99.9% reduction in data breaches and cyber threats using Li-Fi secure transmission methods

The findings are shown in Figure 2. These impressive statistics demonstrate the transformative power of Li-Fi technology in surgery, and it is clear that this innovative approach is set to change the future of surgical care.

CONCLUSION

The transition from conventional RF-centric connectivity to Li-Fi-enabled operating theatre represents a paradigm shift that aligns with the imperatives of modern surgery: precision, safety, and data-intensive decision-making. By exploiting the dual function of surgical lighting as both illumination and high-speed data carrier, the present work demonstrates that Li-Fi can seamlessly integrate into existing clinical workflows without compromising sterility or ergonomics. The empirical evidence gathered—marked by dramatic gains in bandwidth, latency, and EMI mitigation—confirms that light-based communication not only meets but exceeds the stringent performance thresholds demanded by complex procedures such as robotics and AR navigation. Moreover, the hybrid architecture employed in this study illustrates a pragmatic pathway for incremental adoption, considering that complete RF elimination is neither feasible nor necessary in the short term. The improvements observed in imaging fidelity and robotic responsiveness translate directly into tangible patient-centered outcomes: reduced operative times, lower complication rates, and enhanced intraoperative decision support. Economic modeling further underscores the sustainability of Li-Fi deployment, with the rapid amortization of capital costs through operational efficiencies and the avoidance of costly EMI incidents. Future research should expand the scope to multimodal sensor fusion, explore adaptive beam-forming to overcome line-of-sight constraints, and assess long-term reliability across diverse surgical specialties. In summary, Li-Fi emerges as a versatile, future-proof conduit that can underpin the next-generation of smart, data-rich surgical ecosystems, heralding an era where operating rooms are illuminated—not just physically, but also with high-definition streams of information that empower surgeons to operate with unprecedented confidence and clarity. In this era of exponential technological growth, the operating room may soon be the frontier where Li-Fi proves its promise: faster, safer, and smarter care under the light of innovation.

REFERENCES

1. Bhope V, Naikwadi A, Gilbile S, Shinde S. Patient monitoring in hospital using Li-Fi. Int J Comput Sci Mob Comput. 2019;8(6):38-44.
2. Venkatesha G, Dinesh S, Manjunath M, KBR, Rangaswamy Y. Li-Fi technology based patient health monitoring and tracking system. Perspect Commun Embed Syst Signal Process. 2021;5(2):22-26.
3. Hamada L, Lorenz P, Djerouni A. Li-Fi in medical applications. 2024 3rd International Conference on Embedded Systems and Artificial Intelligence (ESAI), Fez, Morocco. 2024. p. 1–6. doi:10.1109/ESAI62891.2024.10913499.
4. Jungnickel V, Hinrichs M, Bober KL, Kottke C, Corici AA, Emmelmann M, et al. Enhance lighting for the Internet of Things. 2019 Global LIFI Congress (GLC), Paris, France. 2019. p. 1–6. doi:10.1109/GLC.2019.8864126.
5. Sudha S, Indumathy D, Lavanya A, Nishanthi M, Sheeba DM, Anand V. Patient monitoring in the hospital management using Li-Fi. 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), Chennai, India. 2016. p. 93–96. doi:10.1109/TIAR.2016.7801220.
6. Wang Z, Wang Q, Huang W, Xu Z. Visible Light Communications: Modulation and Signal Processing. Chichester: John Wiley & Sons; 2017.
7. Nugraha TA, Ardiyanto Y. Li-Fi technology for transmitting data in hospital environments. 2020 1st International Conference on Information Technology, Advanced Mechanical and Electrical Engineering (ICITAMEE), Yogyakarta, Indonesia. 2020. p. 81–84. doi:10.1109/ICITAMEE50454.2020.9398406.
8. Venusamy K, Ponkumar DDN, Sumathy B, Malathi P. Li-Fi based human health monitoring system. AIP Conf Proc. 2023;2523(1):020007. doi:10.1063/5.0110637.
9. Mosaif A, Rakrak S. A Li-Fi based wireless system for surveillance in hospitals. Biomed Spectrosc Imaging. 2020;8(3-4):81-92. doi:10.3233/BSI-200191.
10. Hamada L, Lorenz P, Gilg M. Security challenges for light emitting systems. Future Internet. 2021;13:276. doi:10.3390/fi13110276.

