Indications, Technical Advantages, and Debatable Aspects of Laparoscopic Appendectomy: A Comprehensive Review

Ann. Ital. Chir., 2026 97, 5: 785–798
https://doi.org/10.62713/aic.4399

Guido Basile[1], Marco Vacante[2], Francesco Roberto Evola[3], Lucia Romano[4,5], Martina Barchitta[6], Giuseppe Musumeci[7], Giuseppe Evola[8]

[1]Department of General Surgery and Medical-Surgical Specialties, University of Catania, 95123 Catania, Italy
[2]Unit of Internal Medicine Critical Area, Garibaldi Hospital, 95122 Catania, Italy
[3]Department of Surgery, Division of Orthopedics and Trauma Surgery, Cannizzaro Hospital, 95021 Catania, Italy
[4]Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, 67100 L'Aquila, Italy
[5]Department of Surgery, San Salvatore Hospital, 67100 L'Aquila, Italy
[6]Department of Medical and Surgical Sciences and Advanced Technologies "GF Ingrassia", University of Catania, 95124 Catania, Italy
[7]Department of Biomedical and Biotechnological Sciences, Section of Anatomy, Histology and Movement Sciences, University of Catania, 95124 Catania, Italy
[8]General and Emergency Surgery Department, Garibaldi Hospital, 95122 Catania, Italy

Laparoscopic appendectomy has emerged as the preferred surgical approach for treating acute appendicitis, one of the most common abdominal emergencies. This review explores the key indications, technical benefits and ongoing controversies surrounding laparoscopic appendectomy. While diagnosing acute appendicitis is typically straightforward, atypical presentations due to variable appendix locations can complicate management. Advances in imaging and scoring systems have improved diagnostic accuracy, yet timely surgical intervention remains crucial. Compared to open appendectomy, laparoscopic appendectomy offers several advantages, including reduced postoperative pain, a shorter hospital stay, quicker recovery and better cosmetic outcomes. However, concerns persist regarding intra-abdominal abscess formation, operative time, and cost effectiveness, particularly in complicated or atypical cases. Additionally, debates continue on whether to remove a macroscopically normal appendix and the appropriateness of laparoscopic appendectomy in certain patient populations. This review synthesizes the current evidence to clarify the evolving role of laparoscopic appendectomy in managing both routine and complex cases of acute appendicitis.

Keywords: acute appendicitis; appendectomy; laparoscopic appendectomy; single incision laparoscopic appendectomy; needlescopic appendectomy

Introduction

Acute appendicitis (AA) is among the most frequently encountered abdominal emergencies, accounting for approximately 4%–8% of emergency department admissions and necessitating surgical intervention [1]. It typically affects individuals between 10 and 20 years of age with a male predominance (male-to-female ratio of 1.4:1) [1]. Diagnosis of AA is generally straightforward and is based on clinical signs, physical assessment, and imaging. Unusual anatomical positions of the appendix, however, can complicate detection and delay treatment, increasing the risk of complications, such as abscesses, perforation, or peritonitis.

Submitted: 13 October 2025 Revised: 11 December 2025 Accepted: 23 December 2025 Published: 10 May 2026
Correspondence to: Guido Basile, Department of General Surgery and Medical-Surgical Specialties, University of Catania, 95123 Catania, Italy (e-mail: gbasile@unict.it).
Editor: Weihua Gong

The appendix can be found in various anatomical locations. The retrocecal position is the most prevalent (74%), followed by pelvic (21%), subcecal (1.5%), preileal (1%), and postileal (0.5%) placements [2]. Less common appendix positions include subhepatic [3], left-sided [4], within a hernia [5,6], lumbar, lateral pouch, and mesocolic areas [7].

Notably, in most cases (around 60%), AA presents initially as vague discomfort in the epigastric or periumbilical region, often accompanied by nausea and vomiting. Pain usually shifts to the right lower quadrant near McBurney's point within a few hours. Other symptoms of AA may include fever, rebound tenderness, Rovsing's sign, psoas sign, diarrhea, and loss of appetite. However, due to the variability in appendix location discussed, nearly one-third of patients report pain in atypical areas. Beyond inflammation, symptoms of AA may sometimes be linked to rare neoplasms of the appendix [8–10].

Several scoring systems have been developed to estimate the likelihood of AA, including the Alvarado, Fenyo, Eskelinen, Ohman, Tzankis, and RIPASA scores [11,12]. Although laboratory tests are not definitive for diagnosing

AA, elevated levels of C-reactive protein (CRP), white blood cells (WBC), and neutrophils together strongly suggest the condition. Conversely, when all three are within their normal ranges, the likelihood of AA is significantly reduced.

Imaging plays a crucial role in confirming AA. Abdominal ultrasound (US) is commonly used as an initial diagnostic tool, with an accuracy ranging between 71% and 97%, and can help locate the inflamed appendix. If US results are inconclusive, computed tomography (CT) is recommended [13]. Contrast-enhanced CT (CECT) is especially effective, with diagnostic accuracy ranging between 90% and 98% [14]. Magnetic resonance imaging (MRI) offers similar sensitivity and specificity but is not always readily accessible in emergency settings [15].

The differential diagnosis of AA encompasses a variety of conditions, including (1) gastrointestinal causes, such as gastroenteritis, a perforated peptic ulcer, inflammatory bowel disease (e.g., Crohn's disease), Meckel's diverticulitis, right-sided colitis, a bowel obstruction, cholecystitis and biliary colic, epiploic appendagitis, and appendiceal diverticulitis [16]; (2) gynecologic causes, such as ovarian torsion, ectopic pregnancy, pelvic inflammatory disease, a ruptured ovarian cyst, a tubo-ovarian abscess, and endometriosis; (3) urologic causes, such as ureteral or renal colic, a urinary tract infection, and pyelonephritis; and (4) other causes, including mesenteric adenitis and musculoskeletal disorders.

Surgical removal of the appendix is the standard treatment for AA, though antibiotics may be appropriate for certain patients with uncomplicated cases. Open appendectomy, first standardized by McBurney in 1894 [17], has long been the traditional method. Laparoscopic appendectomy, introduced in the late 20th century by de Kok [18] and later by gynecologist Kurt Semm [19], has since become widely adopted: In 1997, laparoscopic appendectomy was performed in just 17.4% of cases, but its use has steadily grown over the years, with some recent reports indicating rates of up to 85% [20,21]. Complications from laparoscopic procedures may include intra-abdominal abscesses (IAA), bleeding, and wound infections. With appendix removal being a fairly common procedure, the rate of negative appendectomies (removal of a non-inflamed appendix) varies but was recently estimated at 13% in a large meta-analysis [22]. According to the World Society of Emergency Surgery (WSES) guidelines (updated in 2020), even a macroscopically normal appendix may be considered for removal, with the surgeon deciding on a case-by-case basis in the operating room, as this recommendation is based on low-quality evidence [23].

Overall, AA remains a prevalent surgical emergency, generally associated with low morbidity and mortality when treated promptly. However, delayed diagnosis and treatment, often due to misdiagnosis, can increase the mortality rate from under 1% in uncomplicated cases to as high as 5% in perforated AA [24].

Methods

We conducted a literature search across key databases, including PubMed, Embase, and Scopus, using Medical Subject Headings (MeSH) terms to collect data relevant to laparoscopic appendectomy from January 1991 until October 2025 for all databases. The primary search terms included "acute appendicitis", "appendectomy", "surgical appendectomy", and "laparoscopic appendectomy". The literature search was broadened with secondary search terms, which included "technique" OR "videolaparoscopic" OR "videolaparoscopy" AND "complications" OR "success rate" OR "efficacy" OR "contraindications". Although we did not undertake a formal risk-of-bias assessment, we assigned greater weight to higher levels of evidence, including international guidelines, systematic reviews, meta-analyses, and large cohort studies, when available, to enhance the methodological transparency and scholarly rigor of the review. Publications dealing solely with animal models and non–English language articles were excluded. Using a narrative review approach, we assessed the existing literature to provide consistent, evidence-based insights into laparoscopic appendectomy.

Surgical Techniques

Conventional Three-Port Laparoscopic Appendectomy Surgical Technique

Laparoscopic appendectomy is now widely regarded as the standard surgical approach for treating both uncomplicated and complicated cases of AA. Within this approach, after creating pneumoperitoneum and achieving an intra-abdominal pressure of approximately 12–14 mmHg, three trocars are inserted. A 10 mm trocar is placed at the umbilicus for the laparoscope, and two 5 mm trocars are positioned in the left lower quadrant and either the suprapubic or right lower quadrant to accommodate operative instruments. A 10 mm 30-degree laparoscope is used to examine the abdominal cavity, confirming the diagnosis and excluding other potential causes of abdominal pain. Next, the mesoappendix is dissected with energy devices or surgical clips to control the appendiceal vessels. The base of the appendix is then secured at the cecum using endoloops, clips, or a surgical stapler before transection. The excised appendix is usually extracted via the umbilical port using an endoscopic retrieval bag to prevent spillage and contamination. Additionally, a passive drain may be placed near the cecum or in the pelvic region. Once the procedure is complete, the pneumoperitoneum is deflated, and the trocars are carefully removed under direct vision.

Reported conversion rates from laparoscopic to open surgery range between 0% and 27% [25]. In comparison with open appendectomy, the conventional three-port laparoscopic approach is associated with decreased postoperative pain, a reduced incidence of wound infections, more rapid postoperative recovery, improved cosmetic outcomes, and enhanced diagnostic accuracy.

Single-Incision Laparoscopic Appendectomy Surgical Technique

Single-incision laparoscopic appendectomy (SILA) is a minimally invasive technique in which the appendix is removed through a single entry point, usually made at the umbilicus. To begin, a vertical or curved incision measuring approximately 2–3 cm is made within the umbilical area. A specialized single-port access device, such as a single incision laparoscopic surgery (SILS) port or glove port, is then introduced into the peritoneal cavity. Alternatively, multiple trocars (5 mm or 10 mm) may be inserted through the same umbilical incision using a multi-channel port system. Carbon dioxide is insufflated to create pneumoperitoneum, usually to a pressure of 12–15 mmHg. A 30-degree laparoscopic camera is then inserted for intra-abdominal visualization. Subsequently, the mesoappendix is carefully dissected and divided using energy-based devices or with clips or ligatures. The appendiceal base is secured using an endoloop, stapler, or clips, followed by transection. The specimen is ultimately extracted through the umbilical port. In cases of perforation or necrosis, the peritoneal cavity is irrigated and aspirated as needed.

Critically, SILA should be limited to appropriately selected patients (most commonly young, non-obese individuals with uncomplicated AA) and undertaken by surgeons with advanced laparoscopic expertise, given the technical complexity arising from instrument crowding, diminished triangulation, and ergonomic constraints. This approach has been associated with improved cosmetic outcomes—skin closure results in a nearly invisible scar concealed within the umbilicus—and may offer reduced postoperative pain when compared with conventional multi-port laparoscopic techniques.

Needlescopic Appendectomy Surgical Technique

Needlescopic appendectomy is an advanced, minimally invasive technique that involves removing the appendix using ultra-thin surgical instruments, typically 3 mm or less in diameter, significantly smaller than those used in conventional laparoscopic procedures (5–10 mm). These fine instruments, known as “needlescopes”, were first introduced in 1998 and are designed to minimize surgical trauma, reduce postoperative discomfort, and enhance cosmetic results [26]. The initial port, either 5 mm or 10 mm in size, is placed at the umbilicus using either the open (Hasson) technique or a Veress needle, allowing for the establishment of pneumoperitoneum with carbon dioxide. This port accommodates the laparoscopic camera. Two additional ports (each 2–3 mm in diameter) are then inserted, commonly in the left lower quadrant and suprapubic region. In some cases, a third instrument may be inserted percutaneously without a trocar. The mesoappendix is then separated using methods such as electrocautery, clips, or energy-based sealing devices. Blood vessels are carefully secured using ligatures, clips, or thermal energy devices. The base of the appendix is closed using endoloops, clips, or a stapler based on the surgeon’s preference and available tools. After transection, the appendix is generally removed within a retrieval bag through the umbilical port.

Compared with the conventional multi-port laparoscopic approach, this technique is associated with reduced abdominal wall trauma, improved cosmetic outcomes due to the extremely small size of the needlescopic incisions often making sutures unnecessary, and a lower risk of port-site hernia. On the other hand, owing to the technical challenges related to the use of reduced-diameter instruments and limited traction, needlescopic appendectomy should only be performed by surgeons with advanced laparoscopic expertise. Its application is primarily recommended for uncomplicated AA, with careful patient selection (particularly young, non-obese individuals) being essential.

Indications/Limitations

Indications for and Advantages of Laparoscopic Appendectomy Compared to Open Appendectomy

In recent years, multiple professional surgical organizations have issued evidence-based guidelines for the management of AA. Notably, the WSES, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). and the European Association for Endoscopic Surgery (EAES) have recommend laparoscopic appendectomy as the first-line surgical approach over open appendectomy in both adults and children, provided that the necessary equipment and surgical expertise are available [23,27,28]. Extensive systematic reviews and meta-analyses of randomized controlled trials have supported this recommendation. These studies have consistently shown that laparoscopic appendectomy is associated with numerous benefits compared to the open technique. These include reduced postoperative pain, fewer instances of postoperative ileus, lower surgical site infection (SSI) rates, improved cosmetic outcomes, shorter hospital stays, a faster return to daily activities, and work, better overall quality of life [29–31]. These advantages largely stem from the use of smaller incisions in laparoscopy, resulting in less tissue trauma, decreased blood loss, and quicker healing with lower infection risk. Laparoscopic surgery also allows for enhanced visualization of the abdominal cavity, which improves diagnostic accuracy, particularly in cases where the clinical presentation is unclear. This, in turn, can aid in identifying alternative intra-abdominal pathologies and tailoring the therapeutic strategy accordingly.

According to the 2018 Cochrane review comparing laparoscopic and open appendectomy, laparoscopy outperformed open surgery in terms of pain reduction on the first postoperative day and led to lower SSI rates, a shorter hospitalization, and a faster return to normal activity. However, it did report a higher incidence of IAA following laparoscopic surgery in adults [32].

SSI remains the most frequently encountered complication after appendectomy, whether performed laparoscopically or via open surgery. These infections may be caused by bacterial or fungal contamination of the surgical site, either directly or hematogenously. A major benefit of the laparoscopic approach is the lower risk of wound infection, largely attributable to the controlled extraction of the inflamed appendix through a trocar or protective retrieval bag, as well as the smaller incisions used in this minimally invasive surgery [33].

Reported hospital length of stay (LOS), meanwhile, varies across published studies. Generally, open appendectomy is associated with stays of approximately 1.2 to 6.0 days, whereas laparoscopic appendectomy typically results in a slightly shorter LOS, ranging from about 1.1 to 5.0 days. [33,34].

Laparoscopic appendectomy also offers significant advantages for specific patient populations, including obese patients, elderly individuals, pregnant women, and those with underlying medical conditions. In obese patients, open surgery is technically more difficult due to increased abdominal wall thickness, often requiring larger incisions, which may then lead to greater postoperative pain and delayed wound healing. In pregnant patients requiring surgical intervention for appendicitis, laparoscopic appendectomy is also preferred, assuming proper laparoscopic expertise is available, due to its minimally invasive nature and lower complication rates [23,27,28].

A systematic review and meta-analysis comparing outcomes in complicated appendicitis further demonstrated that while laparoscopic appendectomy is associated with longer operative times, it significantly reduces the risk of SSI. Importantly, no significant differences were observed between laparoscopic and open techniques in terms of IAA rates, overall morbidity, or mortality [31–35].

Contraindications and Disadvantages of Laparoscopic Appendectomy

Despite being a well-established technique, laparoscopic appendectomy continues to face several practical challenges that can hinder its widespread adoption in all clinical environments. These include concerns over IAA formation, longer operative times, and increased procedural costs. The former concern is particularly noteworthy, as IAA represents a more severe and potentially life-threatening postoperative complication, often manifesting with recurrent or persistent abdominal pain, fever, leukocytosis, and changes in bowel function.

One contributing factor to IAA formation is that, unlike in open surgery, the laparoscopic method typically omits the traditional practice of ligating and inverting the appendiceal stump into the cecum, a maneuver that may influence postoperative outcomes. The technique used to secure the appendiceal stump plays a critical role in patient recovery and complication rates, making it essential to evaluate and compare different closure methods to determine the most effective and safest approach.

The likelihood and severity of IAA formation are shaped by a range of factors, including the underlying infectious process, such as the presence of a phlegmon, along with carbon dioxide insufflation, which may promote anaerobic bacterial proliferation and facilitate their spread within the peritoneal cavity. A prolonged operative time—often associated with surgeon experience, vigorous handling of an inflamed appendix, and extensive use of irrigation, which may further disseminate contaminated fluid—has also been implicated in increasing IAA risk [33,36,37]. Crucially, though, as proficiency improves and standardized, well-established laparoscopic techniques are adopted, the incidence of postoperative IAA appears to decline.

Although several randomized controlled trials have historically suggested a marginally higher rate of IAA, longer operative times, and increased costs with the laparoscopic approach, more recent evidence has altered this perspective. A cumulative meta-analysis by Ukai *et al*. [38] showed that early trials (published up to 2001) favored open appendectomy regarding IAA prevention; this trend diminished, however, in later studies, ultimately producing a non-significant cumulative odds ratio of 1.32 (95% CI 0.84–2.10) when comparing laparoscopic and open procedures.

Similarly, reports on operative duration remain inconsistent. While a clinical study has noted longer operative times with laparoscopic appendectomy, Horvath *et al*. [39] found significantly shorter operative times in complicated cases treated laparoscopically among 1762 patients. In contrast, Quezada *et al*. [40], evaluating 227 patients, observed shorter operative times with open surgery for similar cases. Overall, the small differences reported across studies suggest that surgeon expertise and technique exert a greater influence on operative time than the surgical approach itself.

Cost analyses show substantial variability as well. A review of 4757 laparoscopic appendectomies across 20 hospitals reported supply costs ranging from $650 to $1067 per case, with no marked difference in postoperative outcomes between higher- and lower-cost centers. Single-use energy devices and endoscopic staplers accounted for the largest cost increases, raising the average case cost to $1181 when both were used, compared with $734 when only staplers were used and $197 when neither device was employed. Avoiding energy devices could reduce expenses by more than $417 per case, and selective stapler use could increase savings to nearly $984 [41]. Despite these potential efficiencies, laparoscopic appendectomy generally remains more expensive, with a mean cost of $5510 compared with $4472 for open appendectomy [42].

Additional potential complications of laparoscopic appendectomy persist. The most significant of these complications include intraoperative bleeding and accidental injury to adjacent organs, both of which underscore the importance of surgical experience and careful technique in minimizing risks.

Controversies

Debatable Aspects of Laparoscopic Appendectomy

In laparoscopic abdominal surgery, approximately half of all injuries occur during the creation of pneumoperitoneum. Several techniques are available for abdominal access, including direct trocar insertion (using blunt or bladed trocars before insufflation), Veress needle access (blind carbon dioxide (CO_2) insufflation), direct optical entry (visualizing each tissue layer during trocar insertion), and the Hasson (open) technique (placing a trocar under direct vision through a larger incision). A systematic review found no statistically significant differences in perioperative complications among these techniques, though lower-quality evidence has demonstrated a slight favorability toward direct trocar entry. However, this method is rarely utilized in clinical practice [43].

During appendectomy, division of the mesoappendix, which houses the appendiceal artery, can be performed using various instruments, such as endoscopic staplers, ultrasonic devices (e.g., harmonic scalpel), tissue-sealing tools (e.g., LigaSure), traditional ligatures, and clips (e.g., endoloops). Technique selection depends on several factors, including surgeon preference, inflammation severity, cost, and safety considerations. Currently, there is insufficient evidence to definitively recommend one method over another based on morbidity or mortality outcomes alone. Therefore, factors like efficiency and cost-effectiveness are also important in guiding surgical decisions.

One of the most crucial components of laparoscopic appendectomy is the secure closure of the appendiceal stump, as improper sealing can lead to complications, such as stump leakage, abscess formation, or reoperation. Over time, multiple techniques have been developed for stump closure, including intracorporeal suturing, external knot-pushing, endoloops, linear endostaplers [Endo GIA (Endoscopic Gastrointestinal Anastomosis)], hem-o-lok polymeric clips, and metallic clips [43–47]. Absorbable suture materials, like Vicryl and polydioxanone, have also been shown to be effective. The endoloop, derived from the Roeder loop, is a pre-tied ligature that can be tightened around the base of the appendix [48]. Titanium endoclips, first reported by Cristalli *et al*. [49], offer a safe and efficient closure option and are thought to minimize inflammation due to their inert properties. However, clips can fail in cases where the appendiceal base is inflamed or friable, leading to potential leakage.

Similarly, foreign materials used in stump closure can provoke significant intra-abdominal inflammation, increasing the risk of adhesive small bowel obstruction. Specific drawbacks include knot slippage with endoloops [50,51] and clip dislodgement, particularly when clips are applied to bases larger than 12 mm [52,53].

Different techniques have also shown different operative times. In a prospective randomized study of 53 patients comparing non-absorbable polymer clips with endoloop ligatures for appendiceal stump closure during laparoscopic appendectomy, the mean operative time was shorter in the hem-o-lok group than in the endoloop group (64.7 $\pm$ 19.2 minutes vs. 75.4 $\pm$ 23 minutes). However, this difference did not reach statistical significance, and no meaningful differences were observed between the groups in terms of either surgical or non-surgical postoperative complications [48].

Staplers like Endo GIA are costly and require a 12 mm port, making them less accessible for routine use. A prospective randomized study involving 61 patients compared intracorporeal knot-tying sutures with titanium endoclips for appendiceal stump closure. Both methods were found to be safe and effective, with the endoclip group demonstrating a shorter mean operative time. No significant differences were observed between the groups regarding hospital stay, follow-up duration, or pre- and postoperative complications ($p > 0.05$) [47].

In a separate retrospective review of 242 patients comparing endoloop ligatures and endostaplers for appendiceal stump closure, a higher incidence of IAA was noted in patients treated with the endostapler. This finding may reflect a selection bias, as endostaplers were more frequently used in cases with severely inflamed appendiceal stumps, a limitation acknowledged by the study authors [44].

Despite the variety of closure techniques, the literature to date has not conclusively favored one method over another. In 2017, for instance, Mannu *et al*. [54] conducted a systematic review and pairwise meta-analysis to compare various techniques for appendiceal stump closure. The authors concluded that the current evidence is insufficient to recommend any mechanical device over the traditional ligature-based method. Given that most studies in this area have involved relatively small patient populations and have not demonstrated a clear advantage of one technique over another, the choice of stump closure method is generally left to the surgeon, often guided by factors such as equipment availability, cost, and personal experience.

Recently, the harmonic scalpel has gained attention as a sutureless method for both mesoappendix and stump division. This tool allows for both steps to be completed with a single instrument, reducing operative time by eliminating the need for tool exchanges (e.g., needle holders, clip appliers, staplers). Moreover, the harmonic scalpel can be used through a standard 5 mm port, avoiding the need for larger ports and minimizing foreign body exposure, which may decrease adhesion formation. Several studies and meta-analyses have shown that this method is comparable to conventional techniques in terms of postoperative complications, wound infection, ileus, and hospital stay, all while offering the added benefit of a shorter operative time [55,56].

Across six randomized trials comparing stump closure methods, none showed a significant difference in complication rates. Consequently, no single technique has emerged as superior, and practical considerations, such as cost, availability, and surgeon experience, often guide the choice [43].

Another point of surgical consideration is the optimal length of the appendiceal stump post-resection. A length of 3–5 mm is generally preferred to minimize risks: Too short (<3 mm) may damage the cecum, while too long (>5–10 mm) may predispose the patient to stump appendicitis, a rare but recognized complication. Although often underreported, the recent literature has estimated an incidence of 0.06% to 0.15%, with the only curative treatment being re-excision, which may be done laparoscopically or through open surgery [57,58].

Appendix extraction technique is another debated topic. Some retrospective studies have suggested that using a specimen retrieval bag reduces the risk of SSI and IAA compared to direct extraction [59,60]. Proper fascial closure, particularly at larger port sites (≥10 mm), is critical in preventing port-site hernias. Dilating trocars are thought to reduce fascial trauma compared to cutting trocars. Fascial closure can be performed using tools like the Carter–Thomason suture passer, swedged needles, or a neoClose device.

The use of peritoneal drainage after laparoscopic appendectomy, especially in complicated cases, has long been practiced. However, recent evidence challenges its utility, showing that routine drainage does not reduce postoperative complications and may in fact prolong surgery and hospital stay and increase costs. Additionally, it may elevate the risk of complications, such as fistulas, wound infections, IAA, ileus, and adhesive bowel obstructions [61,62]. Indeed, a recent meta-analysis found significantly worse outcomes in patients who received peritoneal drainage, including higher pain scores [visual analogue scale (VAS)], increased wound infection rates, and delayed recovery. Consequently, the authors advised against routine drainage in complicated AA cases managed laparoscopically. However, more robust randomized trials are needed to confirm these findings [63]. Currently, WSES guidelines do not recommend the use of drains after appendectomy for complicated AA in adult patients [quality of evidence: moderate; strength of recommendation: strong; 1B] [23].

Special Populations

Laparoscopic Appendectomy During Pregnancy

AA is the most frequent non-obstetric surgical emergency encountered during pregnancy, with an estimated incidence of approximately one in 500 pregnancies [64]. According to the literature, AA tends to occur more commonly during the second trimester compared to the first or third trimesters and the postpartum period [65]. Since nonoperative management with antibiotics alone is generally discouraged, as it carries a high risk of failure in both the short and long term and there is limited evidence supporting its use in pregnant patients, appendectomy remains the definitive treatment for AA during pregnancy [66].

Notably, the incidence of appendiceal perforation is relatively higher during pregnancy, with a study reporting rates as high as 43%, compared to approximately 19% in the general population [67]. If perforation of the appendix leads to peritonitis, the risk of obstetric complications, including fetal loss, rises significantly; reports indicate fetal mortality can be as high as 20% in perforated cases, while remaining under 5% in uncomplicated appendicitis [68].

Relatedly, a systematic review and meta-analysis that included 22 comparative cohort studies with a total of 4694 pregnant women found a higher reported rate of fetal loss among those undergoing laparoscopic appendectomy compared with open appendectomy. However, this finding was largely influenced by a single study; excluding that study eliminated the significant difference between the two approaches (odds ratio (OR): 1.163, 95% CI: 0.68–1.99; p = 0.581). The same analysis found no significant differences between laparoscopic and open appendectomy regarding preterm delivery, birth weight, operative time, or postoperative intra-abdominal abscess formation. The review also suggested that laparoscopic appendectomy may be associated with a lower risk of wound infection and a shorter hospital length of stay [69].

A more recent systematic review of 15 comparative cohort studies, which encompassed 2837 pregnant women (1103 laparoscopic, 1656 open), reached the opposite conclusion, finding laparoscopic surgery to be slightly safer for the fetus than open surgery. Specifically, the review reported fetal demise rates of 2.44% for laparoscopic surgery versus 2.64% for the open surgery and preterm delivery rates of 9.79% versus 10.7%, respectively. These data indicate that both laparoscopic and open appendectomy are generally safe and effective for treating AA in pregnancy, with no statistically significant differences in fetal outcomes, although laparoscopic appendectomy may offer slightly lower risks of preterm delivery and fetal loss [70].

Given the variability in the literature regarding the optimal surgical approach for AA in pregnant patients, specifically concerning fetal outcomes, further large-scale studies are warranted to establish a clear gold standard. Nonetheless, the laparoscopic approach offers several clear advantages over open surgery, including reduced wound complications and shorter hospital stays. As a result, laparoscopic appendectomy has become the preferred surgical method in pregnant women, and it is the approach endorsed by the SAGES [27].

For optimal safety during pregnancy, the SAGES guidelines outline several important modifications to the standard laparoscopic technique. These include using an open (Hasson) entry technique to avoid inadvertent injury to maternal organs or the uterus from blind Veress needle insertion. Trocar placement must also be adjusted based on the gestational age to accommodate the enlarged uterus and ensure safer access to the abdominal cavity. Patients should be positioned in a left lateral tilt to reduce pressure on the inferior vena cava, improving venous return and preventing hypotension. Additionally, the guidelines recommend an ultrasonic energy device over electrocautery to minimize

potential risks of electrical current transmission to the fetus. The primary port is usually placed at the umbilicus, with secondary ports adjusted to the right upper and lower abdominal quadrants, depending on uterine size and gestational age. To maintain maternal cardiopulmonary stability, insufflation pressures should be kept between 10 and 15 mm Hg; pressures above this range may negatively impact pulmonary function and venous return, particularly in later stages of pregnancy. Carbon dioxide pneumoperitoneum can also contribute to venous stasis, potentially increasing the risk of deep vein thrombosis. For example, even at 12 mm Hg, intra-abdominal pressure may reduce venous return significantly, and this effect is not fully reversed by using compression devices. So long as these guidelines are followed, laparoscopic appendectomy is considered safe across all trimesters of pregnancy, and current evidence supports its use as the standard of care in pregnant individuals with suspected AA [64].

Laparoscopic Appendectomy in Elderly Patients

Although the incidence of AA declines after adolescence, it remains relatively common in the elderly. Among patients over 50 presenting to the emergency department with acute abdominal pain, approximately 15% are diagnosed with AA, making it the second most frequent acute surgical condition in this age group [71]. Elderly patients are also more likely than younger individuals to present with complicated appendicitis, including abscess or perforation. Reported rates of complicated AA in older adults range from 18% to 70%, compared with 3% to 29% in patients under 65 years of age [72]. The increased risk of perforation in the elderly may be attributable to vascular sclerosis of the appendix and fibrotic narrowing of the lumen. Additionally, fatty infiltration of the muscular layers and structural weakness of the appendiceal wall predispose patients to early perforation. These anatomical changes, combined with delays in diagnosis and treatment, likely contribute to the more severe clinical course observed in this population.

In all adult patients, there are several well-known risk factors, such as increased age, open surgery, and complicated AA, for postoperative complications [73]. In elderly patients in particular, several independent factors, including anemia, a history of cardiac disease, chronic renal insufficiency, higher frailty scores, and the use of an open surgical approach for appendectomy, have been associated with an increased risk of postoperative complications [74]. Overall postoperative morbidity in this population ranges from 19.3% to 46.2%, compared to just 5.06% to 9.3% in younger patients [28,36]. Surgical site infections are the most frequent complication, occurring in 9.0% to 15.4% of cases, which is markedly higher than the 2.6% to 3.7% observed in younger individuals [75]. When selecting the optimal surgical method for AA in elderly patients, the physiological effects of pneumoperitoneum must be considered, including reduced pulmonary compliance, decreased urinary output, lower glomerular filtration rate, and renal blood flow, as well as increases in heart rate, mean arterial pressure, and cardiac output.

While the benefits of laparoscopic appendectomy over open surgery have been well established in the general population, data specifically focused on the elderly remain limited. A 2012 meta-analysis of patients older than 60 years reported lower postoperative mortality, complication rates, and hospital LOS with laparoscopic appendectomy compared with the open approach; however, this analysis mainly included retrospective study, and the laparoscopic groups had lower mean ages, introducing potential selection bias [76]. A more recent 2019 meta-analysis and systematic review confirmed these findings, also demonstrating reduced complication rates with laparoscopy in cases of complicated appendicitis [77].

In light of the limited high-quality evidence dedicated to elderly patients, international guidelines, including those from the Italian Society of Surgical Pathophysiology (SIFIPAC), WSES, Italian Society of Geriatric Surgery (SICG), and Italian Society of Emergency Medicine (SIMEU), recommend the following: (1) laparoscopic appendectomy as the preferred approach due to reduced LOS, morbidity and costs (conditional recommendation, moderate-quality evidence); (2) a stump closure technique based on local expertise and availability (conditional recommendation, moderate-quality evidence); (3) the placement of abdominal drainage in cases of complicated appendicitis (conditional recommendation, very low-quality evidence); and (4) the prompt performance of appendectomy as soon as possible (conditional recommendation, very low-quality evidence); critically, there is no consensus on the removal of a normal appendix due to insufficient evidence [72]. Conversion from laparoscopic to open appendectomy is more frequent in elderly patients, with rates ranging from 3% to 17%, with the most common reasons for conversion being periappendicular infiltration or the presence of an inflammatory mass [73].

Laparoscopic Appendectomy in Obese Patients

Laparoscopic appendectomy appears to be a safer and more effective approach than open appendectomy in obese patients. A systematic review that included seven retrospective cohort studies and one randomized controlled trial found that laparoscopic appendectomy in this population was associated with significantly lower mortality (risk ratio [RR]: 0.19, 95% CI: 0.12–0.30), reduced overall morbidity (RR: 0.49, 95% CI: 0.47–0.51), decreased rates of superficial wound infections (RR: 0.27, 95% CI: 0.21–0.35), and shorter operative times and postoperative hospital stays compared to open appendectomy [78]. Similarly, a retrospective study of 1231 patients undergoing either laparoscopic or open appendectomy for AA between 2017 and 2022 reported that the laparoscopic approach was associated with shorter operative times ($p = 0.004$), reduced hos-

pital LOS ($p = 0.009$), and lower rates of SSI (5.6% vs. 13.5%, $p < 0.001$) [79]. Within this patient population, the advantages of laparoscopy include improved access to the appendix, enhanced visualization, and reduced wound complications.

Due to these findings, current guidelines support the laparoscopic approach in obese patients. The WSES guidelines recommend laparoscopic appendectomy with moderate-quality evidence but a weak strength of recommendation (2B) [23]. The SAGES guidelines similarly assert that laparoscopic appendectomy is safe and effective in obese patients (level II evidence, grade B) and may be preferred, although the recommendation is weaker (level III evidence, grade C) in certain contexts. Crucially, in morbidly obese patients, longer trocars and instruments may be required to facilitate the procedure [27].

Laparoscopic Appendectomy in Pediatric Patients

Over the past 25 years, laparoscopic appendectomy has become widely accepted in pediatric surgery. Both SAGES [27] and WSES [23] guidelines indicate that laparoscopic appendectomy can be safely performed in children. Supporting these guidelines, in the early 1990s, a French group published a large series of pediatric laparoscopic appendectomies, demonstrating that the procedure was a feasible and effective alternative for treating AA in this population [80]. The reported benefits of laparoscopy in children are largely similar to those observed in adults, including shorter hospital stays, lower rates of wound infection, a faster return to normal activities, improved cosmetic outcomes, more effective peritoneal lavage, and better visualization of the abdominal cavity [81].

Some studies, though, have raised concerns about a potentially higher incidence of IAA following laparoscopic appendectomy [36,82]. A 2017 meta-analysis of nine studies examining perforated appendicitis in children found that laparoscopic appendectomy was associated with reduced rates of SSI and bowel obstruction but a slightly higher incidence of IAA compared with open surgery [83]. Another meta-analysis, incorporating two randomized controlled trials and 14 retrospective cohort studies, confirmed that laparoscopic appendectomy for complicated appendicitis lowers the risk of SSI but found no increase in postoperative IAA [35]. Despite the conflicting data in the literature regarding the rate of postoperative IAA formation, WSES guidelines [23] recommend that laparoscopic appendectomy should be preferred over open appendectomy in children where laparoscopic equipment and expertise are available [Quality of evidence: Moderate; Strength of recommendation: Strong; 1B].

Quantitative Comparison of Different Laparoscopic Approaches

While SILA is a viable and generally safe technique, the conventional three-port version of laparoscopic appendectomy remains the preferred method for completing the procedure in its entirety. Although SILA is comparable in safety and overall effectiveness to the traditional approach, a meta-analysis of randomized control trials indicated that SILA is associated with increased need for postoperative analgesia, a slightly higher risk of surgical site infections, a longer operative duration, greater technical complexity, and higher hospitalization costs. However, these differences appear to be clinically minor. Conversely, SILA also offers notable cosmetic benefits, such as a virtually scarless appearance, and may result in reduced postoperative discomfort and quicker recovery times in well-selected patients [84]. Nevertheless, the technique poses technical challenges due to instrument crowding and restricted triangulation, which make it less suitable for patients with complicated appendicitis, obesity, or limited abdominal workspace. Because of these challenges, SILA requires surgeon proficiency and access to specialized instruments. Relatedly, when facing technically complex cases, such as retrocecal appendices or significant inflammation, SILA may become unwieldy and require the use of additional instruments. In these situations, the three-port laparoscopic setup allows for faster and more efficient dissection and mobilization, with less disruption to the operation.

Patient selection is also critical for SILA. The technique is most feasible in uncomplicated appendicitis cases with minimal inflammation and without features like phlegmon or perforation. On the other hand, in patients with complicated appendicitis, SILA has a lower feasibility and a higher risk of conversion to open surgery and limits the ability to place intra-abdominal drains, all of which reduce its overall practicality [85].

Notably, the enlarged umbilical incision needed for this approach may increase the risk of postoperative incisional hernia. In fact, a recent systematic review and meta-analysis reported that patients undergoing SILA had a threefold increased risk of developing incisional hernias compared to those treated with the three-port method [86], underscoring the importance of preventative measures during closure.

Several studies have indicated that needlescopic appendectomy is a safe and effective option for treating appendicitis, primarily due to the smaller trocar incisions and reduced tissue trauma associated with the procedure [87,88]. However, a randomized controlled trial comparing needlescopic appendectomy with the standard three-port laparoscopic approach found that the needlescopic technique was associated with significantly longer operative times and a higher rate of conversion to conventional surgery. The study attributed this to the technical challenges posed by the long, thin needlescopic instruments and the small jaws of the 3 mm dissecting forceps, which were insufficiently robust for precise manipulation. Consequently, the authors advised against the routine use of needlescopic appendectomy in general practice [89].

As intimated by this finding, compared to the conventional three-port laparoscopy, needlescopic instruments present specific limitations. Beyond those mentioned above, these

limitations include increased lens fogging, a smaller video monitor image, and difficulty in centering the target area, which requires more frequent adjustments to maintain optimal focus [90]. Additionally, handling a 3 mm forceps with a slender shaft and small jaws demands greater surgical skill compared to standard instruments. A systematic review also noted a higher conversion rate to open appendectomy with the needlescopic approach, reflecting the initial technical difficulties surgeons encounter when using these finer instruments. These findings have led to the recommendation that needlescopic appendectomy be reserved for surgeons with significant experience in conventional three-port laparoscopic appendectomy [47]. Nevertheless, the extant evidence suggests that needlescopic appendectomy may be an effective technique in selected cases, particularly in younger patients with mild appendicitis [87]. Further research, however, is needed to clarify the optimal indications and timing for needlescopic versus conventional three-port laparoscopic appendectomy in AA.

Ideal Time to Perform Laparoscopic Appendectomy

The ideal timing for laparoscopic appendectomy depends largely on the clinical presentation and severity of AA. It is widely accepted that the severity of AA tends to increase over time, with a rising risk of perforation if surgical intervention is delayed. As a result, immediate surgery has traditionally been considered the standard of care for these patients. However, practical factors, such as limited overnight resources and concerns about the safety of nighttime surgery, have led to an approach of delaying appendectomy until the following morning for patients presenting at night. When deciding on urgent surgery, the potential risks associated with nighttime operating must be considered, as fatigue and sleep deprivation have been linked to increased technical errors [91].

Multiple large retrospective studies have documented variability in clinical practice regarding the timing of appendectomy [92,93]. However, these retrospective studies have had several notable limitations. In these studies, patient identification relied on operative and postoperative coding rather than direct clinical assessment. Moreover, key variables, such as body mass index and white blood cell count, were often unavailable, and researchers were unable to review abdominal CT scans, access pathology reports, or obtain detailed information regarding patients' presenting symptoms, the timing of their emergency department visit, or the reasons for any delays in reaching the operating room.

Relatedly, the current observational evidence remains inconclusive about the safety of delaying surgery. Some retrospective studies have found a correlation between surgical delay and increased rates of perforation, which in turn is associated with worse outcomes, including a more severe pathology, IAA, longer antibiotic courses, higher postoperative complication rates, extended hospital stays, and increased costs [94,95]. Conversely, more recent studies have questioned these findings and reported no significant differences in outcomes when appendectomy is performed within 12 to 24 hours after presentation or when delayed until the next morning for nighttime admissions [93,96]. For example, Patel *et al*. [97] (delay study, randomized control trial with level 1 evidence) found increased postoperative complications of laparoscopic appendectomy only after delays exceeding 24 hours from emergency department triage to surgery. Indeed, delaying to avoid a nighttime surgery may be more beneficial than immediate surgery, as some research has suggested that nighttime surgery is associated with higher complication rates, increased conversion to open surgery, more frequent reoperations, and longer hospital stays [98,99]. However, another study has shown no increase in overall complications related to nighttime procedures [100]. A 2018 meta-analysis of 21 studies (20 observational and one randomized controlled trial) published between 1997 and 2018 and accounting for 54,435 patients found no significant differences in rates of complicated appendicitis or SSI between surgeries performed at various intervals, namely six hours, six to 12 hours, and over 12 hours after presentation. Delays beyond 24 hours, however, were associated with increased patient risks [101].

While studies on the optimal timing of laparoscopic appendectomy have produced conflicting results, mainly because many were retrospective and subject to confounding biases, recent high-quality randomized controlled trials have reached similar conclusions, indicating that delaying surgery for up to 24 hours after symptom onset does not adversely affect patient outcomes. For uncomplicated AA, surgery is generally recommended within 12 to 24 hours of diagnosis to reduce the risk of perforation and associated complications. In contrast, for complicated AA, defined by gangrenous or perforated appendicitis with or without peritonitis, abscess, or phlegmon, immediate laparoscopic appendectomy is advised, particularly if the patient is unstable or septic. The EAES guidelines recommend performing appendectomy as promptly as possible, since it is difficult to predict whether appendicitis will follow a mild or fulminant course. Delaying surgery increases the risk of perforation, which is associated with higher rates of both short- and long-term morbidity [28]. WSES guidelines [23] recommend planning laparoscopic appendectomy for the next available operating list within 24 hours in case of uncomplicated AA, minimizing the delay wherever possible (Quality of Evidence: Moderate; Strength of recommendation: Strong; 1B).

Conclusions

Established Consensus

Guidelines from multiple scientific societies, drawing on evidence from retrospective studies, cohort studies, randomized controlled trials, systematic reviews, and meta-analyses, indicate that laparoscopic appendectomy is the preferred surgical approach for AA. This recommendation

is based on the numerous advantages of laparoscopy over open appendectomy. When laparoscopic equipment and expertise are available, WSES recommends this technique as the preferred approach over open appendectomy for both uncomplicated and complicated AA [Quality of Evidence: High; Strength of recommendation: Strong; 1A]. Furthermore, early diagnosis of AA, including the use of appropriate scores for risk assessment of AA, appropriate surgical management, and infection prevention strategies are important to prevent complications.

Crucially, the evidence-based standardization and optimization of operative steps offer a valuable opportunity to enhance surgical outcomes for a large patient population. As surgeons have gained greater experience with laparoscopic techniques, this minimally invasive approach has been widely adopted to maximize patient benefits, including reduced rates of wound infection and postoperative ileus, faster recovery, and potentially fewer adhesional complications in the long term. The enhanced visualization of the abdominal cavity provided by laparoscopy also facilitates more accurate diagnoses and enhanced management of other intra-abdominal pathologies.

Laparoscopic appendectomy may be undertaken using various technical approaches, including the standard multi-port technique (SILA) and needlescopic methods, provided that appropriate patient selection and adequate surgeon expertise are ensured. Indeed, rates of conversion and procedure-related complications are closely linked to the level of laparoscopic experience. Although laparoscopic appendectomy may involve higher initial costs and demands advanced surgical skills, its overall advantages establish it as a safe, effective, and preferred technique in contemporary surgical practice.

Persisting Controversies

Currently, the literature does not provide sufficient evidence to establish definitive guidelines on the optimal timing of laparoscopic appendectomy without increasing patient risk, largely due to the limitations and confounding biases inherent in retrospective studies. Similarly, uncertainty persists regarding the optimal choice of laparoscopic technique; this uncertainty extends to the clinical advantages of single-incision and needlescopic approaches over standard laparoscopic appendectomy, the most effective method for appendiceal stump closure (endoloops, clips, or stapling devices), and the cost–benefit balance of advanced minimally invasive techniques and disposable instruments.

Directions for Future Research

Further high-quality research is required to address these unresolved issues and to refine best practices in laparoscopic appendectomy. Well-designed randomized controlled trials are needed to (1) compare different laparoscopic techniques, with a particular focus on clinically meaningful outcomes, and (2) evaluate the role of artificial intelligence and digital technologies in clinical decision support and surgical education. In addition, long-term studies examining chronic postoperative pain, quality of life, and cosmetic outcomes are warranted. Lastly, both patients and practitioners would benefit from the development of patient selection algorithms based on clinical, radiological, and demographic factors, along with cost-effectiveness analyses to support the optimal allocation of health-care resources.

Availability of Data and Materials

Not applicable.

Author Contributions

GE and GB coordinated and organized the development of the review and contributed to the protocol design, literature screening, data extraction, and drafting of the initial manuscript. MV, FRE, LR, MB and GM contributed to the data analysis, interpretation, critical review, and revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflicts of interest.

References

[1] Guan L, Liu Z, Pan G, Zhang B, Wu Y, Gan T, *et al*. The global, regional, and national burden of appendicitis in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. BMC Gastroenterology. 2023; 23: 44. https://doi.org/10.1186/s12876-023-02678-7.

[2] Singh S, Jha AK, Sharma N, Mishra TS. A case of right upper abdominal pain misdiagnosed on computerized tomography. The Malaysian Journal of Medical Sciences: MJMS. 2014; 21: 66–68.

[3] Evola G, Lanaia A, Cantella R, Di Fidio C, Di Fede GF, Piazza L. Subhepatic perforated acute appendicitis in a patient with midgut malrotation: A case report and review of the literature. International Journal of Surgery Case Reports. 2022; 95: 107249. https://doi.org/10.1016/j.ijscr.2022.107249.

[4] Evola G, Ferrara F, Di Fede GF, Patanè M, Sarvà S, Piazza L. Left-sided acute appendicitis in a patient with situs viscerum inversus totalis: A case report. International Journal of Surgery Case Reports. 2022; 90: 106658. https://doi.org/10.1016/j.ijscr.2021.106658.

[5] Caruso G, Toscano C, Evola G, Benfatto SAM, Reina M, Reina GA. Gangrenous appendicitis in Amyand's hernia: Surgical approach under local anesthesia. Case report and review of the literature. International Journal of Surgery Case Reports. 2021; 79: 215–218. https://doi.org/10.1016/j.ijscr.2021.01.048.

[6] Alkhalifa AA, Alabbad M, Alshahri HM, Aljughaiman B, Helal HF, Al Omair AM, *et al*. Appendicitis in De Garengeot Hernia: A Rare Presentation. Cureus. 2024; 16: e68352. https://doi.org/10.7759/cureus.68352.

[7] Hakim M, Mostafa R, Al Shehri M, Sharawy S. Surgical management of subhepatic perforated appendicitis: a case report. Journal of Medical Case Reports. 2020; 14: 151. https://doi.org/10.1186/s13256-020-02499-2.

[8] Evola G, Caruso G, Caramma S, Dapri G, Spampinato C, Reina C, *et al*. Tubulo-villous adenoma of the appendix: A case report and review of the literature. International Journal of Surgery Case Reports. 2019; 61: 60–63. https://doi.org/10.1016/j.ijscr.2019.06.061.

[9] Van de Moortele M, De Hertogh G, Sagaert X, Van Cutsem E. Appendiceal cancer: a review of the literature. Acta Gastro-enterologica Belgica. 2020; 83: 441–448.

[10] Barut B, Gönültaş F. Carcinoid tumors of appendix presenting as acute appendicitis. Ulusal Travma Ve Acil Cerrahi Dergisi = Turkish Journal of Trauma & Emergency Surgery: TJTES. 2019; 25: 510–513. https://doi.org/10.5505/tjtes.2018.99569.

[11] Walczak DA, Pawełczak D, Żółtaszek A, Jaguścik R, Fałek W, Czerwińska M, *et al*. The Value of Scoring Systems for the Diagnosis of Acute Appendicitis. Polski Przeglad Chirurgiczny. 2015; 87: 65–70. https://doi.org/10.1515/pjs-2015-0021.

[12] Favara G, Maugeri A, Barchitta M, Ventura A, Basile G, Agodi A. Comparison of RIPASA and ALVARADO scores for risk assessment of acute appendicitis: A systematic review and meta-analysis. PloS One. 2022; 17: e0275427. https://doi.org/10.1371/journal.pone.0275427.

[13] Hwang ME. Sonography and Computed Tomography in Diagnosing Acute Appendicitis. Radiologic Technology. 2018; 89: 224–237.

[14] Bahrami M, Mirgaloyebayat H, Mohajeri Z, Mohammadi H, Afshari SA, Fazeli P, *et al*. The diagnostic value of the computed tomography scan and ultrasonography in acute appendicitis. American Journal of Nuclear Medicine and Molecular Imaging. 2023; 13: 11–17.

[15] Barger RL, Jr, Nandalur KR. Diagnostic performance of magnetic resonance imaging in the detection of appendicitis in adults: a meta-analysis. Academic Radiology. 2010; 17: 1211–1216. https://doi.org/10.1016/j.acra.2010.05.003.

[16] Evola G, Caruso G, Pulvirenti E, D'Angelo M, Reina M, Reina GA. Complicated appendiceal diverticulitis a extremely rare cause of acute abdomen: A case report and literature review. International Journal of Surgery Case Reports. 2023; 109: 108535. https://doi.org/10.1016/j.ijscr.2023.108535.

[17] McBurney C. The incision made in the abdominal wall in cases of appendicitis, with a description of a new method of operating. Annals of Surgery. 1894; 20: 38–43. https//doi.org/10.1097/00000658-189407000-00004.

[18] de Kok HJ. A new technique for resecting the non-inflamed not-adhesive appendix through a mini-laparotomy with the aid of the laparoscope. Archivum Chirurgicum Neerlandicum. 1977; 29: 195–198.

[19] Semm K. Endoscopic appendectomy. Endoscopy. 1983; 15: 59–64. https://doi.org/10.1055/s-2007-1021466.

[20] Esposito C, Calvo AI, Castagnetti M, Alicchio F, Suarez C, Giurin I, *et al*. Open versus laparoscopic appendectomy in the pediatric population: a literature review and analysis of complications. Journal of Laparoendoscopic & Advanced Surgical Techniques. Part a. 2012; 22: 834–839. https://doi.org/10.1089/lap.2011.0492.

[21] Guller U, Hervey S, Purves H, Muhlbaier LH, Peterson ED, Eubanks S, *et al*. Laparoscopic versus open appendectomy: outcomes comparison based on a large administrative database. Annals of Surgery. 2004; 239: 43–52. https://doi.org/10.1097/01.sla.0000103071.35986.c1.

[22] Henriksen SR, Christophersen C, Rosenberg J, Fonnes S. Varying negative appendectomy rates after laparoscopic appendectomy: a systematic review and meta-analysis. Langenbeck's Archives of Surgery. 2023; 408: 205. https://doi.org/10.1007/s00423-023-02935-z.

[23] Di Saverio S, Podda M, De Simone B, Ceresoli M, Augustin G, Gori A, *et al*. Diagnosis and treatment of acute appendicitis: 2020 update of the WSES Jerusalem guidelines. World Journal of Emergency Surgery: WJES. 2020; 15: 27. https://doi.org/10.1186/s13017-020-00306-3.

[24] Hardin DM, Jr. Acute appendicitis: review and update. American Family Physician. 1999; 60: 2027–2034.

[25] Humes DJ, Simpson J. Acute appendicitis. BMJ (Clinical Research Ed.). 2006; 333: 530–534. https://doi.org/10.1136/bmj.38940.664363.AE.

[26] Gagner M, Garcia-Ruiz A. Technical aspects of minimally invasive abdominal surgery performed with needlescopic instruments. Surgical Laparoscopy & Endoscopy. 1998; 8: 171–179.

[27] Kumar SS, Collings AT, Lamm R, Haskins IN, Scholz S, Nepal P, *et al*. SAGES guideline for the diagnosis and treatment of appendicitis. Surgical Endoscopy. 2024; 38: 2974–2994. https://doi.org/10.1007/s00464-024-10813-y.

[28] Gorter RR, Eker HH, Gorter-Stam MAW, Abis GSA, Acharya A, Ankersmit M, *et al*. Diagnosis and management of acute appendicitis. EAES consensus development conference 2015. Surgical Endoscopy. 2016; 30: 4668–4690. https://doi.org/10.1007/s00464-016-5245-7.

[29] Li X, Zhang J, Sang L, Zhang W, Chu Z, Li X, *et al*. Laparoscopic versus conventional appendectomy–a meta-analysis of randomized controlled trials. BMC Gastroenterology. 2010; 10: 129. https://doi.org/10.1186/1471-230X-10-129.

[30] Wei B, Qi CL, Chen TF, Zheng ZH, Huang JL, Hu BG, *et al*. Laparoscopic versus open appendectomy for acute appendicitis: a meta-analysis. Surgical Endoscopy. 2011; 25: 1199–1208. https://doi.org/10.1007/s00464-010-1344-z.

[31] Athanasiou C, Lockwood S, Markides GA. Systematic Review and Meta-Analysis of Laparoscopic Versus Open Appendicectomy in Adults with Complicated Appendicitis: an Update of the Literature. World Journal of Surgery. 2017; 41: 3083–3099. https://doi.org/10.1007/s00268-017-4123-3.

[32] Jaschinski T, Mosch CG, Eikermann M, Neugebauer EA, Sauerland S. Laparoscopic versus open surgery for suspected appendicitis. The Cochrane Database of Systematic Reviews. 2018; 11: CD001546. https://doi.org/10.1002/14651858.CD001546.pub4.

[33] Cipe G, Idiz O, Hasbahceci M, Bozkurt S, Kadioglu H, Coskun H, *et al*. Laparoscopic versus open appendectomy: where are we now? Chirurgia (Bucharest, Romania: 1990). 2014; 109: 518–522.

[34] Bulut A, Ucar M. Laparoscopic Appendectomy versus Open Surgery. JSLS: Journal of the Society of Laparoendoscopic Surgeons. 2025; 29: e2024.00077. https://doi.org/10.4293/JSLS.2024.00077.

[35] Yu MC, Feng YJ, Wang W, Fan W, Cheng HT, Xu J. Is laparoscopic appendectomy feasible for complicated appendicitis ?A systematic review and meta-analysis. International Journal of Surgery (London, England). 2017; 40: 187–197. https://doi.org/10.1016/j.ijsu.2017.03.022.

[36] Krisher SL, Browne A, Dibbins A, Tkacz N, Curci M. Intra-abdominal abscess after laparoscopic appendectomy for perforated appendicitis. Archives of Surgery (Chicago, Ill.: 1960). 2001; 136: 438–441. https://doi.org/10.1001/archsurg.136.4.438.

[37] Gupta R, Sample C, Bamehriz F, Birch DW. Infectious complications following laparoscopic appendectomy. Canadian Journal of Surgery. Journal Canadien De Chirurgie. 2006; 49: 397–400.

[38] Ukai T, Shikata S, Takeda H, Dawes L, Noguchi Y, Nakayama T, *et al*. Evidence of surgical outcomes fluctuates over time: results from a cumulative meta-analysis of laparoscopic versus open appendec-

tomy for acute appendicitis. BMC Gastroenterology. 2016; 16: 37. https://doi.org/10.1186/s12876-016-0453-0.

[39] Horvath P, Lange J, Bachmann R, Struller F, Königsrainer A, Zdichavsky M. Comparison of clinical outcome of laparoscopic versus open appendectomy for complicated appendicitis. Surgical Endoscopy. 2017; 31: 199–205. https://doi.org/10.1007/s00464-016-4957-z.

[40] Quezada F, Quezada N, Mejia R, Brañes A, Padilla O, Jarufe N, *et al*. Laparoscopic versus open approach in the management of appendicitis complicated exclusively with peritonitis: a single center experience. International Journal of Surgery (London, England). 2015; 13: 80–83. https://doi.org/10.1016/j.ijsu.2014.11.027.

[41] Malhotra L, Pontarelli EM, Grinberg GG, Isaacs RS, Morris JP, Yenumula PR. Cost analysis of laparoscopic appendectomy in a large integrated healthcare system. Surgical Endoscopy. 2022; 36: 800–807. https://doi.org/10.1007/s00464-020-08266-0.

[42] Vernon AH, Georgeson KE, Harmon CM. Pediatric laparoscopic appendectomy for acute appendicitis. Surgical Endoscopy. 2004; 18: 75–79. https://doi.org/10.1007/s00464-002-8868-9.

[43] Bessoff KE, Choi J, Wolff CJ, Kashikar A, Carlos GM, Caddell L, *et al*. Evidence-based surgery for laparoscopic appendectomy: A stepwise systematic review. Surgery Open Science. 2021; 6: 29–39. https://doi.org/10.1016/j.sopen.2021.08.001.

[44] Safavi A, Langer M, Skarsgard ED. Endoloop versus endostapler closure of the appendiceal stump in pediatric laparoscopic appendectomy. Canadian Journal of Surgery. Journal Canadien De Chirurgie. 2012; 55: 37–40. https://doi.org/10.1503/cjs.023810.

[45] Yang HR, Wang YC, Chung PK, Jeng LB, Chen RJ. Laparoscopic appendectomy using the LigaSure Vessel Sealing System. Journal of Laparoendoscopic & Advanced Surgical Techniques. Part a. 2005; 15: 353–356. https://doi.org/10.1089/lap.2005.15.353.

[46] Marcinkeviciute K, Luksaite-Lukste R, Jasiunas E, Poskus T. Self-Locking Polymeric Clips Are Safe for the Closure of Appendiceal Stump in Laparoscopic Appendectomy. Medicina (Kaunas, Lithuania). 2023; 59: 533. https://doi.org/10.3390/medicina59030533.

[47] Ates M, Dirican A, Ince V, Ara C, Isik B, Yilmaz S. Comparison of intracorporeal knot-tying suture (polyglactin) and titanium endoclips in laparoscopic appendiceal stump closure: a prospective randomized study. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2012; 22: 226–231. https://doi.org/10.1097/SLE.0b013e31824f25cd.

[48] Colak E, Kement M, Ozlem N, Mutlu T, Yildirim K, Gurer A, *et al*. A comparison of nonabsorbable polymeric clips and endoloop ligatures for the closure of the appendicular stump in laparoscopic appendectomy: a prospective, randomized study. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2013; 23: 255–258. https://doi.org/10.1097/SLE.0b013e31828b8382.

[49] Cristalli BG, Izard V, Jacob D, Levardon M. Laparoscopic appendectomy using a clip applier. Surgical Endoscopy. 1991; 5: 176–178. https://doi.org/10.1007/BF02653257.

[50] Graham CW, Komidar L, Perger L. Comparison of Polymeric Clips and Endoscopic Staplers for Laparoscopic Appendectomy. Journal of Laparoendoscopic & Advanced Surgical Techniques. Part a. 2019; 29: 240–242. https://doi.org/10.1089/lap.2018.0173.

[51] Wilson M, Maniam P, Ibrahim A, Makaram N, Knight SR, Patil P. Polymeric clips are a quicker and cheaper alternative to endoscopic ligatures for securing the appendiceal stump during laparoscopic appendicectomy. Annals of the Royal College of Surgeons of England. 2018; 100: 454–458. https://doi.org/10.1308/rcsann.2018.0036.

[52] Guldogan CE, Sarp G, Soyer Guldogan E. Comparison of Hem-o-lok and Endoloop for Appendiceal Stump Closure in Laparoscopic Appendectomy: An Observational Retrospective Study. Annali Italiani Di Chirurgia. 2024; 95: 105–108.

[53] Lv B, Zhang X, Li J, Leng S, Li S, Zeng Y, *et al*. Absorbable polymeric surgical clips for appendicular stump closure: A randomized control trial of laparoscopic appendectomy with lapro-clips. Oncotarget. 2016; 7: 41265–41273. https://doi.org/10.18632/oncotarget.9283.

[54] Mannu GS, Sudul MK, Bettencourt-Silva JH, Cumber E, Li F, Clark AB, *et al*. Closure methods of the appendix stump for complications during laparoscopic appendectomy. The Cochrane Database of Systematic Reviews. 2017; 11: CD006437. https://doi.org/10.1002/14651858.CD006437.pub3.

[55] Gupta V, Singh SP, Singh SP, Bansal M, Pandey A. Sutureless Appendectomy by Using Harmonic Scalpel: Is It Possible? Journal of Laparoendoscopic & Advanced Surgical Techniques. Part a. 2020; 30: 429–432. https://doi.org/10.1089/lap.2019.0782.

[56] Borkar N, Sharma C, Mohanty D, Singha SK. A Systematic Review and Meta-Analysis of Harmonic Scalpel Versus Conventional Techniques of Appendiceal Stump Closure in Laparoscopic Appendicectomy. Cureus. 2022; 14: e28759. https://doi.org/10.7759/cureus.28759.

[57] Ismail I, Iusco D, Jannaci M, Navarra GG, Grassi A, Bonomi S, *et al*. Prompt recognition of stump appendicitis is important to avoid serious complications: a case report. Cases Journal. 2009; 2: 7415. https://doi.org/10.4076/1757-1626-2-7415.

[58] Dikicier E, Altintoprak F, Ozdemir K, Gundogdu K, Uzunoglu MY, Cakmak G, *et al*. Stump appendicitis: a retrospective review of 3130 consecutive appendectomy cases. World Journal of Emergency Surgery: WJES. 2018; 13: 22. https://doi.org/10.1186/s13017-018-0182-5.

[59] Fields AC, Lu P, Palenzuela DL, Bleday R, Goldberg JE, Irani J, *et al*. Does retrieval bag use during laparoscopic appendectomy reduce postoperative infection? Surgery. 2019; 165: 953–957. https://doi.org/10.1016/j.surg.2018.11.012.

[60] Turner SA, Jung HS, Scarborough JE. Utilization of a specimen retrieval bag during laparoscopic appendectomy for both uncomplicated and complicated appendicitis is not associated with a decrease in postoperative surgical site infection rates. Surgery. 2019; 165: 1199–1202. https://doi.org/10.1016/j.surg.2019.02.010.

[61] Li Z, Li Z, Zhao L, Cheng Y, Cheng N, Deng Y. Abdominal drainage to prevent intra-peritoneal abscess after appendectomy for complicated appendicitis. The Cochrane Database of Systematic Reviews. 2021; 8: CD010168. https://doi.org/10.1002/14651858.CD010168.pub4. [Update in: Cochrane Database Syst Rev. 2025 Apr 11;4:CD010168. doi: 10.1002/14651858.CD010168.pub5. PMID: 34402522; PMCID: PMC8407456.]

[62] Abu A, Mohamedahmed AY, Alamin A, Mohamed M, Osman M, Mohammed MJ, *et al*. Evaluation of Drain Insertion After Appendicectomy for Complicated Appendicitis: A Systematic Review and Meta-Analysis. Cureus. 2022; 14: e32018. https://doi.org/10.7759/cureus.32018.

[63] Wu H, Liao B, Cao T, Ji T, Luo Y, Huang J, *et al*. Advantages comparison of peritoneal drainage versus no drainage after laparoscopic appendectomy for complicated appendicitis: a meta-analysis. BMC Gastroenterology. 2024; 24: 411. https://doi.org/10.1186/s12876-024-03500-8.

[64] Matsui S, Tanioka T, Kamata Y, Hoshi H, Ryu K, Honda M, *et al*. Laparoscopic appendectomy during the second trimester of a twin pregnancy. Asian Journal of Endoscopic Surgery. 2021; 14: 594–597. https://doi.org/10.1111/ases.12907.

[65] Andersson RE, Lambe M. Incidence of appendicitis during pregnancy. International Journal of Epidemiology. 2001; 30: 1281–1285. https://doi.org/10.1093/ije/30.6.1281.

[66] Joo JI, Park HC, Kim MJ, Lee BH. Outcomes of Antibiotic Therapy for Uncomplicated Appendicitis in Pregnancy. The American Journal of Medicine. 2017; 130: 1467–1469. https://doi.org/10.1016/j.amjmed.2017.04.046.

[67] Cai YL, Yang SS, Peng DZ, Jia QB, Li FY, Ye H, *et al*. Laparoscopic appendectomy is safe and feasible in pregnant women during second trimester: A retrospective study in a top-level Chinese center. Medicine. 2020; 99: e21801. https://doi.org/10.1097/MD.0000000000021801.

[68] Fallon WF, Jr, Newman JS, Fallon GL, Malangoni MA. The surgi-

cal management of intra-abdominal inflammatory conditions during pregnancy. The Surgical Clinics of North America. 1995; 75: 15–31. https://doi.org/10.1016/s0039-6109(16)46530-8.

[69] Lee SH, Lee JY, Choi YY, Lee JG. Laparoscopic appendectomy versus open appendectomy for suspected appendicitis during pregnancy: a systematic review and updated meta-analysis. BMC Surgery. 2019; 19: 41. https://doi.org/10.1186/s12893-019-0505-9.

[70] Rountis A, Dimitroulis D, Nikiteas N. Laparoscopic appendectomy vs open appendectomy during pregnancy: a systematic re-view. Hippokratia. 2022; 26: 1–6.

[71] Kraemer M, Franke C, Ohmann C, Yang Q, Acute Abdominal Pain Study Group. Acute appendicitis in late adulthood: incidence, presentation, and outcome. Results of a prospective multicenter acute abdominal pain study and a review of the literature. Langenbeck's Archives of Surgery. 2000; 385: 470–481. https://doi.org/10.1007/s004230000165.

[72] Fugazzola P, Ceresoli M, Agnoletti V, Agresta F, Amato B, Carcoforo P, *et al*. The SIFIPAC/WSES/SICG/SIMEU guidelines for diagnosis and treatment of acute appendicitis in the elderly (2019 edition). World Journal of Emergency Surgery: WJES. 2020; 15: 19. https://doi.org/10.1186/s13017-020-00298-0.

[73] Lapsa S, Ozolins A, Strumfa I, Gardovskis J. Acute Appendicitis in the Elderly: A Literature Review on an Increasingly Frequent Surgical Problem. Geriatrics (Basel, Switzerland). 2021; 6: 93. https://doi.org/10.3390/geriatrics6030093.

[74] Poillucci G, Podda M, Pisanu A, Mortola L, Dalla Caneva P, Massa G, *et al*. Risk factors for postoperative morbidity following appendectomy in the elderly: a nationwide prospective cohort study. European Journal of Trauma and Emergency Surgery: Official Publication of the European Trauma Society. 2021; 47: 1729–1737. https://doi.org/10.1007/s00068-019-01186-2.

[75] Weinandt M, Godiris-Petit G, Menegaux F, Chereau N, Lupinacci RM. Appendicitis is a Severe Disease in Elderly Patients: A Twenty-Year Audit. JSLS: Journal of the Society of Laparoendoscopic Surgeons. 2020; 24: e2020.00046. https://doi.org/10.4293/JSLS.2020.00046.

[76] Southgate E, Vousden N, Karthikesalingam A, Markar SR, Black S, Zaidi A. Laparoscopic vs open appendectomy in older patients. Archives of Surgery (Chicago, Ill.: 1960). 2012; 147: 557–562. https://doi.org/10.1001/archsurg.2012.568.

[77] Wang D, Dong T, Shao Y, Gu T, Xu Y, Jiang Y. Laparoscopy versus open appendectomy for elderly patients, a meta-analysis and systematic review. BMC Surgery. 2019; 19: 54. https://doi.org/10.1186/s12893-019-0515-7.

[78] Dasari BVM, Baker J, Markar S, Gardiner K. Laparoscopic appendicectomy in obese is associated with improvements in clinical outcome: systematic review. International Journal of Surgery (London, England). 2015; 13: 250–256. https://doi.org/10.1016/j.ijsu.2014.11.052.

[79] Teke E, Besler E, Özdilek HB, Akyüz C, Aydın Aksu S, Tilki M, *et al*. Laparoscopic Appendectomy Is Superior in Patients with Higher Fat Thickness. JSLS: Journal of the Society of Laparoendoscopic Surgeons. 2025; 29: e2025.00096. https://doi.org/10.4293/JSLS.2025.00096.

[80] el Ghoneimi A, Valla JS, Limonne B, Valla V, Montupet P, Chavrier Y, *et al*. Laparoscopic appendectomy in children: report of 1,379 cases. Journal of Pediatric Surgery. 1994; 29: 786–789. https://doi.org/10.1016/0022-3468(94)90371-9.

[81] International Pediatric Endosurgery Group (IPEG). IPEG guidelines for appendectomy. Journal of Laparoendoscopic & Advanced Surgical Techniques. Part a. 2009; 19 Suppl 1: vii–ix. https://doi.org/10.1089/lap.2009.9983.supp.

[82] Tang E, Ortega AE, Anthone GJ, Beart RW, Jr. Intraabdominal abscesses following laparoscopic and open appendectomies. Surgical Endoscopy. 1996; 10: 327–328. https://doi.org/10.1007/BF00187382.

[83] Zhang S, Du T, Jiang X, Song C. Laparoscopic Appendectomy in Children With Perforated Appendicitis: A Meta-Analysis. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2017; 27: 262–266. https://doi.org/10.1097/SLE.0000000000000411.

[84] Chen JM, Geng W, Xie SX, Liu FB, Zhao YJ, Yu LQ, *et al*. Single-incision versus conventional three-port laparoscopic appendectomy: A meta-analysis of randomized controlled trials. Minimally Invasive Therapy & Allied Technologies: MITAT: Official Journal of the Society for Minimally Invasive Therapy. 2015; 24: 195–203. https://doi.org/10.3109/13645706.2014.995675.

[85] Chen Y, Fan Z, Zhang X, Fu X, Li J, Yuan J, *et al*. A brief overview of single-port laparoscopic appendectomy as an optimal surgical procedure for patients with acute appendicitis: still a long way to go. The Journal of International Medical Research. 2023; 51: 3000605231183781. https://doi.org/10.1177/03000605231183781.

[86] Connell MB, Selvam R, Patel SV. Incidence of incisional hernias following single-incision versus traditional laparoscopic surgery: a meta-analysis. Hernia: the Journal of Hernias and Abdominal Wall Surgery. 2019; 23: 91–100. https://doi.org/10.1007/s10029-018-1853-6.

[87] Sajid MS, Khan MA, Cheek E, Baig MK. Needlescopic versus laparoscopic appendectomy: a systematic review. Canadian Journal of Surgery. Journal Canadien De Chirurgie. 2009; 52: 129–134.

[88] Huang MT, Wei PL, Wu CC, Lai IR, Chen RJ, Lee WJ. Needlescopic, laparoscopic, and open appendectomy: a comparative study. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2001; 11: 306–312. https://doi.org/10.1097/00129689-200110000-00004.

[89] Lau DHW, Yau KKK, Chung CC, Leung FCS, Tai YP, Li MKW. Comparison of needlescopic appendectomy versus conventional laparoscopic appendectomy: a randomized controlled trial. Surgical Laparoscopy, Endoscopy & Percutaneous Techniques. 2005; 15: 75–79. https://doi.org/10.1097/01.sle.0000160290.78288.f4.

[90] Karabacak O, Tiras MB, Taner MZ, Guner H, Yildiz A, Yildirim M. Small diameter versus conventional laparoscopy: a prospective, self-controlled study. Human Reproduction (Oxford, England). 1997; 12: 2399–2401. https://doi.org/10.1093/humrep/12.11.2399.

[91] Eastridge BJ, Hamilton EC, O'Keefe GE, Rege RV, Valentine RJ, Jones DJ, *et al*. Effect of sleep deprivation on the performance of simulated laparoscopic surgical skill. American Journal of Surgery. 2003; 186: 169–174. https://doi.org/10.1016/s0002-9610(03)00183-1.

[92] Boomer LA, Cooper JN, Anandalwar S, Fallon SC, Ostlie D, Leys CM, *et al*. Delaying Appendectomy Does Not Lead to Higher Rates of Surgical Site Infections: A Multi-institutional Analysis of Children With Appendicitis. Annals of Surgery. 2016; 264: 164–168. https://doi.org/10.1097/SLA.0000000000001396.

[93] Ingraham AM, Cohen ME, Bilimoria KY, Ko CY, Hall BL, Russell TR, *et al*. Effect of delay to operation on outcomes in adults with acute appendicitis. Archives of Surgery (Chicago, Ill.: 1960). 2010; 145: 886–892. https://doi.org/10.1001/archsurg.2010.184.

[94] Bickell NA, Aufses AH, Jr, Rojas M, Bodian C. How time affects the risk of rupture in appendicitis. Journal of the American College of Surgeons. 2006; 202: 401–406. https://doi.org/10.1016/j.jamcollsurg.2005.11.016.

[95] Ditillo MF, Dziura JD, Rabinovici R. Is it safe to delay appendectomy in adults with acute appendicitis? Annals of Surgery. 2006; 244: 656–660. https://doi.org/10.1097/01.sla.0000231726.53487.dd.

[96] Kim HK, Kim YS, Lee SH, Lee HH. Impact of a Delayed Laparoscopic Appendectomy on the Risk of Complications in Acute Appendicitis: A Retrospective Study of 4,065 Patients. Digestive Surgery. 2017; 34: 25–29. https://doi.org/10.1159/000447724.

[97] Patel SV, Groome PA, J Merchant S, Lajkosz K, Nanji S, Brogly SB. Timing of surgery and the risk of complications in patients with acute appendicitis: A population-level case-crossover study. The Journal of Trauma and Acute Care Surgery. 2018; 85: 341–347. https://doi.org/10.1097/TA.0000000000001962.

[98] Phatak UR, Chan WM, Lew DF, Escamilla RJ, Ko TC, Wray CJ, *et al*. Is nighttime the right time? Risk of complications after laparoscopic cholecystectomy at night. Journal of the American College of Surgeons. 2014; 219: 718–724. https://doi.org/10.1016/j.jamcollsurg.2014.05.009.

[99] Turrentine FE, Wang H, Young JS, Calland JF. What is the safety of nonemergent operative procedures performed at night? A study of 10,426 operations at an academic tertiary care hospital using the American College of Surgeons national surgical quality program improvement database. The Journal of Trauma. 2010; 69: 313–319. https://doi.org/10.1097/TA.0b013e3181e49291.

[100] Wu JX, Nguyen AT, de Virgilio C, Plurad DS, Kaji AH, Nguyen V, *et al*. Can it wait until morning? A comparison of nighttime versus daytime cholecystectomy for acute cholecystitis. American Journal of Surgery. 2014; 208: 911–911–918; discussion 917–918. https://doi.org/10.1016/j.amjsurg.2014.09.004.

[101] Li J, Xu R, Hu DM, Zhang Y, Gong TP, Wu XL. Effect of Delay to Operation on Outcomes in Patients with Acute Appendicitis: a Systematic Review and Meta-analysis. Journal of Gastrointestinal Surgery: Official Journal of the Society for Surgery of the Alimentary Tract. 2019; 23: 210–223. https://doi.org/10.1007/s11605-018-3866-y.