gastrointestinal disorders

MDPI

Review

The Role of Artificial Intelligence and Information Technology in Enhancing and Optimizing Stapling Efficiency in Metabolic and Bariatric Surgery: A Comprehensive Narrative Review

Sjaak Pouwels [1,2,*], Alex Mwangi [3], Michail Koutentakis [4,5], Moises Mendoza [6], Sanskruti Rathod [7], Santosh Parajuli [8], Saurabh Singhal [9], Uresha Lakshani [10], Wah Yang [11], Kahei Au [12] and Safwan Taha [13]

1 Department of Surgery, University Hospital OWL of Bielefeld University–Campus Klinikum Lippe, 32756 Detmold, Germany
2 Department of Intensive Care Medicine, Elisabeth-Tweesteden Hospital, 90151 Tilburg, The Netherlands
3 College of Health Sciences, University of Nairobi, Nairobi 00100, Kenya
4 1st Chair and Department of Cardiology, Medical University of Warsaw, 02-091 Warsaw, Poland
5 Department of Experimental and Clinical Pharmacology, Medical University of Warsaw, Center for Preclinical Research and Technology CEPT, 02-097 Warsaw, Poland
6 Department of Medicine, Universidad Centroccidental Lisandro Alvarado, Barquisimeto 4501, Venezuela
7 Dr. Panjabrao Alias Bhausaheb Deshmukh Memorial Medical College, Sant Gadge Baba Amravati University, Amravati 444602, India
8 Nepal Medical College and Teaching Hospital, Kathmandu 44600, Nepal
9 Center for Liver-Gastro Intestinal Diseases and Transplantation, Aakash Healthcare, New Delhi 110045, India
10 Faculty of Medicine, University of Kelaniya, Dalugama 11600, Sri Lanka
11 Department of Metabolic and Bariatric Surgery, The First Affiliated Hospital of Jinan University, Guangzhou 510632, China
12 School of Medicine, Jinan University, Guangzhou 510632, China
13 The Metabolic and Bariatric Surgery Center of Excellence (SRC), Mediclinic Airport Road Hospital, Abu Dhabi 48481, United Arab Emirates
* Correspondence: sjaakpwls@gmail.com

check for updates

Academic Editor: Tomasz Brzozowski

Received: 29 August 2025
Revised: 18 September 2025
Accepted: 24 September 2025
Published: 30 September 2025

Citation: Pouwels, S.; Mwangi, A.; Koutentakis, M.; Mendoza, M.; Rathod, S.; Parajuli, S.; Singhal, S.; Lakshani, U.; Yang, W.; Au, K.; et al. The Role of Artificial Intelligence and Information Technology in Enhancing and Optimizing Stapling Efficiency in Metabolic and Bariatric Surgery: A Comprehensive Narrative Review. *Gastrointest. Disord.* **2025**, *7*, 63. https://doi.org/10.3390/gidisord7040063

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Abstract

Background: Over the years, surgical techniques have evolved, resulting in an abundance of available procedures in the armamentarium of metabolic and bariatric surgeons, and the technology has also advanced in a similar way. Significant steps have been made in stapling technology especially, introducing artificial intelligence (AI) in optimizing this technology for better treatment outcomes. The introduction of AI in stapling technology showed a decrease in potential stapling complications not only in MBS, but also in other (surgical) specialties. **Areas Covered**: This review will cover the general principles of stapling in surgery, but with an emphasis on both the technical and anatomical considerations. We will also discuss the mechanisms of staplers and potential safety hazards. Finally, we will focus on how AI is integrated in stapling technology, potential pros and cons, and areas for future development of stapling technology and the integration of AI. **Conclusions**: In metabolic and bariatric surgery, stapling is a technical procedure that requires a comprehensive understanding of the anatomical and physiological characteristics of the target tissue. Variability in tissue thickness, vascularity, elasticity, and mechanical load, compounded by patient-specific factors and intraoperative dynamics, demands constant vigilance and adaptability from the surgeon. The integration of AI and digital technologies offers potential improvements in refining this process. By providing real-time feedback on tissue properties and supporting intraoperative decision-making, these tools can assist surgeons in optimizing staple-line integrity and minimizing complications. The ongoing combination of surgical expertise with intelligent technology may contribute to advancing precision stapling in metabolic and bariatric surgery.

Keywords: metabolic surgery; bariatric surgery; information technology; artificial intelligence; stapling

1. Background

Over the course of the past few decades, obesity has grown to epidemic proportions and is estimated to grow even more in the coming years [1,2]. Similar growth patterns are shown in other chronic diseases and metabolic comorbidities associated with obesity [1,2]. It has been estimated that taking into account the historical growth trends, the total number of adults with either overweight or obesity in 2050 will reach a drastic number of 3.8 billion. This is approximately half of the likely global adult population at that time [1,2]. Metabolic and bariatric surgery (MBS) has proven to be an effective treatment method for obesity and associated comorbidities with durable and long-term effects [3].

Over the years, surgical techniques have evolved, resulting in an abundance of available procedures in the armamentarium of metabolic and bariatric surgeons, and the technology has also advanced in a similar way. Significant steps have been made in stapling technology especially, introducing artificial intelligence (AI) in optimizing this technology for better treatment outcomes [4]. The introduction of AI in stapling technology (also known as AI-powered stapling [4]) showed a decrease in potential stapling complications not only in MBS, but also in other (surgical) specialties [4–6]. AI can also be very helpful in designing surgical trials [7].

This comprehensive narrative review will describe the core anatomical concepts in stapling and will also describe pitfalls in AI-powered stapling. Finally, we outline future research topics to potentially further optimize stapling technology using AI and information technology.

2. General and Anatomical Considerations in Stapling for MBS

The development of surgical stapling devices has fundamentally changed the practice of MBS. Modern staplers enable surgeons to construct gastrointestinal anastomoses and resections with speed, consistency, and hemostasis, advances that have made minimally invasive bariatric procedures such as laparoscopic sleeve gastrectomy (LSG), Roux-en-Y gastric bypass (RYGB), and one-anastomosis gastric bypass (OAGB) safer and more reproducible worldwide. However, the technical success of stapling extends beyond the mechanical performance of the device. At its core, successful stapling relies on the surgeon's understanding of the target anatomy and the biological behavior of the tissues involved [8]. Variations in tissue thickness, elasticity, vascularity, mechanical load, and dynamic intraoperative changes all influence staple-line formation and healing. Moreover, these factors are modulated by patient characteristics such as age, body mass index (BMI), ethnicity, comorbidities, and prior surgical procedures [9,10].

In MBS, this complexity is particularly pronounced. Staple lines often extend across regions with highly variable tissue properties, such as the gastric wall transitioning from the thicker antrum to the thinner fundus, with corresponding differences in vascularity and elasticity. Additionally, bariatric patients often present with multiple risk factors, including diabetes mellitus, smoking, or chronic inflammation, that compromise tissue quality. The surgeon must therefore have a comprehensive understanding of how these anatomical variables interact with stapling technique. Incorrect cartridge selection or inadequate intraoperative assessment can lead to complications, such as staple-line bleeding, leaks, ischemia, or stricture formation [11,12].

At the same time, the field is entering an era of technological advancement. Digital imaging, artificial intelligence (AI), and robotic platforms are increasingly capable of providing intraoperative feedback on tissue properties, helping to guide surgical decisions in real time. To fully leverage these innovations, surgeons must maintain a strong foundation in the anatomical principles of stapling [13,14].

2.1. Tissue Thickness and Staple Height Selection

Tissue thickness remains one of the most critical anatomical variables influencing stapling outcomes [10]. Optimal staple formation requires that the closed staple height match the compressed thickness of the tissue being transected or anastomosed [15]. Mismatches can lead to over-compression, resulting in tissue ischemia, tearing, or necrosis, or under-compression, which compromises staple-line integrity and can cause bleeding or leaks [16]. Despite technological advances, most staplers still rely on the surgeon's judgment to select the appropriate cartridge, typically color-coded by closed staple height.

As stated before in MBS, tissue thickness is highly variable. Studies demonstrate regional differences along the gastric wall. The antrum, particularly near the lesser curvature, is typically 3.0–3.5 mm thick, while the fundus, particularly along the greater curvature, may measure only 1.0–1.7 mm [12]. These differences especially present challenges during sleeve gastrectomy, where a single staple-line must traverse this gradient. Misjudging this variation can result in using a cartridge suited to the antrum in the thin fundus, causing over-compression and ischemia, or selecting a cartridge based on the fundus and under-compressing the antrum [17].

Compounding these intrinsic differences are patient-specific factors. Obesity itself alters gastric wall characteristics. Increased visceral adiposity and submucosal fat infiltration can thicken the gastric walls [18], while chronic inflammation modifies tissue compliance and compressibility. Prior surgeries or endoscopic procedures, such as balloon therapy or sleeve revision, induce fibrosis and scarring, further affecting tissue behavior [19]. Visual inspection alone may be insufficient in such cases. Tactile feedback and intraoperative imaging are increasingly important for guiding cartridge choice.

Poor matching between staple height and tissue thickness can result in incomplete staple closure, early bleeding, or delayed leaks. Conversely, over-compression can impair perfusion and predispose to ischemic breakdown [8]. The emergence of AI-based thickness measurement tools, integrated into robotic platforms and next-generation staplers, offers potential for improving this process, moving the field towards more objective, intraoperative decision-making [20].

2.2. Vascularity and Perfusion

Vascularity and tissue perfusion are key factors influencing stapling outcomes. An adequately perfused staple line is essential for healing, whereas impaired blood flow increases the risk of leaks and anastomotic failure [21]. Stapling applies compression to tissue, which transiently reduces capillary blood flow. The degree of compression, coupled with pre-existing vascular status, determines the risk of ischemia along the staple line [22].

The gastrointestinal tract exhibits variable vascular architecture. The gastric fundus, supplied largely by the short gastric arteries, has relatively tenuous collateral circulation, whereas the antrum is richly supplied by the left and right gastric arteries [23,24]. Anastomoses involving the jejunum or ileum differ in vascular strength, depending on mesenteric perfusion and prior surgical manipulation [25]. Surgeons must account for these variations when constructing staple lines. In bariatric patients, comorbidities further complicate this. Diabetes mellitus, common in this population, is associated with microvascular disease, impairing tissue healing. Smoking, chronic steroid use, and prior radiation therapy also

compromise perfusion. Additionally, energy devices used during dissection, while minimizing bleeding, can damage submucosal vessels near the staple line [26]. The risk of creating an ischemic staple line is particularly significant in revision cases or previously manipulated tissues [9]. Intraoperative assessment of perfusion is increasingly recommended to mitigate this risk. Fluorescence angiography with indocyanine green (ICG) is an established method for the real-time visualization of blood flow, allowing for an assessment of staple-line viability [21]. Recent developments in AI are exploring the quantitative interpretation of ICG fluorescence, providing objective perfusion data to guide intraoperative decisions [27]. The integration of such AI-enhanced imaging into surgical workflows may further reduce the incidence of ischemia-related complications in bariatric surgery [28].

2.3. Tissue Elasticity and Mechanical Load

Tissue elasticity, defined as the ability of tissue to deform under stress and return to its original shape, significantly influences stapling outcomes. Elasticity affects tissue response to compression, the ability of staple legs to form correctly, and the behavior of the staple line under postoperative mechanical forces [8]. Younger patients with healthy gastric tissue typically exhibit favorable elasticity, allowing for uniform compression and staple formation. In contrast, fibrotic or scarred tissue, often encountered in revision surgery, may be less compliant, resulting in uneven staple formation or incomplete closure [29]. On top of that, staple lines are subject to dynamic mechanical loads postoperatively. The stomach and small intestine experience constant peristaltic motion, intraluminal pressure variations, and, in some cases, episodes of retching or vomiting, particularly during the early postoperative period [30,31]. Anastomoses under tension, such as the gastrojejunostomy in RYGB, are especially vulnerable to these forces. Improperly formed staples or staple lines under excessive tension can dehisce, leading to leaks or stricture formation [32]. Surgeons must therefore anticipate both immediate and long-term behavior of the staple line under physiological stresses. Selection of staple height, use of staple-line reinforcement, and attention to tissue tension during construction are informed by an understanding of tissue elasticity and mechanical load [33]. AI-enabled platforms that can assess tissue compliance and adjust stapling parameters in real time may contribute to improving staple-line durability [34]. With the increase in AI and related technologies, some intrinsic factors of tissue science need to be understood. In general, it can be stated that soft tissues possess intrinsic structures that are highly incompressible and anisotropic [35]. This is mainly due to the high water continent and disease states, but surgery also induces changes in the water contents of tissues and therefore their microstructure [35]. As a result, the mechanical properties of tissues might change. Over the years, research in this field has developed from simple finger-tip experiments (e.g., studying tissue properties by just touching them with your index finger) to sophisticated bio (chemical) and physical experiments to test and study the properties of human tissues in normal and disease states [35]. Especially with the emerging technologies and AI, the data of conventional mechanical characterization techniques, tension testers, compression experiments, and rotary shear applications are being integrated in computational methods to study and adapt to tissue changes, which is the case in disease and in stapling/powered stapling technology [35]. Integrating mathematical models in machine learning algorithms, especially, provides a new dimension to this research field, which results in the ability to study complex structural features and properties of biological tissues, thereby predicting the elasticity of tissues from computed stress and strain values. This basically provides a less destructive approach for the biomechanical characterization of human tissues, which has enormous advantages in research, especially stapling technology [35].

2.4. Patient Factors: Age, Ethnicity, BMI, and Prior Surgeries

Patient-specific factors exert a significant influence on tissue behavior and stapling outcomes. Age affects tissue structure and healing capacity. In pediatric patients, tissues are typically thin and highly elastic, necessitating specialized small-staple devices and careful technique to avoid over-compression [36]. In elderly patients, tissues may exhibit atrophy, fibrosis, and compromised perfusion, increasing the risk of ischemic complications and impaired healing [19]. Ethnicity may also influence tissue characteristics, though data specific to gastrointestinal tissues remain limited. Variations in collagen composition, skin and soft tissue thickness, and scarring tendencies across ethnic groups can affect tissue handling and healing responses [37]. For example, populations prone to hypertrophic scar formation may demonstrate altered responses to surgical injury, potentially impacting staple-line remodeling. BMI is a critical factor as well. In patients with morbid obesity, visceral fat deposition alters intra-abdominal anatomy and can influence gastric wall thickness and compliance [38]. Increased intra-abdominal pressure affects stapling dynamics, particularly during laparoscopic procedures [39,40].

Furthermore, prior surgeries or interventions, whether surgical (e.g., failed gastric banding) or endoscopic (e.g., balloon therapy), often result in fibrosis and scarring, complicating stapling [41,42]. These patients require careful preoperative planning and intraoperative adaptability. AI tools capable of providing real-time feedback on tissue properties hold particular value in such complex cases, offering the potential to enhance surgical precision and safety.

2.5. Intraoperative and Postoperative Tissue Changes

Tissue characteristics are not static during surgery and continue to evolve in the postoperative period, presenting an additional layer of complexity for surgical stapling in bariatric procedures. Intraoperatively, pneumoperitoneum influences tissue tension and vascular perfusion. The application of pneumoperitoneum increases intra-abdominal pressure, which in turn compresses the visceral organs and can temporarily alter tissue thickness [43,44]. Furthermore, repeated stapler firings and tissue manipulation can progressively modify tissue properties. For instance, in sleeve gastrectomy, sequential stapling from the antrum to the fundus results in a gradual reduction in tissue thickness due to both mechanical compression and fluid displacement [15,17,45].

Postoperative tissue changes further complicate staple-line behavior. In the immediate postoperative phase, edema and inflammatory responses may increase tissue thickness and alter compliance, potentially affecting perfusion along the staple line [46]. In addition to this, surgical trauma and ischemia–reperfusion injury can exacerbate these responses, leading to temporary tissue fragility. Over time, the healing process involves collagen deposition, fibrosis, and remodeling of the tissue architecture. This results in stiffening of the staple line, which may be beneficial for long-term strength but also carries the risk of functional narrowing or stricture formation, particularly in anatomically sensitive areas such as the incisura angularis in sleeve gastrectomy [47,48]. Understanding these dynamic intraoperative and postoperative changes is crucial for optimizing stapling outcomes. Surgeons must anticipate variations in tissue behavior, adjusting staple height selection, considering the use of buttressing materials, and avoiding excessive tension during staple-line construction [17,34]. Additionally, careful postoperative monitoring is essential to detect complications such as leaks or strictures that may arise from the evolving properties of the staple line [49]. As AI and digital technologies continue to advance, future tools may provide predictive insights based on intraoperative data, enabling surgeons to tailor their approach in real time to accommodate the dynamic nature of gastrointestinal tissues [50,51].

3. Current Staplers on the Market and Their Working Mechanisms

With the advancement in tools and technologies, modern surgery has seen the metamorphosis in the staplers used in surgery [52–55]. Various peculiar features of advanced staplers distinguish it from the previously used staplers. On the basis of technological use and integration of modern advancements, we can broadly classify modern surgical staplers into manual, powered, and robotic-assisted [55–57]. Furthermore, we can also emphasize the nature, quality, and ideal use cases of various modern staplers based on the company producing it. Ethicon (J&J), Medtronic (Signia™, Endo GIA™), and Intuitive Surgical (SureForm™/EndoWrist™ for DaVinci™ system) are the leading commercial systems available at market currently and are highly appreciated by surgeons [4,14,58,59].

3.1. Stapler Mechanism and Outcome

The three systems differ from each other in various aspects. Manual staplers are purely hand operated and depend upon the fineness and experience of the surgical technique of a surgeon while the powered one is operated by the use of electricity/batteries. In addition, robotic staplers are the ones which are fully automated, operated by robotic mechanisms along with fitted sensors and/or augmented reality/AI [4,14,58,59].

While focusing on the ergonomics and articulation of the staplers, the three systems differ among each other significantly. The surgeon's ability to access the complex anatomical structures and sites is aided by the precision with which the staplers can be bent or moved at its tip during surgery, i.e., articulation. Articulation of staplers used aids in defining the strength of the ergonomic of the procedure as well. Manual staplers (Ethicon Echelon™, Endo GIA™) [59]. have limited end-effector rotation, i.e., between 30–60 degrees only, which requires a surgeon to exert a significant amount of wrist torque, eventually leading to fatigue. For example, during sleeve gastrectomy, the staple lines are longer up to 60 cm, which demands a higher torque, and fatigue is inevitable. On the other hand, powered staplers (Signia™, Echelon Flex GST™) [58,59] provide a motorized articulation with each angulation, i.e., 60–90 degree and reduce the surgeon's fatigue significantly. The handles are ergonomically sound and minimize the repetitive stress injuries of the surgeons. Moreover, robotic staplers (SureForm™, EndoWrist™) when integrated into DaVinci™ console provides a wide range of multi-jointed wrist articulation up to 120 degrees [14,60]. With tremor reduction and motion-scaling sensors incorporated within the robotic system, the precision of targeting is increased while assessing the complex anatomical structure, and it is also able to support fine dissections. Furthermore, the advanced robotic system allows for remote operations, nullifying the issues related to operation table bedside ergonomics [14,60].

Various stapler cartridges are coded according to color. The diversity in stapler cartridge color helps the surgeons to track tissue thickness and compressions needed. Broadly, three colors are used, i.e., white for thin tissues like vessels, blue for standard soft tissues like small intestine, and green/black for thick and/or fibrotic tissues like the stomach and colon [4,14,58,59]. The real-time adapted nature of smart reloads (Signia™, SureForm™) allows for micro sensor-assisted firing pressure as well as preventing misalignment, and allows for automatic shutdown when compression thresholds are not met [4,58].

Compression, firing feedback, and speed play a vital role in surgery. The amount of blood loss, leakage, assurance of stapler safety, and the rate at which the wounds heal are governed by this. Being purely subjective, manual staplers are applied based on surgeons' instincts and muscle memory, and the firing speed may be slow or uneven or longer as well. Apart from this, powered staplers utilize the SmartClamp or Adaptive Firing technology which provides pre-firing checks and also provides real-time alerts regarding pressure which minimize the rate of failure as well as reducing firing-time variance. Further, during

robotic stapler use, sample compression is nearly thousand times per second, and the firing speed is auto-modulated, along with continuous monitoring of staple integrity which is helpful to nullify the errors and this system aids in consistent firing with minimal tissue shift [4,14,58,59]. Newer staplers, for example, the XNY™ Multi-Use Intelligent Powered Stapler, uses the Adaptative Cutting System (ACS), together with advanced technology like pressure sensors that adapt cutting speed and depth, while stapling tissue [61]. The XNY™ Multi-Use Intelligent Powered Stapler incorporates the ACS in combination with advanced technology such as integrated pressure sensors that dynamically adjust both cutting speed and depth during tissue stapling [61]. In addition, the device integrates a suite of AI-driven features supported by a Third-Generation Smart Chip and the ACS algorithm. These include high-frequency tissue detection for precise recognition of tissue properties, intelligent cutting adjustment that adapts to intraoperative variations, and efficient, stable performance that ensures consistency throughout procedures [61].

3.2. Clinical Performance and Applications

The reliability of a stapler used in surgery is reflected by the quality metrics. It encompasses the compression uniformity, and bleeding and leakage rate, as well as access to the tissue integrity along with the healing pattern of the wound. Stapling misfires are fewer in auto-adjusted motors, among which robotic staplers outperform all others, with higher compression uniformity [4,14,58,59]. The rate of staple-line bleeding is minimal among powered and robotic systems as well as reduced leak rates by 15–20% as compared to traditional manual stapling [14,55,57,60,62]. Additionally, uniformity among and along the staple line that is consistent in automated systems (powered and robotic stapling) tends to decrease the rate of infection and accelerate the rate of healing as compared to manual method of stapling [55].

4. Areas for Improvement of Current Stapling Technologies

Stapling devices have become essential tools in MBS, yet they are not without limitations. One of the most frequently encountered complications is bleeding from the staple line, which is reported to be up to 9.4 times more likely in certain settings, making it a leading cause of postoperative hemorrhage following sleeve gastrectomy [63]. Another significant concern is staple-line leakage, with leak rates ranging from 1% to 3%, and an associated mortality risk that can be nearly 20 times higher [63,64].

Mechanical failures, including misfiring, incomplete staple formation, and repeated firings can further compromise staple-line integrity and contribute to both bleeding and leakage [63]. A key technical challenge lies in selecting the appropriate staple height. The thickness of intra-abdominal tissues varies significantly, and mismatches can be detrimental. Staples that are too short may cut through the tissue or cause ischemia, leading to leaks. Conversely, staples that are too tall may not compress tissues sufficiently, increasing the risk of bleeding and failure to seal [65]. Surgeon-dependent variables also play a critical role in the outcome. Inadequate tissue handling, poor alignment, tissue tearing, and incorrect staple selection all contribute to higher complication rates [65,66].

These issues highlight the need for technological innovations and standardization in stapling practices. Table 1 outlines key limitations of current stapling technologies, the underlying causes, and potential improvements, many of which involve the integration of artificial intelligence (AI), real-time sensing, and smart feedback systems.

Table 1. Areas for improvement of current stapling technology.

Weakness	Underlying Issues	Evidence	Potential Improvement
Staple-line bleeding and hemorrhage	Inadequate staple compression Vascular rich areas, which are more prone to bleeding.	Research indicates that waiting a brief period after compression before firing can reduce bleeding, although it may extend the operative time [67]. Reinforcement techniques, such as oversewing and buttressing, might help decrease bleeding but can also result in ischemia and stenosis [64].	**Delay-Fire Technology:** Implement pre-programmed compression delays before stapler firing. **Feedback Mechanisms:** Provide audible or haptic alerts when minimum compression time is achieved.
Staple-line leaks (fistula)	Excessive staple-line tension. Incomplete closure due to variable gastric wall thickness	Reinforcement methods, such as oversewing, may reduce leak rates (1.4–3%), but they can prolong surgery [64]. Some meta-analyses have found no clear benefit of reinforcement in reducing leaks; in some cases, they even suggested slightly higher leak rates with buttresses [68].	**Smart staplers**: Measure firing force and tissue resistance; however, they still lack precise measurements of wall thickness. **AI-guided cartridge selection**: Based on intraoperative imaging could enhance matching accuracy.
Stapler malfunctions	Excessive staple firing	Controlled firing with slow, sequential compression (waiting approximately 30–60 s before firing) could improve staple formation and reduce bleeding [67]. Predictive tools or fewer, fuller-length loads (single-staple load devices) may help reduce total firings and complication rates [45].	**Pre-loaded 60+ mm reloads and single staple loaded devices:** This feature minimizes reloads and tissue manipulation. **Stapler Path Planning:** Intraoperative AI or AR systems project firing paths across anatomy to optimize cutting.
Tissue device mismatch	Variable gastric wall thickness Surgeons rely on "feel" and visual cues which vary with patient BMI, comorbidities. Unavailability of intraoperative device to measure exact wall thickness	Variable gastric wall thickness, which ranges from 1.6 to 4.5 mm, necessitates the use of cartridges that are appropriate for the specific location. Utilizing devices that measure tissue thickness in real-time can help guide the selection of the optimal cartridge and staple height, potentially reducing mismatches. Additionally, gripping-class stapler platforms, such as newer powered variants, can minimize tissue slippage [69].	**Smart sensing technologies**: Utilize optical or ultrasound-based sensors in stapler jaws to measure gastric wall thickness in real time. **Surface technology devices,** such as the Medtronic Signia™, aim for consistent compression force, but they do not yet feature tissue-adaptive firing.
Surgeon-related complications like improper tissue handling	Lack of training and standardization	Standardizing guidelines for firing delays, reinforcement usage, and cartridge selection would minimize variability among surgeons [65,66].	**Training and protocol standardization** Simulation training with realistic tissue models **Error-tracking staplers**

5. Necessity of Staple-Line Reinforcement

Staple-line reinforcement (SLR) is a widely utilized technique aimed at improving the security and integrity of staple lines during surgical procedures, particularly in bariatric surgery. Techniques for SLR include the use of synthetic or biological buttress materials, oversewing with sutures, and application of fibrin glue or sealants. Common materials used are synthetic (e.g., ePTFE, PGA) or biologic (e.g., bovine pericardium, SIS) [70].

The clinical necessity of SLR remains debated [66,71,72]. While many studies support SLR for reducing postoperative bleeding and leaks [72–75], others raise concerns

about increased cost, operative time, and even paradoxical increases in complication rates [64,66,68].

Meta-analyses and randomized controlled trials (RCTs) indicate a significant reduction in bleeding and leak rates with SLR (Table 2). However, outcomes are highly influenced by surgical expertise. Some findings suggest that experienced surgeons achieve similar outcomes regardless of reinforcement, while inexperienced hands may paradoxically introduce complications due to misuse of reinforcement methods [70,71].

Notably, the systematic review by Morandeira-Rivas et al. [71] cautions against indiscriminate use of SLR, citing risks such as increased inflammatory response, scar formation, anastomotic or gastric sleeve stenosis, and complications from misplacement. In conclusion, while SLR is often beneficial in reducing bleeding and leaks, it is not universally mandatory. Surgeon's skill, technical precision, and appropriate patient selection remain crucial determinants of success.

Table 2. Studies assessing outcomes of staple-line reinforcement in metabolic and bariatric surgery.

Study	Author, Journal, Year	Method	Finding	Conclusion
Is There Necessity for Oversewing the Staple Line During Laparoscopic Sleeve Gastrectomy? An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials	Wu et al. [72] Journal of investigative surgery, Dec 2019	Compared 11 RCT which included, 2411 patients (1219 patients in oversewing group (OS) and 1192 in no-oversewing group (NOS) to evaluate the effectiveness of oversewing the staple line during laparoscopic sleeve gastrectomy (LSG)	Postoperative bleeding-2.94% in NOS group and 1.23% in OS group. Postoperative leakage-1.76% on NOS group and 0.66% in OS group. Hospital stay—mean hospital stay of OS vs. NOS was 2.98 ± 2.96 days vs. 2.96 ± 1.61 days. Operative time—mean operative time of OS vs. NOS was 74.45 ± 27.48 min vs. 58.87 ± 22.86 min.	Oversewing the staple line significantly decreases the incident of postoperative bleeding by 52% and decreases the incidence of postoperative leakage by 56%. It has no effect on length of hospital stay, but prolongs the operative time.
Clinical Benefit of Gastric Staple Line Reinforcement (SLR) in Gastrointestinal Surgery: a Meta-analysis	Shikora et al. [73] Obes Surg. 2015	Data extracted in 253 studies. Leaking and bleeding compared in surgeries with no staple-line reinforcement, staple-line reinforcement using oversuture/bovine pericardium/glycolide copolymer.	Non-staple-line reinforcement (SLR) vs. reinforcement with oversuture vs. bovine pericardium vs. glycolide copolymer; Postoperative bleeding: 42.5% vs. 34.3% vs. 16.1% vs. 7.0% Postoperative leaking: 46.2% vs. 35.1% vs. 12.1% vs. 6.6%	SLR provided superior results for patients compared to no reinforcement for reducing staple-line complications. Buttressing with bovine pericardium resulted in the most favorable outcomes.

Table 2. *Cont.*

Study	Author, Journal, Year	Method	Finding	Conclusion
Staple-line reinforcement during laparoscopic sleeve gastrectomy: Systematic review and network meta-analysis of randomized controlled trials	Aiolfi et al. [74] Obes Surg. 2022	17 RCTs compared to an analysis of no reinforcement (NR), suture oversewing (SR), glue reinforcement (GR), bioabsorbable staple-line reinforcement (Gore® Seamguard®) (GoR), and clips reinforcement (CR) during laparoscopic sleeve gastrectomy.	SR was associated with a significantly reduced risk of bleeding (RR = 0.51; 95% CrI 0.31–0.88), staple-line leak (RR = 0.56; 95% CrI 0.32–0.99), and overall complications (RR = 0.50; 95% CrI 0.30–0.88) compared to NR while no differences were found vs. GR, GoR, and CR. Operative time was significantly longer for SR (WMD = 16.2; 95% CrI 10.8–21.7), GR (WMD = 15.0; 95% CrI 7.7–22.4), and GoR (WMD = 15.5; 95% CrI 5.6–25.4) compared to NR.	SR seems associated with a reduced risk of bleeding, leak, and overall complications in spite of a reasonable longer operative time compared to NR while no differences were found vs. GR, GoR, and CR.
The efficacy of staple-line reinforcement during laparoscopic sleeve gastrectomy: A meta-analysis of randomized controlled trials	Wang et al. [76] International journal of surgery. 2016	8 RCTs were analyzed. The outcomes of staple-line hemorrhage and leakage, overall complications, and operative time were compared in surgeries with reinforcement and without reinforcement.	Compared to performing no reinforcement, staple-line reinforcement was associated with a lower risk of staple-line hemorrhage (RR = 0.609, 95%CI = 0.439-0.846, $p = 0.003$) and overall complications (RR = 0.673, 95%CI = 0.507–0.892, $p = 0.006$). No significant difference was observed regarding postoperative leakage (RR = 0.654, 95%CI = 0.275–1.555, $p = 0.337$). Oversewing of the staple line took longer operative time (WMD = 13.211, 95%CI = 6.192–20.229, $p = 0.000$)	Staple-line reinforcement using buttressing or roofing materials could reduce staple-line hemorrhage and overall complications. No obvious advantages of oversewing the staple line were found and it took longer operative time. No significant reduction in leak rate was evidenced after reinforcement.
Reinforcing the staple line during laparoscopic sleeve gastrectomy: does it have advantages? A meta-analysis	Choi et al. [75] Obes Surg. 2012	2 RCTs and 6 cohort studies were analyzed. A comparison was made between the reinforcement of the staple line and no reinforcement of the staple line.	Comparing the reinforcement of the staple line to no reinforcement of the staple line, the odds ratio (OR) for overall complications was 0.521 (95% confidence intervals [CI], 0.349–0.777). In addition, the OR for staple-line leak was 0.425 (95% CI, 0.226–0.799), and for staple-line hemorrhage it was 0.559 (95% CI, 0.247–1.266).	Reinforcing the staple line during LSG has the following advantages: decreased incidence of postoperative leak and overall complications.

6. The General View and Power of AI in Surgery

In recent years, the landscape has been profoundly transformed by the integration of artificial intelligence (AI) and surgery. These technologies are reshaping surgical practices, offering unprecedented opportunities for enhancing precision, efficiency, and patient outcomes. The emergence of AI, particularly those rooted in advanced data analytics and machine learning (ML), has introduced a new era in the surgical field. It enables the analysis of vast datasets and the provision of real-time decision support, thereby augmenting the surgeon's capabilities. ML algorithms have shown promising capabilities in predicting surgical outcomes after metabolic and bariatric surgery (MBS) [77]. There are already models using ML to provide individual preoperative predictions of weight loss trajectories five years after MBS, and at the same time assist in informing clinical decisions before surgery [78]. AI-driven surgical systems have made significant progress, improving decision-making, reducing surgical errors, and facilitating the implementation of personalized treatment strategies. Breakthroughs include imaging, real-time data analysis, and automated robotic instruments, improving surgical efficiency and patient safety [20]. Integrating these tools into surgical practice marks a significant leap forward, enhancing the precision of surgical interventions.

The role of AI in preoperative planning is multifaceted, encompassing diagnostic imaging analysis, risk assessment, and personalized treatment planning. The current applications mainly focus on preoperative risk assessment and suggesting improved decisions in the field [79]. AI can bring about tremendous advances in healthcare, as it improves the accessibility, affordability, and quality of medical services [80]. AI-driven hybrid chatbots, like ChatGPT, can be used as an auxiliary tool for surgical diagnosis and treatment in many ways [81–83]. It has great potential, significantly predicting and intervening in weight loss and related complications [84]. Research indicates that ChatGPT-4 performs well in various medical and surgical examinations; without prior training, ChatGPT-4 achieved a high score in the largest practice question bank of the FPD-MBS exam [85]. Chatbots have shown significant benefits in the healthcare field, such as reducing hospital readmission rates by up to 25%, increasing patient engagement by 30%, and reducing consultation-waiting times by 15% [86]. The AI chatbots based on LLMs can effectively respond appropriately to clinical issues related to MBS, and at the same time, the supervision of clinicians is necessary to ensure accuracy [87–89]. It can be widely used in chronic disease management, mental health support, and patient education. Preoperative planning is a critical phase in the surgical pathway, laying the groundwork for successful outcomes. Moreover, analyzing medical images, such as CT scans, MRIs, and X-rays, is fundamental to surgical planning. AI has revolutionized this process in detecting anatomical structures, pathologies, and anomalies with high accuracy, aiding in diagnosis and surgical strategy development.

For instance, in MBS, AI can delineate the location of the stomach, assess size and location, and identify critical surrounding structures. It provides surgeons with a comprehensive understanding of the surgical field. AI can be used for preoperative planning and decision support, extracting patient information and providing surgery-related information and simulations to patients [90]. Using AI algorithms to evaluate in an automated manner can improve technical performance and intraoperative decision-making. The use of three-dimensional reconstructions and virtual simulations further enhances this process. AI also plays a crucial role in risk stratification and predictive analytics, by analyzing electronic health records (EHRs) and other patient data that can identify factors associated with surgical complications, prolonged recovery, and adverse outcomes. Predictive AI models can forecast the likelihood of postoperative complications such as infections, thromboembolic events, or organ failure. This information enables surgeons to tailor their

perioperative management strategies, implementing preventive measures and optimizing resource allocation.

AI enables personalized treatment planning by simulating various surgical scenarios. The simulations consider tissue characteristics, anatomical variations, and physiological parameters to optimize surgical strategies. AI has significant impacts in predicting the duration of surgical cases, optimizing the allocation of resources in post-anesthesia care units, and detecting the cancelation of surgical cases; the integration of artificial intelligence in operating room management is expected to enhance medical efficiency and the treatment outcomes of patients [91–94]. In MBS, AI can simulate the effects of different gastric bypass techniques on weight loss and metabolic outcomes. Surgeons can select the most appropriate approach for each patient by comparing these simulations. MBS for obesity subtypes identified by artificial intelligence improves glucose metabolism and alleviates diabetes and hyperinsulinemia [95]. AI helps to reveal the hidden metabolomic relationships before and after weight loss, assisting clinicians in choosing patients' decision-making processes in a personalized way [96]. The intraoperative phase is where AI has an impact on surgical procedures. Real-time decision support, enhanced visualization, and advanced instrumentation transform the operating environment. It can provide continuous decision support during surgery by analyzing intraoperative data, monitoring vital signs, blood loss, and tissue oxygenation, and alerting the surgical team to potential complications.

Advanced visualization technologies play a crucial role in minimally invasive surgeries. Augmented reality (AR) systems overlay digital information onto the surgeon's view, providing real-time guidance and improving surgical precision. Developing advanced surgical instruments and robotic systems represents a significant technological milestone. Robotic platforms like the DaVinci Surgical System combine precision instrumentation with enhanced visualization and ergonomic benefits. At the same time, AI is revolutionizing the field of surgical education. It can generate automated skills assessments and also has the potential to create and provide highly specialized intraoperative surgical feedback to surgeons in training. Systems filter out hand tremors, scale movements for precision, and provide haptic feedback to surgeons, then enable complex procedures with minimal invasiveness.

Postoperative care is essential for ensuring patient recovery and long-term outcomes. AI enhances this phase through continuous monitoring, predictive analytics, and outcomes assessment. Postoperative gastrointestinal bleeding (GIB) is a serious complication in MBS. Some scholars have utilized machine learning (ML) to create a model for predicting postoperative GIB to assist surgeons in making decisions and improve patients' consultations on postoperative bleeding [97]. On the other hand, wearable devices and remote sensing technologies collect real-time patient data. AI then analyses this data to detect early signs of complications, alert healthcare providers promptly, reduce hospital readmissions, and improve patient safety. It is crucial in assessing surgical outcomes and driving quality improvement initiatives. By aggregating and analyzing data from multiple sources, including EHRs, patient-reported outcomes, and surgical registries, researchers can identify trends and areas for improvement, provide insights into the effectiveness of different surgical techniques, perioperative care protocols, and postoperative management strategies. For example, AI analyses of MBS outcomes can compare the efficacy of different gastric bypass techniques in achieving weight loss and resolving comorbidities. By identifying best practices and areas for improvement, these analyses guide evidence-based practice recommendations and enhance the quality of surgical interventions.

The integration of AI in surgery is underpinned by several methods to enhance surgical care and improve patient outcomes. AI offers numerous benefits, driving precision; efficiency, and patient care advancements. AI-assisted surgery is safer and more effective than traditional surgery [98]. Algorithms can alert surgeons to potential risks, such as unin-

tended injuries to critical structures or improper instrument usage. This proactive approach to error prevention enhances patient safety and surgical success rates. In MBS, AI systems can analyze instrument movements and tissue interactions to detect potential injuries. It is also revolutionizing surgical education, generating automated skills assessments. It also has the potential to generate and provide highly specialized intraoperative surgical feedback to surgeons in training [99]. These systems help surgeons avoid complications and ensure safe surgical practices by providing real-time feedback.

AI improves patient safety and outcomes by personalizing surgical care and predicting complications. Tailoring surgical plans to individual patient characteristics ensures optimal treatment strategies. Additionally, continuous postoperative monitoring and early complication detection facilitate timely interventions, promoting faster recovery and better long-term results. By optimizing surgical strategies, these models improve outcomes and reduce the risk of adverse events. The application of AI in surgical operations is a rapidly developing and promising innovative field, which relies on strengthening interdisciplinary cooperation [100]. Meanwhile, AI is completely transforming the rapid development of precision medicine [101]. AI algorithms can be applied in clinical practice to predict the response to MBS intervention, promoting the development of precision medicine. Future research should focus on addressing data quality and security challenges, and ethical issues also need to be noted and used under the supervision of a doctor.

AI's general view and power in surgery are transformative, offering unprecedented opportunities for enhancing surgical precision, efficiency, and patient care. These technologies reshape surgical practices from preoperative planning and intraoperative navigation to postoperative monitoring. While data privacy, workflow integration, and ethical considerations must be addressed, the potential benefits of computational technologies in surgery are undeniable. As AI continues to evolve, it will drive further innovations in surgical techniques, education, and global healthcare. The integration of AI in surgery holds the promise of revolutionizing surgical care for generations to come.

7. Enhancing Stapling Efficiency Through AI Integration

Artificial intelligence (AI) is rapidly becoming a critical component of modern surgical systems, especially in metabolic and bariatric surgery, where precise tissue handling and stapling are key to optimizing patient outcomes [102]. Traditional powered staplers already incorporate basic adaptive features, such as the Medtronic Signia™ system, which adjusts compression and firing based on real-time feedback to accommodate variable tissue thickness [58]. AI-driven stapling advances these systems beyond automation into learning-based adaptation, continuously analyzing sensor data, including tissue resistance, compression behavior, and anatomical differences, to dynamically adjust stapling parameters in real time [103].

This real-time responsiveness offers significant potential to reduce intraoperative errors. When abnormal tissue behavior is detected, such as excessive resistance or inconsistent compression, the AI system can either notify the surgeon or interrupt the firing process, thereby avoiding misfires or improperly formed staples [58]. The incorporation of AI with computer vision further enables surgical tools to interpret visual information from the operative field [104]. Machine learning models have already achieved up to 85.6% accuracy in identifying procedural steps during laparoscopic sleeve gastrectomy, suggesting that similar visual analysis could be applied to evaluate staple-line uniformity, detect bleeding risks, or identify nearby critical structures [50].

Moreover, AI systems support postoperative learning by continuously incorporating insights from completed procedures [105,106]. Through the analysis of thousands of stapler firings across diverse patient groups, these systems can improve performance,

identify patterns associated with complications, and deliver tailored feedback to individual surgeons [103]. This reflects current advancements in robotic surgery, where real-time AI feedback enhances procedural safety, minimizes variability, and detects anomalous behaviors that can be addressed through data-informed interventions [13]. Another key advantage is predictive maintenance, as AI can anticipate mechanical problems within the stapler based on usage trends and component degradation before they lead to intraoperative failures [107].

8. Can AI Eliminate the Need for Staple-Line Reinforcement?

One of the longstanding discussions in MBS involves whether staple-line reinforcement (SLR) is truly necessary [108]. Materials such as GORE® SeamGuard® and bovine pericardium buttresses have demonstrated efficacy in lowering postoperative bleeding and leaks by reinforcing the staple line [49,109]. Recent evidence suggests that reinforcement is associated with lower complication rates compared to non-reinforced techniques, particularly in sleeve gastrectomy [108]. However, these advantages must be balanced against higher costs, the potential for localized tissue inflammation, and prolonged operative times [74].

Although current trends suggest that AI-driven staplers may eventually eliminate the need for staple-line reinforcement, present peer-reviewed studies indicate that AI-enhanced stapling systems produce more uniform staple formation, which may help reduce, but not fully eliminate, the reliance on reinforcement in future applications [110]. Common causes of postoperative bleeding and leaks, such as staple malformation, small tissue gaps, or excessive compression, could potentially be anticipated and avoided by AI-enabled staplers that actively respond to real-time tissue data [107]. A conceptual model of an AI-supported stapler would be capable of detecting poor tissue perfusion, overly thick tissue bundles, or staple misalignment and could modify firing force, alter speed, or halt operation altogether to achieve reinforcement-like outcomes without using external materials [103].

Interestingly, new evidence already supports the practicality of non-reinforced techniques: data from a large UK bariatric registry showed that between 2012 and 2021, use of staple-line reinforcement declined from 99.7% to 57.3%, with no corresponding increase in staple-related complications, suggesting that with advancing technology and improved technique, reinforcement may not be as essential as once believed [111]. If AI systems can ensure staple-line quality equivalent to reinforced approaches, particularly in patients with lower risk, omitting reinforcement may become routine practice, leading to reductions in time, resource use, and surgical expenses [76].

9. Price Efficiency and Economic Implications of AI-Guided Stapling

Considering both the initial investment and long-term savings should assess the economic implications of AI-assisted stapling systems. For traditional powered staplers, a recent study reported that the cost of a pair of glycolide copolymer sleeves is approximately USD 120, with an average of 8.4 sleeves used per case in the treatment group, amounting to an added procedural cost of USD 1009 [112]. Additionally, oversewing the staple line has been shown to prolong surgery by around 13 min (WMD = 13.2 min, 95 % CI 6.2–20.2 min; $p < 0.001$), and given operating room expenses ranging from USD 36–37 per minute, this results in an added cost of USD 400–500 per case [76,113]. While AI-enhanced staplers may have a higher initial price point due to integrated technologies, they could lead to overall savings by decreasing the need for reinforcement and reducing operative time [114].

In a study by Miller et al. [114]., powered staplers were associated with a reduction in total hospital costs of roughly USD 2211 per Video-Assisted Thoracoscopic Surgery (VATS) lobectomy case, largely attributed to shorter inpatient stays and fewer bleeding-

related issues, despite the greater cost per stapler unit [114]. Building on this, AI-enabled staplers that further improve efficiency and standardize performance may offer even more substantial cost benefits [114]. If reinforcement is eliminated and surgery duration is shortened by just 10 min per case, this could yield combined savings of USD 400–600 per patient [76,113].

Additionally, AI's indirect contributions may include fewer hospital readmissions, decreased need for postoperative Intensive Care Unit (ICU) care, and reduced length of stay, owing to enhanced staple-line consistency [74,105]. AI technologies may also support institutional cost management through better analytics on device utilization, improved inventory forecasting, and early identification of underperforming components that might otherwise affect clinical outcomes [13]. Over time, high-volume surgical centers employing AI-guided stapling platforms may establish internal benchmarks for evaluating outcomes and driving continuous quality and cost improvements [102,105].

With the development of new stapling technologies, there should attention for the burden on the environment, but also the generation of waste of new stapling products. Unfortunately, there is a scarcity of literature, especially on the effects of development of stapling technology on the environment. Future research should focus on this matter, to keep surgical technology green and sustainable.

10. Conclusions

Artificial intelligence and digital technologies are poised to refine the practice of stapling in bariatric surgery. Intraoperative imaging platforms now facilitate real-time assessment of tissue thickness and perfusion. AI-driven algorithms can interpret these data, providing objective guidance for cartridge selection. Robotic staplers equipped with force sensors and haptic feedback offer the potential to adjust compression based on tissue compliance, reducing variability and enhancing consistency [77,115,116].

These innovations may contribute to reducing human error in stapling, particularly in complex bariatric cases. As AI technologies continue to mature, their integration into standard surgical practice is likely to enhance both safety and outcomes.

Author Contributions: Conceptualization, S.P. (Sjaak Pouwels), A.M., M.K., M.M., S.R., S.P. (Santosh Parajuli), S.S., U.L., W.Y., K.A. and S.T.; investigation, S.P. (Sjaak Pouwels), A.M., M.K., M.M., S.R., S.P. (Santosh Parajuli), S.S., U.L., W.Y., K.A. and S.T.; writing—original draft preparation, S.P. (Sjaak Pouwels), A.M., M.K., M.M., S.R., S.P. (Santosh Parajuli), S.S., U.L., W.Y., K.A. and S.T.; writing—review and editing, S.P. (Sjaak Pouwels), A.M., M.K., M.M., S.R., S.P. (Santosh Parajuli), S.S., U.L., W.Y., K.A. and S.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ng, M.; Gakidou, E.; Lo, J.; Abate, Y.H.; Abbafati, C.; Abbas, N.; Abbasian, M.; Abd ElHafeez, S.; Abdel-Rahman, W.M.; Abd-Elsalam, S.; et al. Global, regional, and national prevalence of adult overweight and obesity, 1990-2021, with forecasts to 2050: A forecasting study for the Global Burden of Disease Study 2021. *Lancet* **2025**, *405*, 813–838. [CrossRef] [PubMed]
2. Kerr, J.A.; Patton, G.C.; Cini, K.I.; Abate, Y.H.; Abbas, N.; Abd Al Magied, A.H.; Abd ElHafeez, S.; Abd-Elsalam, S.; Abdollahi, A.; Abdoun, M.; et al. Global, regional, and national prevalence of child and adolescent overweight and obesity, 1990-2021,

with forecasts to 2050: A forecasting study for the Global Burden of Disease Study 2021. *Lancet* **2025**, *405*, 785–812. [CrossRef] [PubMed]
3. Buchwald, H. Metabolic Surgery: Progenitor of Effective Therapy for Atherosclerotic Cardiovascular Disease, Cancer, Type 2 Diabetes, and Obesity. *Ann. Surg.* **2025**, *281*, 725–729. [CrossRef]
4. Suzuki, M.; Imoto, T.; Shimizu, R.; Nakagawa, K. Manual slow firing mode of Signia™ Stapling System can achieve less staple line bleeding from pulmonary artery. *J. Thorac. Dis.* **2025**, *17*, 4948–4956. [CrossRef]
5. Hany, M.; Abouelnasr, A.A.; Gaballah, M.; Ragab, A.; Hafez, D.M.; Torensma, B. Gastrocolic Fistula Due to Staple Line Leak Following Metabolic Bariatric Surgery: A Systematic Review. *Obes. Surg.* **2025**, *35*, 2277–2295. [CrossRef]
6. Wu, C.C.; Tan, Y.L.; Hsu, C.W.; Tseng, H.P.; Miskovic, D.; Huang, S.F. Robotic intracorporeal single-stapling versus double-stapling anastomosis in left-sided colorectal cancer: A propensity score-weighted pilot study. *J. Robot. Surg.* **2025**, *19*, 430. [CrossRef]
7. Foppa, C.; D'Amico, S.; Delleani, M.; Maroli, A.; Savevski, V.; Della Porta, M.G.; Carvello, M.; Montorsi, M.; Repici, A.; Hassan, C.; et al. Synthetic Data Generated by Artificial Intelligence to Optimize Surgical Trial Design. *Ann. Surg.* **2025**. *online ahead of print*. [CrossRef]
8. Chekan, E.; Whelan, R.L. Surgical stapling device-tissue interactions: What surgeons need to know to improve patient outcomes. *Med. Devices* **2014**, *7*, 305–318. [CrossRef]
9. Verras, G.I.; Mulita, F.; Lampropoulos, C.; Kehagias, D.; Curwen, O.; Antzoulas, A.; Panagiotopoulos, I.; Leivaditi, V.; Kehagias, I. Risk Factors and Management Approaches for Staple Line Leaks Following Sleeve Gastrectomy: A Single-Center Retrospective Study of 402 Patients. *J. Pers. Med.* **2023**, *13*, 1422. [CrossRef] [PubMed]
10. Rawlins, L.; Rawlins, M.P.; Teel, D., 2nd. Human tissue thickness measurements from excised sleeve gastrectomy specimens. *Surg. Endosc.* **2014**, *28*, 811–814. [CrossRef]
11. Boeker, C.; Schneider, B.; Markov, V.; Mall, J.; Reetz, C.; Wilkens, L.; Hakami, I.; Stroh, C.; Köhler, H. Primary Sleeve Gastrectomy and Leaks: The Impact of Fundus-Wall Thickness and Staple Heights on Leakage—An Observational Study of 500 Patients. *Front. Surg.* **2021**, *8*, 747171. [CrossRef] [PubMed]
12. Lee, Y.J.; Kim, Y.N.; Park, S. Measurement of Stomach Wall Thickness to Guide Staple Selection during Sleeve Gastrectomy. *Obes. Surg.* **2020**, *30*, 2140–2146. [CrossRef] [PubMed]
13. Iftikhar, M.; Saqib, M.; Zareen, M.; Mumtaz, H. Artificial intelligence: Revolutionizing robotic surgery: Review. *Ann. Med. Surg.* **2024**, *86*, 5401–5409. [CrossRef]
14. Clapp, B.L.; Billy, H.; Lutfi, R.E.; Pan, I.W. Effectiveness of bedside staplers in bariatric robotic procedures. *Surg. Endosc.* **2024**, *38*, 5310–5318. [CrossRef]
15. Salyer, C.; Spuzzillo, A.; Wakefield, D.; Gomaa, D.; Thompson, J.; Goodman, M. Endocutter Staple Height Auto-Adjusts to Tissue Thickness. *J. Surg. Res.* **2021**, *267*, 705–711. [CrossRef]
16. Mery, C.M.; Shafi, B.M.; Binyamin, G.; Morton, J.M.; Gertner, M. Profiling surgical staplers: Effect of staple height, buttress, and overlap on staple line failure. *Surg. Obes. Relat. Dis. Off. J. Am. Soc. Bariatr. Surg.* **2008**, *4*, 416–422. [CrossRef] [PubMed]
17. Barski, K.; Binda, A.; Kudlicka, E.; Jaworski, P.; Tarnowski, W. Gastric wall thickness and stapling in laparoscopic sleeve gastrectomy—A literature review. *Videosurgery Other Miniinvasive Tech.* **2018**, *13*, 122–127. [CrossRef]
18. Lu, T.; Kan, J.; He, X.; Zou, J.; Sheng, D.; Xue, Y.; Wang, Y.; Xu, L. Gastric Submucosal Fat Accumulation Is Associated with Insulin Resistance in Patients with Obesity. *Obes. Surg.* **2024**, *34*, 534–541. [CrossRef]
19. Patrzyk, M.; Sonke, J.; Glitsch, A.; Kessler, R.; Steveling, A.; Lünse, S.; Partecke, L.I.; Heidecke, C.-D.; Kessler, W. Gastric Balloon Implantation as Part of Morbid Adiposity Therapy Changes the Structure of the Stomach Wall. *Visc. Med.* **2021**, *37*, 418–425. [CrossRef]
20. Wah, J.N.K. Revolutionizing surgery: AI and robotics for precision, risk reduction, and innovation. *J. Robot. Surg.* **2025**, *19*, 47. [CrossRef]
21. Meng, M.; Saini, J.; Fan, D.; Singh, A.; Farkas, D.T. Use of Indocyanine Green to Detect Intraoperative Staple-Line Leaks in Robotic Bariatric Surgery: An Observational Cohort Study. *Cureus* **2024**, *16*, e56991. [CrossRef]
22. Pavone, G.; Fersini, A.; Pacilli, M.; De Fazio, M.; Panzera, P.; Ambrosi, A.; Tartaglia, N. Can indocyanine green during laparoscopic sleeve gastrectomy be considered a new intraoperative modality for leak testing? *BMC Surg.* **2022**, *22*, 341. [CrossRef] [PubMed]
23. Popa, M.T.; Ginghină, O.; Mardare, M.; Nodiţi, A.; Puşcaşu, A.; Peleaşă, T.M.; Miron, A.; Blidaru, A. The Celiac Trunk: Anatomical Variants and Malformations—A Narrative Review. *Chirurgia* **2025**, *120*, 303–313. [CrossRef] [PubMed]
24. Riebeling, J.; Patejdl, R.; Zipf, D.; Conradi, L.C.; Ghadimi, M.; Gundling, F.; Bruegmann, T. Update on Gastric Pacemaking: Relevance for Gastroparesis. *Zentralblatt Chir.* **2025**, *150*, 337–345.
25. Man, J.; Hrabe, J. Anastomotic Technique-How to Optimize Success and Minimize Leak Rates. *Clin. Colon Rectal Surg.* **2021**, *34*, 371–378. [CrossRef]

26. Kumar, N.; Thompson, C.C. Endoscopic management of complications after gastrointestinal weight loss surgery. *Clin. Gastroenterol. Hepatol. Off. Clin. Pract. J. Am. Gastroenterol. Assoc.* **2013**, *11*, 343–353. [CrossRef]
27. Ishizawa, T.; Wang, P.Y. "Bon mariage" of artificial intelligence and intraoperative fluorescence imaging for safer surgery. *Art. Int. Surg.* **2023**, *3*, 163–165. [CrossRef]
28. Wityk, M.; Dowgiałło-Gornowicz, N.; Feszak, I.; Bobowicz, M. Fluorescence use in minimally invasive metabolic and bariatric surgery—A systematic review of the literature. *Langenbeck's Arch. Surg.* **2023**, *408*, 216. [CrossRef]
29. Braghetto, I.; Czwiklitzer, G.; Korn, O.; Brante, P.; Burgos, A. Results of Mechanic Versus Motorized Stapler Used in Gastric Surgery: Prospective Study. *Arq. Bras. Cir. Dig. ABCD = Braz. Arch. Dig. Surg.* **2024**, *37*, e1818. [CrossRef]
30. Chung, Y.; Park, D.G.; Kim, Y.J. Endoscopic Management of Staple Line Leak after Bariatric Surgery: Surgeon's Perspective. *Clin. Endosc.* **2021**, *54*, 805–809. [CrossRef] [PubMed]
31. Catchlove, W.; Liao, S.; Lim, G.; Brown, W.; Burton, P. Mechanism of Staple Line Leak After Sleeve Gastrectomy via Isobaric Pressurisation Concentrating Stress Forces at the Proximal Staple Line. *Obes. Surg.* **2022**, *32*, 2525–2536. [CrossRef]
32. Acquafresca, P.A.; Palermo, M.; Rogula, T.; Duza, G.E.; Serra, E. Early surgical complications after gastric by-pass: A literature review. *Arq. Bras. Cir. Dig. ABCD = Braz. Arch. Dig. Surg.* **2015**, *28*, 74–80. [CrossRef] [PubMed]
33. Knapps, J.; Ghanem, M.; Clements, J.; Merchant, A.M. A systematic review of staple-line reinforcement in laparoscopic sleeve gastrectomy. *JSLS J. Soc. Laparoendosc. Surg.* **2013**, *17*, 390–399. [CrossRef]
34. Barski, K.; Binda, A.; Jaworski, P.; Gonciarska, A.; Kudlicka, E.; Żurkowska, J.; Wawiernia, K.; Tałałaj, M.; Wąsowski, M. Influence of preoperative weight loss on gastric wall thickness-analysis of laparoscopic sleeve gastrectomy histological material. *Langenbeck's Arch. Surg.* **2022**, *407*, 3315–3322. [CrossRef]
35. Alekya, B.; Rao, S.; Pandya, H.J. Engineering approaches for characterizing soft tissue mechanical properties: A review. *Clin. Biomech.* **2019**, *69*, 127–140. [CrossRef]
36. Cho, E.J.; Kim, S.M. Revisional surgery after removal of eroded adjustable gastric bands. *Asian J. Surg.* **2019**, *42*, 688–695. [CrossRef] [PubMed]
37. Khattab, M.A.; Mohammed, A.T.A.; Alqahtani, A.Z.M.; Alqahtani, E.Z.M.; Alslim, M.M.A.; Alharbi, N.E.A.; A Alslim, R.M.; Saleh, Z.; Atia, M.A.Q.; Shanaq, A.J.; et al. The Role of Ethnic Disparities in the Outcomes of Bariatric Surgery: A Systematic Review and Meta-Analysis. *Cureus* **2022**, *14*, e24743. [CrossRef] [PubMed]
38. Choban, P.S.; Jackson, B.; Poplawski, S.; Bistolarides, P. Bariatric surgery for morbid obesity: Why, who, when, how, where, and then what? *Clevel. Clin. J. Med.* **2002**, *69*, 897–903. [CrossRef]
39. Varela, J.E.; Hinojosa, M.; Nguyen, N. Correlations between intra-abdominal pressure and obesity-related co-morbidities. *Surg. Obes. Relat. Dis. Off. J. Am. Soc. Bariatr. Surg.* **2009**, *5*, 524–528. [CrossRef]
40. Fass, O.Z.; Mashimo, H. The Effect of Bariatric Surgery and Endoscopic Procedures on Gastroesophageal Reflux Disease. *J. Neurogastroenterol. Motil.* **2021**, *27*, 35–45. [CrossRef]
41. Evans, L.A.; Castillo-Larios, R.; Cornejo, J.; Elli, E.F. Challenges of Revisional Metabolic and Bariatric Surgery: A Comprehensive Guide to Unraveling the Complexities and Solutions of Revisional Bariatric Procedures. *J. Clin. Med.* **2024**, *13*, 3104. [CrossRef] [PubMed]
42. Hany, M.; Zidan, A.; Ibrahim, M.; Sabry, A.; Agayby, A.S.S.; Mourad, M.; Torensma, B. Revisional One-Step Bariatric Surgical Techniques After Unsuccessful Laparoscopic Gastric Band: A Retrospective Cohort Study with 2-Year Follow-up. *Obes. Surg.* **2024**, *34*, 814–829. [CrossRef]
43. Poirier, P.; Cornier, M.A.; Mazzone, T.; Stiles, S.; Cummings, S.; Klein, S.; McCullough, P.A.; Fielding, C.R. Bariatric surgery and cardiovascular risk factors: A scientific statement from the American Heart Association. *Circulation* **2011**, *123*, 1683–1701. [CrossRef]
44. Henry, J.A.; Abdesselam, I.; Deal, O.; Lewis, A.J.; Rayner, J.; Bernard, M.; Dutour, A.; Gaborit, B.; Kober, F.; Soghomonian, A.; et al. Changes in epicardial and visceral adipose tissue depots following bariatric surgery and their effect on cardiac geometry. *Front. Endocrinol.* **2023**, *14*, 1092777. [CrossRef]
45. Salyer, C.; Spuzzillo, A.; Wakefield, D.; Gomaa, D.; Thompson, J.; Goodman, M. Assessment of a novel stapler performance for laparoscopic sleeve gastrectomy. *Surg. Endosc.* **2021**, *35*, 4016–4021. [CrossRef]
46. Kodilinye, S.M.; Kumbhari, V.; Badurdeen, D. Complications of Metabolic and Bariatric Surgery for the Gastroenterologist: A Comprehensive Review. *Gastroenterol. Hepatol.* **2025**, *21*, 97–110.
47. Turcu, F.; Balahura, C.; Doras, I.; Constantin, A.; Copaescu, C. Symptomatic Stenosis after Laparoscopic Sleeve Gastrectomy—Incidence and Management in a High-Volume Bariatric Surgery Center. *Chirurgia* **2018**, *113*, 826–836. [CrossRef] [PubMed]
48. Agnihotri, A.; Barola, S.; Hill, C.; Neto, M.G.; Campos, J.; Singh, V.K.; Schweitzer, M.; A Khashab, M.; Kumbhari, V. An Algorithmic Approach to the Management of Gastric Stenosis Following Laparoscopic Sleeve Gastrectomy. *Obes. Surg.* **2017**, *27*, 2628–2636. [CrossRef] [PubMed]

49. Vitiello, A.; Mok, J.; Elkalaawy, M.; Pucci, A.; Jenkinson, A.; Battheram, R.; Pilone, V.; Adamo, M. Staple Line Reinforcement during Sleeve Gastrectomy with SeamGuard: Single-Center Retrospective Case-Control Study over a 5-Year Period. *J. Clin. Med.* **2024**, *13*, 3410. [CrossRef]
50. Hashimoto, D.A.; Rosman, G.; Witkowski, E.R.; Stafford, C.; Navarette-Welton, A.J.; Rattner, D.W.; Lillemoe, K.D.; Rus, D.L.; Meireles, O.R. Computer Vision Analysis of Intraoperative Video: Automated Recognition of Operative Steps in Laparoscopic Sleeve Gastrectomy. *Ann. Surg.* **2019**, *270*, 414–421. [CrossRef]
51. Hassan Mukhtar, M.A.; Babiker Ahmed, A.U.; Siddig Mohammed, M.A.; Ibrahim Omer, N.O.; Altom, D.S.; Elnour, M.A.A. The Role of Artificial Intelligence in the Prediction of Bariatric Surgery Complications: A Systematic Review. *Cureus* **2025**, *17*, e82461. [CrossRef]
52. Blanc, P.; Breton, C.; Kuperas, C. Robotic Roux-en-Y gastric bypass with hand sewn anastomosis (with video). *J. Visc. Surg.* **2020**, *157*, 157–158. [CrossRef]
53. Spurzem, G.J.; Broderick, R.C.; Kunkel, E.K.; Hollandsworth, H.M.; Sandler, B.J.; Jacobsen, G.R.; Horgan, S. Robotic bariatric surgery reduces morbidity for revisional gastric bypass when compared to laparoscopic: Outcome of 8-year MBSAQIP analysis of over 40,000 cases. *Surg. Endosc.* **2024**, *38*, 6294–6304. [CrossRef]
54. Spurzem, G.J.; Broderick, R.C.; Kunkel, E.K.; Hollandsworth, H.M.; Sandler, B.J.; Jacobsen, G.R.; Horgan, S. Robotic sleeve gastrectomy has higher complication rates compared to laparoscopic: 8-year analysis of robotic versus laparoscopic primary bariatric surgery. *Surg. Obes. Relat. Dis. Off. J. Am. Soc. Bariatr. Surg.* **2025**, *21*, 372–381. [CrossRef]
55. Cirocchi, R.; Boselli, C.; Santoro, A.; Guarino, S.; Covarelli, P.; Renzi, C.; Listorti, C.; Trastulli, S.; Desiderio, J.; Coratti, A.; et al. Current status of robotic bariatric surgery: A systematic review. *BMC Surg.* **2013**, *13*, 53. [CrossRef]
56. Fadel, M.G.; Walshaw, J.; Pecchini, F.; Yiasemidou, M.; Boal, M.; Elhadi, M.; Fehervari, M.; Massey, L.H.; Carrano, F.M.; Antoniou, S.A.; et al. A pan-European survey of robotic training for gastrointestinal surgery: European Robotic Surgery Consensus (ERSC) initiative. *Surg. Endosc.* **2025**, *39*, 907–921. [CrossRef]
57. Pennestrì, F.; Marincola, G.; Procopio, P.F.; Gallucci, P.; Salvi, G.; Ciccoritti, L.; Greco, F.; Raffaelli, M. Comparison between DaVinci(®) and Hugo(™)-RAS Roux-en-Y Gastric Bypass in bariatric surgery. *J. Robot. Surg.* **2024**, *18*, 303. [CrossRef] [PubMed]
58. Medtronic. Touch Surgery™ Enterprise and Signia™ Stapling System: Real-time insights to enhance surgical performance. *White Paper.* 2021. Available online: https://www.medtronic.com/en-us/healthcare-professionals/specialties/touch-surgery.html#aq=%40pagetype%3D%22product-model%22&cq=%40products_category%3D%22Surgical%20energy%22%20OR%20%40ontology_isa%3D%22Surgical%20energy%22 (accessed on 1 August 2025).
59. Ethicon. *ECHELON Circular Powered Stapler and GST Technology: Enhancing Precision Through Advanced Data-Informed Design*; Johnson & Johnson Medical Devices Companies: Irvine, CA, USA, 2021.
60. Hafermann, J.O.; Phelps, J.D.; Tayash, M.F.E. Comparing the effect of laparoscopic and robotic stapling on clinical outcomes, efficiency, and costs of robot-assisted Roux-en-Y gastric bypass. *J. Robot. Surg.* **2025**, *19*, 65. [CrossRef] [PubMed]
61. XNY Multi Use Intelligent Powered Stapler. Available online: https://www.xnymedical.com/#/product-detail (accessed on 21 August 2025).
62. Rogula, T.; Koprivanac, M.; Janik, M.R.; Petrosky, J.A.; Nowacki, A.S.; Dombrowska, A.; Kroh, M.; Brethauer, S.; Aminian, A.; Schauer, P. Does Robotic Roux-en-Y Gastric Bypass Provide Outcome Advantages over Standard Laparoscopic Approaches? *Obes. Surg.* **2018**, *28*, 2589–2596. [CrossRef]
63. Clapp, B.; Schrodt, A.; Ahmad, M.; Wicker, E.; Sharma, N.; Vivar, A.; Davis, B. Stapler Malfunctions in Bariatric Surgery: An Analysis of the MAUDE Database. *JSLS J. Soc. Laparoendosc. Surg.* **2022**, *26*, e2021.00074. [CrossRef] [PubMed]
64. Wang, H.; Lu, J.; Feng, J.; Wang, Z. Staple line oversewing during laparoscopic sleeve gastrectomy. *Ann. R. Coll. Surg. Engl.* **2017**, *99*, 509–514. [CrossRef]
65. Heath, D. Complications Arising from Staple Lines and Anastomotes in Bariatric Surgery: Why They Happen and How to Avoid Them. Available online: https://bariatrictimes.com/complications-arising-from-staple-lines-and-anastomotes-in-bariatric-surgery-why-they-happen-and-how-to-avoid-them/ (accessed on 21 August 2025).
66. de Souza Bastos, E.L.; Ramos, A.C. Staple-line Reinforcement in Laparoscopic Sleeve Gastrectomy: Needful or Excessive Care? *J. Bariatr. Surg.* **2022**, *1*, 61–67. [CrossRef]
67. Gencturk, M.; Dalkilic, M.S.; Erdem, H.; Yılmaz, M.; Sisik, A. Correct Stapling Technique in Laparoscopic Sleeve Gastrectomy: Are We Increasing the Bleeding? A Prospective Cohort Study. *J. Laparoendosc. Adv. Surg. Tech. Part A* **2023**, *33*, 561–565. [CrossRef]
68. Giannopoulos, G.A.; Tzanakis, N.E.; Rallis, G.E.; Efstathiou, S.P.; Tsigris, C.; Nikiteas, N.I. Staple line reinforcement in laparoscopic bariatric surgery: Does it actually make a difference? A systematic review and meta-analysis. *Surg. Endosc.* **2010**, *24*, 2782–2788. [CrossRef]

69. Fegelman, E.; Knippenberg, S.; Schwiers, M.; Stefanidis, D.; Gersin, K.S.; Scott, J.D.; Fernandez, A.Z. Evaluation of a Powered Stapler System with Gripping Surface Technology on Surgical Interventions Required During Laparoscopic Sleeve Gastrectomy. *J. Laparoendosc. Adv. Surg. Tech. Part A* **2017**, *27*, 489–494. [CrossRef]
70. Jing, W.; Huang, Y.; Feng, J.; Li, H.; Yu, X.; Zhao, B.; Wei, P. The clinical effectiveness of staple line reinforcement with different matrix used in surgery. *Front. Bioeng. Biotechnol.* **2023**, *11*, 1178619. [CrossRef]
71. Morandeira-Rivas, A.; Moreno-Sanz, C.; Clerveus, M.; Muñoz de la Espada-Merlo Córdoba, J.B.; Herrero-Bogajo, M.L.; Román-Ortiz, C. Staple line reinforcement for adults undergoing bariatric surgery with gastric transection. *Cochrane Database Syst. Rev.* **2018**, *2018*, CD011853. [CrossRef]
72. Wu, C.; Wang, F.G.; Yan, W.M.; Yan, M.; Song, M.M. Is There Necessity for Oversewing the Staple Line During Laparoscopic Sleeve Gastrectomy? An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J. Investig. Surg. Off. J. Acad. Surg. Res.* **2020**, *33*, 839–850. [CrossRef] [PubMed]
73. Shikora, S.A.; Mahoney, C.B. Clinical Benefit of Gastric Staple Line Reinforcement (SLR) in Gastrointestinal Surgery: A Meta-analysis. *Obes. Surg.* **2015**, *25*, 1133–1141. [CrossRef]
74. Aiolfi, A.; Gagner, M.; Zappa, M.A.; Lastraioli, C.; Lombardo, F.; Panizzo, V.; Bonitta, G.; Cavalli, M. Staple Line Reinforcement During Laparoscopic Sleeve Gastrectomy: Systematic Review and Network Meta-analysis of Randomized Controlled Trials. *Obes. Surg.* **2022**, *32*, 1466–1478. [CrossRef] [PubMed]
75. Choi, Y.Y.; Bae, J.; Hur, K.Y.; Choi, D.; Kim, Y.J. Reinforcing the staple line during laparoscopic sleeve gastrectomy: Does it have advantages? A meta-analysis. *Obes. Surg.* **2012**, *22*, 1206–1213. [CrossRef]
76. Wang, Z.; Dai, X.; Xie, H.; Feng, J.; Li, Z.; Lu, Q. The efficacy of staple line reinforcement during laparoscopic sleeve gastrectomy: A meta-analysis of randomized controlled trials. *Int. J. Surg.* **2016**, *25*, 145–152. [CrossRef]
77. Bektaş, M.; Reiber, B.M.M.; Pereira, J.C.; Burchell, G.L.; van der Peet, D.L. Artificial Intelligence in Bariatric Surgery: Current Status and Future Perspectives. *Obes. Surg.* **2022**, *32*, 2772–2783. [CrossRef] [PubMed]
78. Saux, P.; Bauvin, P.; Raverdy, V.; Teigny, J.; Verkindt, H.; Soumphonphakdy, T.; Debert, M.; Jacobs, A.; Jacobs, D.; Monpellier, V.; et al. Development and validation of an interpretable machine learning-based calculator for predicting 5-year weight trajectories after bariatric surgery: A multinational retrospective cohort SOPHIA study. *Lancet Digit. Health* **2023**, *5*, e692–e702. [CrossRef] [PubMed]
79. Kenig, N.; Monton Echeverria, J.; Muntaner Vives, A. Artificial Intelligence in Surgery: A Systematic Review of Use and Validation. *J. Clin. Med.* **2024**, *13*, 7108. [CrossRef] [PubMed]
80. Reddy, S. Generative AI in healthcare: An implementation science informed translational path on application, integration and governance. *Implement. Sci.* **2024**, *19*, 27. [CrossRef]
81. Au, K.; Yang, W. Auxiliary use of ChatGPT in surgical diagnosis and treatment. *Int. J. Surg.* **2023**, *109*, 3940–3943. [CrossRef]
82. Li, W.; Zhang, Y.; Chen, F. ChatGPT in Colorectal Surgery: A Promising Tool or a Passing Fad? *Ann. Biomed. Eng.* **2023**, *51*, 1892–1897. [CrossRef]
83. Morya, V.K.; Lee, H.W.; Shahid, H.; Magar, A.G.; Lee, J.H.; Kim, J.H.; Jun, L.; Noh, K.-C. Application of ChatGPT for Orthopedic Surgeries and Patient Care. *Clin. Orthop. Surg.* **2024**, *16*, 347–356. [CrossRef]
84. Law, S.; Oldfield, B.; Yang, W. ChatGPT/GPT-4 (large language models): Opportunities and challenges of perspective in bariatric healthcare professionals. *Obes. Rev.* **2024**, *25*, e13746. [CrossRef]
85. Sanders, A.; Lim, R.; Jones, D.; Vosburg, R.W. Artificial intelligence large language model scores highly on focused practice designation in metabolic and bariatric surgery board practice questions. *Surg. Endosc.* **2024**, *38*, 6678–6681. [CrossRef] [PubMed]
86. Wah, J.N.K. Revolutionizing e-health: The transformative role of AI-powered hybrid chatbots in healthcare solutions. *Front. Public Health* **2025**, *13*, 1530799. [CrossRef] [PubMed]
87. Lee, Y.; Shin, T.; Tessier, L.; Javidan, A.; Jung, J.; Hong, D.; Strong, A.T.; McKechnie, T.; Malone, S.; Jin, D.; et al. Harnessing artificial intelligence in bariatric surgery: Comparative analysis of ChatGPT-4, Bing, and Bard in generating clinician-level bariatric surgery recommendations. *Surg. Obes. Relat. Dis.* **2024**, *20*, 603–608. [CrossRef]
88. Lee, Y.; Tessier, L.; Brar, K.; Malone, S.; Jin, D.; McKechnie, T.; Jung, J.J.; Kroh, M.; Dang, J.T. Performance of artificial intelligence in bariatric surgery: Comparative analysis of ChatGPT-4, Bing, and Bard in the American Society for Metabolic and Bariatric Surgery textbook of bariatric surgery questions. *Surg. Obes. Relat. Dis.* **2024**, *20*, 609–613. [CrossRef]
89. Kermansaravi, M.; Chiappetta, S.; Shahabi Shahmiri, S.; Varas, J.; Parmar, C.; Lee, Y.; Dang, J.T.; Shabbir, A.; Hashimoto, D.; Jazi, A.H.D.; et al. International expert consensus on the current status and future prospects of artificial intelligence in metabolic and bariatric surgery. *Sci. Rep.* **2025**, *15*, 9312. [CrossRef]
90. Rodler, S.; Ganjavi, C.; De Backer, P.; Magoulianitis, V.; Ramacciotti, L.S.; De Castro Abreu, A.L.; Gill, I.S.; Cacciamani, G.E. Generative artificial intelligence in surgery. *Surgery* **2024**, *175*, 1496–1502. [CrossRef]

91. Bellini, V.; Russo, M.; Domenichetti, T.; Panizzi, M.; Allai, S.; Bignami, E.G. Artificial Intelligence in Operating Room Management. *J. Med. Syst.* **2024**, *48*, 19. [CrossRef]
92. Abdelrazig Merghani, A.M.; Ahmed Esmail, A.K.; Mubarak Osman, A.M.E.; Abdelfrag Mohamed, N.A.; Mohamed Ali Shentour, S.M.; Abdelrazig Merghani, S.M. The Role of Machine Learning in Management of Operating Room: A Systematic Review. *Cureus* **2025**, *17*, e79400. [CrossRef]
93. Bellini, V.; Guzzon, M.; Bigliardi, B.; Mordonini, M.; Filippelli, S.; Bignami, E. Artificial Intelligence: A New Tool in Operating Room Management. Role of Machine Learning Models in Operating Room Optimization. *J. Med. Syst.* **2019**, *44*, 20.
94. Bellini, V.; Domenichetti, T.; Bignami, E.G. Innovative Technologies for Smarter and Efficient Operating Room Scheduling. *J. Med. Syst.* **2025**, *49*, 37. [CrossRef] [PubMed]
95. Liu, Y.; Sheng, C.; Feng, W.; Sun, F.; Zhang, J.; Chen, Y.; Su, L.; Liu, J.; Du, L.; Jia, X.; et al. A multi-center study on glucometabolic response to bariatric surgery for different subtypes of obesity. *Front. Endocrinol.* **2022**, *13*, 989202. [CrossRef]
96. Pantelis, A.G. Metabolomics in Bariatric and Metabolic Surgery Research and the Potential of Deep Learning in Bridging the Gap. *Metabolites* **2022**, *12*, 458. [CrossRef]
97. Hsu, J.L.; Chen, K.A.; Butler, L.R.; Bahraini, A.; Kapadia, M.R.; Gomez, S.M.; Farrell, T.M. Application of machine learning to predict postoperative gastrointestinal bleed in bariatric surgery. *Surg. Endosc.* **2023**, *37*, 7121–7127. [CrossRef]
98. Nwoye, E.; Woo, W.L.; Gao, B.; Anyanwu, T. Artificial Intelligence for Emerging Technology in Surgery: Systematic Review and Validation. *IEEE Rev. Biomed. Eng.* **2023**, *16*, 241–259. [CrossRef]
99. Knudsen, J.E.; Ghaffar, U.; Ma, R.; Hung, A.J. Clinical applications of artificial intelligence in robotic surgery. *J. Robot. Surg.* **2024**, *18*, 102. [CrossRef]
100. Li, H.; Han, Z.; Wu, H.; Musaev, E.R.; Lin, Y.; Li, S.; Makatsariya, A.D.; Chekhonin, V.P.; Ma, W.; Zhang, C. Artificial intelligence in surgery: Evolution, trends, and future directions. *Int. J. Surg.* **2025**, *111*, 2101–2111. [CrossRef]
101. Adam, K.M.; Ali, E.W.; Elangeeb, M.E.; Abuagla, H.A.; Elamin, B.K.; Ahmed, E.M.; Edris, A.M.; Ahmed, A.A.E.M.; Eltieb, E.I. Intelligent Care: A Scientometric Analysis of Artificial Intelligence in Precision Medicine. *Med. Sci.* **2025**, *13*, 44. [CrossRef] [PubMed]
102. Almunifi, A. Impact of Artificial Intelligence on Metabolic Bariatric Surgery (MBS) and Minimally Invasive Surgery (MIS): A literature review. *Open Access Surg.* **2024**, *17*, 161–166. [CrossRef]
103. Kim, Y.S.; Park, S.H.; Lee, I.Y.; Son, G.M.; Baek, K.R. AI-driven automatic compression system for colorectal anastomosis. *J. Robot. Surg.* **2024**, *18*, 290. [CrossRef]
104. Ward, T.M.; Mascagni, P.; Ban, Y.; Rosman, G.; Padoy, N.; Meireles, O.; Hashimoto, D.A. Computer vision in surgery. *Surgery* **2021**, *169*, 1253–1256. [CrossRef] [PubMed]
105. Rahmadian, R.; Abi Rafdhi, M.A.Q.; Ariliusra, Z. Artificial intelligence in surgery: Role of AI in pre-operative, intra-operative, and post-operative. *Surg. Gastroenterol. Oncol.* **2024**, *29*, 189. [CrossRef]
106. Chevalier, O.; Dubey, G.; Benkabbou, A.; Majbar, M.A.; Souadka, A. Comprehensive overview of artificial intelligence in surgery: A systematic review and perspectives. *Pflug. Arch. Eur. J. Physiol.* **2025**, *477*, 617–626. [CrossRef]
107. Nikam, S.T.; Jadhav, B.; Lal, M. Predictive Maintenance for Medical Equipment Using AI-Powered Digital Twins. In *Accelerating Product Development Cycles With Digital Twins and IoT Integration*; IGI Global Scientific Publishing: Hershey, PA, USA, 2025; pp. 131–154.
108. Abdelmageed, S.A.; Helmy, M.Z. Staple line reinforcement during laparoscopic sleeve gastrectomy: Pros and cons. *Int. Surg. J.* **2019**, *6*, 2677–2681. [CrossRef]
109. D'Ugo, S.; Gentileschi, P.; Benavoli, D.; Cerci, M.; Gaspari, A.; Berta, R.D.; Moretto, C.; Bellini, R.; Basso, N.; Casella, G.; et al. Comparative use of different techniques for leak and bleeding prevention during laparoscopic sleeve gastrectomy: A multicenter study. *Surg. Obes. Relat. Dis. Off. J. Am. Soc. Bariatr. Surg.* **2014**, *10*, 450–454. [CrossRef]
110. Somashekhar, S.P.; Saldanha, E.; Kumar, R.; Pandey, K.; Dahiya, A.; Ashwin, K.R. Prospective analysis of 164 fires of da Vinci SureForm SmartFire stapler in oncological cases: Indian cohort of 76 consecutive cases. *J. Minimal Access Surg.* **2023**, *19*, 384–389. [CrossRef]
111. Niaz, O.; Askari, A.; Currie, A.; McGlone, E.R.; Zakeri, R.; Khan, O.; Welbourn, R.; Pring, C.; Small, P.; Al-Taan, O.; et al. Analysis of the effect of staple line reinforcement on leaking and bleeding after sleeve gastrectomy from the UK National Bariatric Surgery Registry. *World J. Surg.* **2024**, *48*, 1950–1957. [CrossRef]
112. Nguyen, N.T.; Longoria, M.; Welbourne, S.; Sabio, A.; Wilson, S.E. Glycolide copolymer staple-line reinforcement reduces staple site bleeding during laparoscopic gastric bypass: A prospective randomized trial. *Arch. Surg.* **2005**, *140*, 773–778. [CrossRef]
113. Childers, C.P.; Maggard-Gibbons, M. Understanding Costs of Care in the Operating Room. *JAMA Surg.* **2018**, *153*, e176233. [CrossRef]
114. Miller, D.L.; Roy, S.; Kassis, E.S.; Yadalam, S.; Ramisetti, S.; Johnston, S.S. Impact of Powered and Tissue-Specific Endoscopic Stapling Technology on Clinical and Economic Outcomes of Video-Assisted Thoracic Surgery Lobectomy Procedures: A Retrospective, Observational Study. *Adv. Ther.* **2018**, *35*, 707–723. [CrossRef] [PubMed]

115. Bellini, V.; Valente, M.; Turetti, M.; Del Rio, P.; Saturno, F.; Maffezzoni, M.; Bignami, E. Current Applications of Artificial Intelligence in Bariatric Surgery. *Obes. Surg.* **2022**, *32*, 2717–2733. [CrossRef] [PubMed]
116. Dayan, D.; Nizri, E.; Keidar, A. Using artificial intelligence to evaluate adherence to best practices in one anastomosis gastric bypass: First steps in a real-world setting. *Surg. Endosc.* **2025**, *39*, 1945–1951. [CrossRef] [PubMed]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.