Incentivizing Artificial Intelligence in Surgery

Abstract:

Background:
Artificial intelligence (AI) is a rapidly growing technological advancement that can be used to transform surgical practice. Applications range from robotic assistance and computer-vision, to perioperative guidance and administrative tasks. Despite the promising potential of AI in surgery, limitations to its adoption remains an issue.

Objective:
The aim of this article is to produce a framework for the incentivization of widespread adoption of artificial intelligence in surgery; taking into consideration the current landscape of AI in surgery, barriers to its adoption and challenges.

Methods:
A literature search was carried out of peer-reviewed articles, policy documents, and funding program reports that are relevant to the use of AI in healthcare.

Conclusion:
Strategic financial and non-financial incentives frameworks, coupled with a continuous demonstration of clinical and economic value, are required for AI to transition from a promising innovation to a routine component of surgical practice.

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1.0 Introduction:

Artificial intelligence (AI) is a computational technology that uses algorithms to perform cognitive processes that are typically viewed to be of human intelligence, such as perception, reasoning, decision making, predictions, etc. [1, 2]. In the field of surgery, AI is gaining popularity in the use of machine-learning algorithms, computer vision, robotic assistance, automation, and education, all aimed at improving surgical performance and outcomes [1].

The increase of discussions surrounding AI in clinical practice rises from the numerous perceived benefits. Among these is enhancing precision and accuracy during surgeries. Integrating advanced imaging with machine-learning algorithms can assist surgeons in identifying critical anatomical structures, thereby optimizing operative planes and reducing the risk of inadvertent injury [2–4]. Improving efficiency, accelerating patient recovery times, are as well potential benefits of the implementation of AI in surgery [5–7]. Beyond the operating rooms, artificial intelligence has a potential in democratizing access to care [8, 9].

All together, these potential benefits suggest that AI could transform the perioperative continuum of surgery, from preoperative planning, and course prediction, to intraoperative guidance and post-operative management.

Despite the perceived promises of AI in surgery, evaluating the current limitations to its widespread adoption is needed. The economic costs of such advancements is a primary barrier [10–12]. Training requirements further complicate the implementation of artificial intelligence [11, 12]. Additionally, infrastructure limitations such as lack of high-speed connectivity, or inadequate electronic-health records pose a challenge to integration [11].

While AI has demonstrated clear potential for enhancing healthcare practices across the board, barriers to its widespread adoption remain an issue. Therefore, strategic incentives, both financial and non-financial, are critical for future adoption of AI in surgery. Targeted funding mechanisms, reimbursement reform, streamlined regulation, and national training programs that agree with the interests of stakeholders support the integration of artificial intelligence into the standard of surgical practice.

2.0 Current Landscape of AI in surgery:

Artificial Intelligence is increasingly being incorporated into the perioperative care of patients. Current applications include robotic systems, diagnostic and planning applications, risk assessment, and administrative tools [9]. In robotic surgery, AI has been augmented into systems to enhance performance with functions such as computer vision, motion control and guidance. Automation in robotic surgery is a promising addition to AI in robotic surgery, improving precision and minimizing unintended injury [13, 14].

In imaging, AI is being incorporated to provide valuable insights and detect areas of interest in diagnostic scans that can also be personalized using algorithms. AI can also provide surgeons with augmented visualization, and navigation guidance [3]. AI models are increasingly being used in the pre-operative planning stage and risk stratification. Using AI machine learning models, forecasting surgical complications, patient morbidity and mortality, as well as guiding the surgical approach or patient candidacy is possible [9].

The utilization of AI goes beyond the medical purview and into the administrative sphere, where systems can be deployed for scheduling, resource allocation, predictive analytics of patient flow, and optimizing staffing models [15].

3.0 The roles of stakeholder in AI:

Stakeholders across the healthcare ecosystem play a pivotal role in the integration of AI in surgery. There are many key stakeholders when it comes to healthcare, such as the healthcare systems and providers, public and private payers, government and regulatory bodies, technology vendors, and professional societies.

3.1. Healthcare Providers

Healthcare institutions are key stakeholders as they make decisions about investment priorities, quality improvement initiatives, institutional collaborations, data sharing etc.. Integrating artificial intelligence into systems carries a heavy financial price, therefore, healthcare systems must weigh the return on investment for such initiatives [16]. Healthcare providers emphasized the importance of systems interoperability and institutional collaborations on the integration of AI [16].

3.2. Payers

Payers, whether it's private, such as insurers, or governmental, such as Medicare and Medicaid, play a critical role through coverage policies, value-based contracts, and innovation partnerships. Payers are able to influence the adoption of AI systems based on their financial sustainability. Additionally, by setting reimbursement rules, payers can incentivize or even discourage the adoption of artificial intelligence technologies.

3.3. Regulatory Bodies

Governmental and regulatory bodies such as federal agencies, state health departments, and regulatory authorities establish policy frameworks, allocate funding, set standards, and provide oversight. These steps are crucial in establishing safety, efficacy, and ethical guidelines surrounding the use of artificial intelligence in healthcare [17]. Recently, a congressional research service (CRS) report was published by congress issuing guidance for the use of artificial intelligence in healthcare [18].

3.4. Technology Companies

Tech companies that develop AI software and surgical technologies are responsible for producing models that are accessible to varied healthcare uses. They are also responsible for providing training and technical support. All of which comes to a high financial cost, therefore, providing clinical validation and evidence of sustainability is a critical responsibility [16].

3.5. Professional Societies

Professional societies, such as Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), are well able to develop guidelines, recommendations of best practices, certifications, educational programs, and advocacy when it comes to the adoption of artificial intelligence into surgery. Setting standards for safe use, outlining competency requirements, and suggesting ethical norms are also within their purview [16]. Furthermore, healthcare professionals have indicated that there is a need for clear standards surrounding the use of AI [16].

4.0 Barriers to the adoption of AI:

The adoption of artificial intelligence in surgery faces several barriers, some of the most notable include financial costs, infrastructure, training and expertise, medicolegal and ethical considerations, and reimbursements.

Just as with any new technology, one of the main concerns surrounding the integration of AI in surgery relates to financial costs. AI-enabled surgical platforms require large investments into hardware, such as robotic systems, advanced imaging devices, and sensors [19]. Similarly, licensing AI software like machine learning models and computer vision models, are costly. On top of the upfront investments, acquiring technical support staff, regular maintenance, and validating AI models in a new setting all require additional expenditure [20]. Many hospitals around the world cannot afford to fund such initiatives.

The health institution's infrastructure is crucial in the adoption of artificial intelligence, and often acts as a barrier. AI systems require substantial computing power, with reliable data storage, fast and secure networks, and interoperable data systems. Many hospitals globally lack sufficient high-performance computers or data storage facilities that are necessary in integrating real-time data used in machine learning and computer vision. Interoperability issues wherein there is difficulty in the seamless exchange of information between AI models and electronic health records is a major obstacle as this is the main idea behind AI in surgery [21].

The gap in training and expertise when it comes to AI in surgery is another barrier that needs to be addressed [22]. Surgeons, operating room staff, and support staff may not be familiar with AI technology, making them less likely to adopt these technologies [19]. Extensive skills training with continuing education and skill development programmes are required for a successful integration. Training is aimed at adapting provider protocols, administrative workflows, pathways, and business processes [23]. Healthcare professionals will need comprehensive AI literacy, including the ability to acquire new technical skills, train and configure AI systems with high-quality data, accurately interpret algorithmic outputs while recognizing limitations, and understand how the systems learn so that bias mitigation is maintained [23]. Additionally, hospitals would need to acquire new teams with experts that can manage the AI systems [24].

Liability, privacy, bias, and lack of regulation are among the medicolegal and ethical concerns that play a role in impeding the adoption of AI systems [16, 25]. In certain instances, especially with Automation in surgery, questions of liability arise, whether the responsibility of an error rests on the healthcare institution, or the surgeons, or the tech company. Naik et al. highlighted the risk of privacy breaches, as AI systems require large amounts of sensitive patient data which would therefore necessitate rigorous cybersecurity and de-identification protocols[25]. Furthermore, bias may arise with algorithms that have been trained on non-diverse or small datasets, leading to disparities in healthcare [25].

Reimbursement is another practical barrier to the adoption of AI in surgery. To date, there are only a few procedure codes that explicitly cover AI-assisted surgeries or the use of AI in any other clinical way. Payers would be unsure of reimbursements for the use of such technologies whose value is not well established in healthcare [26]. Wu et al. reported that a limited number of AI based services are currently reimbursed under the existing reimbursement structures. The American Medical Association recognized the need for a restructure of the coding system that is well designed to accommodate novel AI tools [26, 27].

5.0 Proposed incentives for the Adoption of AI:

The high financial costs associated with the adoption of artificial intelligence in surgery remains one of the greatest barriers. Introducing a multi-layered incentives program composed of direct grants, subsidies, and targeted reimbursement policies is essential. These incentives work to offset the capital expenditure of obtaining artificial intelligence enabled surgical systems and their associated expenses.

5.1. Financial Incentives

U.S. Agencies such as the National Institutes of Health (NIH) and the Agency for Healthcare Research and Quality (AHRQ) already have programs in place that support the use of AI, and can be adapted to accelerate the adoption of AI in surgery. Both agencies offer grant programs that support the use of artificial intelligence and machine learning in healthcare. For example, the NIH Bridge2AI program is part of the NIH common fund that supports the development of AI for medical practice [28]. The AHRQ is currently funding more than 50 research projects involving AI, and one of which was a grant to control overcrowding at an emergency department of a hospital using AI [29]. The Health Resources and Services Administration (HRSA) funds initiatives that aim at improving quality of care, and more recently have shown a commitment to invest in modernized technology [30].

Private foundations with an interest in supporting healthcare improvement using AI are another source of funding that can play a critical role in the adoption of AI in surgery. Many of those foundations exist, and have played roles in underwriting studies and pilot programs for new technology in healthcare [31, 32].

Governments can also play a role in financially supporting such initiatives through research and development (R&D) tax credits and accelerated depreciation of AI capital equipment. Such incentives reduce the financial risks on the interested party, and are likely effective in encouraging the adoption of artificial intelligence technology. Government agencies and some non-profit organizations offer low-interest loan programs for healthcare facilities to invest in capital improvements, which could include AI infrastructure [33, 34].

Hospitals that demonstrate quality improvement as a result of the integration of AI can create a direct financial return for hospitals using a value-based reimbursement payment reform. Expansion of Medicare and Medicaid incentive programs to reward improved surgical outcomes, reduced readmissions, and high-value care would encourage institutions to invest in AI tools and programs. Additionally, shared-savings arrangements and pay-for-performance programs would also link reimbursements to quality of care metrics that are proven to be improved by AI.

Partnerships and collaborations with technology vendors is another way of further reducing costs. Such collaborations may result in discounted pricing, implementation support, or a shared-risk model. Vendors may provide either discounted pricing or deferred payment schedules to allow hospitals to implement AI platforms at a lower upfront cost. Supplying implementation support, such as technical expertise, training, and integration with the existing hospital systems would help in cutting the high costs of hiring new staff. The shared risk model allows vendors to absorb part of the cost if predefined performance metrics are not met, thereby lowering financial risk for hospitals, but also ensuring that vendors remain actively engaged in ensuring that their AI tools deliver clinical value [35].

Establishing new Current Procedural Terminology (CPT) codes and technology add-on payments for AI-assisted surgery or AI-enhanced care is essential to ensure sustainability. Additionally, implementing quality bonus payments and infrastructure support payments further incentivize providers to adopt AI systems [27].

5.2. Non-financial Incentives

In addition to the financial support needed for the adoption of AI technology into surgical practice. A parallel set of non-financial incentives are needed to create an environment that allows for a smoother process of adoption. Streamlined regulatory pathways, data sharing initiatives, national training programs, medicolegal and ethical considerations, and public awareness are prime examples of non-financial incentives that help in the deployment of artificial intelligence in surgery.

Regulatory agencies can encourage the adoption of new innovations by developing approval processes that are tailored to the unique characteristics of AI technology. Current pathways of approval for medical devices are time-consuming and expensive, acting as a discouraging factor in their adoption. A risk-based approval process for AI-driven surgical hardware and software can help accelerate the adoption of new innovations. For instance, the U.S. Food and Drug Administration published the “Artificial Intelligence and Machine Learning Software as a Medical Device Action Plan” (AI/ML SaMD Action Plan), proposes several mechanisms that help in expediting the ongoing development of AI systems. The expedited review processes for low-risk applications of AI further reduces the burden on developers and hospitals [36].

High-performing AI models, especially those used clinically, depend on training with large, diverse, and well annotated datasets [37]. In surgical applications, these datasets include a wide range of detailed information such as pre-operative and intraoperative imaging, operative videos, electronic health record data, etc.. Therefore, broad collaborations between institutions is critical to ensure that AI algorithms are generalizable. Without the sharing of such critical data across institutions, AI algorithms risk becoming biased toward the population of a single center, limiting generalizability and possibly worsening health disparities [37, 38]. Currently, the NIH’s Bridge2AI program is being developed to create an infrastructure that enables the sharing of biomedical datasets that meet the standards of diversity, privacy, and documentation [39]. Additionally, the American College of Surgeons National Surgical Quality Improvement Program currently offers a data sharing platform that can be expanded to include data for training and validating surgical AI systems [40].

The integration of AI in surgery may change how surgeons and medical teams plan operations, interact with imaging data, and interpret intraoperative guidance. Surgeons will need to learn how to operate new devices, and understand how algorithms are developed, validated, and maintained. National training programs with structured educational curriculums are required to develop these new skills. Collaborations between professional societies and healthcare institutions to develop standardized curricula, and formal certifications for surgeons and surgical staff [41]. Over time, such educational modules could be integrated into the educational curricula of residency programmes and medical schools to ensure foundational knowledge in AI principles.

Artificial Intelligence in surgery required clear standards for liability, and transparency to build a sense of trust in it from both the patients and healthcare professionals [16, 25, 42]. Multi-disciplinary collaboration between healthcare providers, technology vendors, legal experts, and policy makers to create a legal and ethical framework. Regulatory bodies and policy makers must deploy guidelines that ensure data privacy, algorithmic transparency, patient autonomy, and best practices [17]. Professional societies can play a pivotal role in outlining guides for best practices, while regulators enforce transparency reporting and auditing.

The general public's perception of AI in healthcare influences the pace of its adoption. Patients who do not understand how AI may contribute to their care may be hesitant to accept its use [43, 44]. Setting up educational campaigns that explain how AI is used in surgery can help the public understand its advantages. Healthcare providers, professional societies, and government agencies can collaborate on outreach programs that explains how AI works, and tackles the public's concerns about such technology. Such incentives help increase the acceptance and demand for AI in surgery.

6.0 Challenges and risks of AI:

Despite the potential for transforming surgical care, the adoption of AI is not free of challenges and risks. The integration of AI requires a clear understanding of obstacles that come with it.

The efficiency and credibility of AI models depends on the data on which they are trained [37, 45]. Currently, most datasets used in AI models are from large academic medical centers. This concentration introduces algorithmic bias, wherein algorithms may systematically underperform for patients from racial or ethnic minorities, rural communities, or those with uncommon comorbidities, thereby perpetuating existing biases in healthcare. Large, demographically diverse, and carefully annotated datasets collected from various institutions and geographic regions are critical in addressing this risk [37, 45]. Additionally, external validation of algorithms across independent cohorts along with ongoing performance monitoring are equally important.

A robust data infrastructure is essential to integrate AI, yet many hospitals worldwide still operate with outdated systems. To manage the large volumes of data required for the high performing AI algorithms, hospitals require robust safety protocols, advanced cybersecurity measures, modern electronic medical records, and large data storage capacity [46]. These infrastructure upgrades that are necessary for the implementation of AI assisted care further increases the already high costs of implementing AI-assisted care.

Artificial intelligence is aimed at enhancing, not replacing, the clinical judgement of surgeons and healthcare professionals. Clear policies must be set to define when algorithmic recommendations can inform intraoperative decisions and when human intervention must override the guidance. Trained personnel are required to operate and maintain AI platforms, monitor their performance, and interpret their outputs with their own clinical judgement [46].

Workforce disruption is another challenge imposed by the adoption of AI in surgery. In one aspect, AI could render some roles redundant, leading to job loss [47]. Health systems and professional societies would benefit from investing in retraining and upskilling programs that enable affected employees to transition into new roles that deal with AI, or train said employees to work in supervising AI systems within their scope. Such programs would protect the workforce and also create a team of professionals capable of supporting the integration of AI systems [48].

The capital investments and infrastructure required for AI development risk widening the gap between well-funded institutions and under-resourced community or rural hospitals [10, 21, 47]. To help support equitable access to AI technology, policy makers and health systems must work to form a supportive framework for underserved facilities, including subsidies for infrastructure upgrades, creation of regional AI hubs with shared services, and cloud based service models. Institutional collaborations and vendor-hospital collaborations can further help support smaller hospitals to participate in the adoption of AI in surgery.

The long term sustainability of AI in surgery depends on evidence that this technology delivers clinical and economic value. Hospitals seeking grants, payer reimbursement, or private investments will require extensive data collection and analysis that demonstrates these values attributable to the implementation of AI assistance. Prospective datasets, with transparent reporting are needed to build trust in these systems and encourage further advancing in its adoption [49].

7.0 The Roadmap for Incentivization

The successful adoption of artificial intelligence in surgery will require a phased strategy that aligns the previously discussed incentives over time. A structured road map can help interested parties coordinate efforts and track progress. Herein, we propose a three-phase roadmap that can be used to guide the successful integration of AI in surgery.

7.1. 0-5 years:

The first phase should focus on pilot programs that demonstrate feasibility and clinical value of AI in surgery. It is essential that these programs test AI tools in diverse practice settings, collecting prospective data on clinical outcomes, workflow efficiency, and cost saving. These programs should also work to include community hospitals and rural centers to minimize algorithmic bias.

At the same time, regulatory and professional bodies must begin developing the billing and reimbursement protocols for AI assisted services. The Current Procedural Terminology (CPT) codes can be modified to include AI-assisted tasks. This helps reassure hospitals and payers that AI can be smoothly integrated into the existing payment framework.

Additionally, education and awareness campaigns for both the general public, and healthcare professionals are equally important. Professional societies, and academic institutions can contribute to developing educational modules that familiarize surgeons and healthcare staff with the foundations of AI. Furthermore, it would be beneficial if medical schools integrate similar modules into their educational curricula; increasing the readiness of healthcare to adopt AI. Public awareness campaigns can help patients understand how AI is used in surgical care, emphasizing that they augment, not replace, human judgement. This builds public trust and eases the transition into AI-assisted healthcare.

7.2. 5-10 Years:

Following the demonstration of clinical and economic value of AI, the next phase should focus on scaling AI adoption. Government agencies and private investors can launch funding mechanisms that include grants, low interest loans, and targeted subsidies, to help hospitals upgrade infrastructure, purchase the necessary AI equipment, and train staff. During this period, reimbursement models should be expanded to reward measurable improvements in surgical outcomes that are a result of the integration of AI.

This phase also calls for the creation of standardized performance measurement systems. Continuous monitoring of the impact of AI on clinical outcomes, cost savings, and equity is carried out using national registries and prospective, multi-center datasets. Using transparent reporting systems can help increase confidence in these new systems among providers, patients, investors, and regulators.

7.3. 10 years and beyond:

The last stage we propose looks at the long-term sustainability of AI integration into routine surgical practice supported by a well established policy framework. Sustainable financing models, such as outcome-based contracts with technology vendors helps ensure that investments into AI continue to deliver value.

Incentives must be aligned across all stakeholders. Hospitals would have clear codes for reimbursement of AI-assisted procedures and tasks. Payers will require continuous clear evidence of improved outcomes and efficiency. At this stage, the technology vendors would share the risk with hospitals through performance-based contracts. Professional societies and regulators maintain updated guidelines surrounding the use of AI to reflect best practices.

As AI systems grow more complex, international collaboration involving cross-border data sharing and internationally accepted regulatory standards can help in the continuous evolution of AI systems. Such collaborations allow researchers to pool large, diverse datasets that are critical in improving algorithms, generalizability, and minimizing bias.

9.0. Conclusion:

The global adoption of artificial intelligence in surgery will hinge on more than merely technological breakthroughs. Such initiatives require clear evidence that AI in surgery improves patient outcomes and enhances efficiency of healthcare delivery. Demonstrating measurable gains is essential in justifying capital investments, grant procurement, and sustaining such initiatives in the long run.

Collaborative efforts among stakeholders is equally important in realizing the full potential of AI in surgery. Hospitals and surgeons must commit to carrying out clinical validation and transparent reporting of the use of AI. Technology developers need to prioritize continuous performance monitoring, sharing in the risk, and providing support. Policy makers and payers should work to ease funding, create reimbursement models, and regulatory frameworks. Patients and the public must be engaged in this initiative, to build trust and increase acceptance of such technology.

Aligning financial and non-financial incentives with patient-centered outcomes, the surgical community can in the near future transform artificial intelligence from a promising innovation into a trusted, routine component of surgical care: improving quality of care for patients worldwide.

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