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Acute appendicitis in children - review focused on diagnostics and treatment

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Abstract

Introduction and Objective

Appendicitis is one of the most common surgical conditions in both children and adults. There are numerous diagnostic tools available, as well as a variety of treatment options, including both pharmacological and surgical methods. This summary focuses on the current knowledge regarding the disease, its diagnosis and treatment.

Review Methods

A literature review was conducted using the PubMed database to gather information on appendicitis. The main search term used was "appendicitis," with the review specifically concentrating on the diagnosis and treatment of the condition.

Description of the State of Knowledge

Diagnosing appendicitis involves taking a medical history, performing a physical examination, conducting laboratory tests, and using imaging, which also help assess the severity of the condition. Treatment options range from antibiotic therapy to open surgery and laparoscopic appendectomy.

Conclusions

The analysis of the review suggests that both diagnosis and treatment depend on various factors, with the patient's clinical presentation and the surgeon's experience being among the most important. Treatment approaches are continually evolving, such as with the development of different laparoscopic techniques, including one-incision laparoscopic appendectomy in addition to the conventional three-incision method. However, more traditional treatments, like antibiotic therapy and open appendectomy, remain in use.

Key words: appendicitis; children; diagnostics; treatment; appendectomy

Introduction

Acute appendicitis is the leading cause of acute abdominal conditions [1]. It is diagnosed in 1 to 8% of pediatric patients presenting with acute abdominal pain in Emergency Departments [2][3]. The lifetime risk of a child developing appendicitis is estimated to be approximately 2.5% [4][5]. Despite being the most frequently encountered diagnosis in cases of acute abdominal pain, appendicitis can present with a wide range of clinical manifestations. This variability in symptoms often complicates the diagnosis, leading to difficulties in establishing a definitive diagnosis and, in some cases, resulting in unnecessary surgical interventions [6].

Pathophysiology

The exact pathophysiology of appendicitis is still unclear [7]. While the traditional theory suggests that bacterial infection, followed by luminal obstruction caused by an appendicolith, is the primary cause of appendicitis, recent evidence challenges this view. Appendicoliths are only present in a small proportion of cases and may also be found in appendices that are not

inflamed. Despite this, luminal obstruction—whether due to an appendicolith, fibrous bands, lymphoid hyperplasia, or even cecal carcinoma—continues to be widely recognized as a key pathogenic mechanism. Furthermore, increasing interest is being directed toward viral infections as potential initiators, which could lead to secondary bacterial infections as a trigger for the condition [2].

In appendices that are inflamed, both aerobic and anaerobic bacteria are often present, with E. coli and Bacteroides spp. being the most commonly isolated pathogens. Additionally, blunt abdominal trauma, resulting in vascular compromise, has been proposed as another factor contributing to the development of appendicitis. The variability in the incidence of appendicitis across different ethnic groups, geographical regions, and within families suggests that genetic predisposition may play a role, although no specific genes have been identified thus far. Moreover, the interaction between environmental factors, diet, and genetic susceptibility in the development of appendicitis is still not fully understood [2][8][9].

While the appendix has traditionally been considered to have little to no significant function in the human body, this view is being reevaluated. Recent research has suggested that the appendix may play a role in the production of mesenchymal stem cells or serve as a reservoir for beneficial bacterial flora [10][11].

Regarding complications, younger children are more likely to develop diffuse peritonitis rather than a periappendicular abscess. This is attributed to the underdeveloped omentum, which is unable to effectively localize the inflammation, resulting in a more widespread infection [7].

Stating the diagnosis

The diagnosis of appendicitis is primarily based on the clinical presentation of the patient. However, the most accurate diagnosis can be established when multiple diagnostic methods are employed to form a comprehensive understanding of the patient's condition.

Abdominal ultrasonography is widely regarded as the diagnostic method of choice for appendicitis, especially in pediatric patients. Its accuracy is notably high, with sensitivity ranging from 96% to 99% and specificity from 87% to 100% [1][12]. This makes it an

effective tool for identifying appendicitis, particularly in children. However, the reliability of the results is heavily influenced by the skill and experience of the examiner, as well as the quality of the ultrasound performed.

A more objective method, such as abdominal computed tomography (CT), follows but comes with certain limitations, particularly regarding its use in pediatric populations. One of the major concerns is the exposure to radiation, which is a significant drawback. Additionally, small children may require general anesthesia to undergo the CT scan, further complicating its use. In contrast, magnetic resonance imaging (MRI) removes the risk of radiation exposure, making it a safer alternative. However, MRI is still not without its drawbacks; it remains more time-consuming and, in many hospitals, may not be readily available. Furthermore, like CT, it may still require the use of anesthesia in young patients.

When clinical signs such as abdominal tenderness, vomiting, nausea, and an elevated leukocyte count are absent, appendicitis can be reliably ruled out with a diagnostic accuracy of 98% [1][13]. However, abdominal tenderness in the right lower quadrant remains the most common and often first symptom that suggests appendicitis as a possible diagnosis.

Alvarado's scale is a widely used tool that combines various diagnostic components, including the patient's medical history, physical examination findings, and laboratory test results. The scoring system and criteria used in this scale are summarized in Table 1 [14].

Table 1.

SIGNS, SYMPTOMS & LAB VALUES		SCORE
Signs	Right lower quadrant tenderness	+2
	Rebound tenderness	+1
	Elevated Body Temperature >37.3°C	+1
Symptoms	Migratory right lower quadrant pain	+1
	Vomiting/nausea	+1
	Anorexia	+1
Lab results	Leukocytosis >10,000	+2
	Shift to the left of neutrophils >75%	+1
TOTAL SCORE		max. 10

A total score of 7 or more on the Alvarado scale, coupled with a clinical presentation consistent with appendicitis, strongly suggests the diagnosis, and a surgical consultation is recommended as appendicitis is highly likely. For cases scoring between 4 and 6, a CT scan should be considered to further assess the condition. A score of 3 or less generally rules out the diagnosis of appendicitis and, as such, further diagnostic procedures such as CT should not be pursued [15]. However, ultrasound (USG) can still be considered in these cases as a potential diagnostic tool.

The main advantage of the Alvarado scale lies in its accessibility, as all the required data can be obtained in the emergency room (ER) without the need for additional diagnostic tests. However, the scale has limitations in its diagnostic sensitivity and specificity. Its sensitivity is relatively low at 54%, and its specificity is 75%, which reduces its overall effectiveness as a standalone diagnostic tool for appendicitis [6].

Additionally, digital rectal examination does not significantly contribute to the diagnosis of appendicitis and, therefore, is not necessary in the diagnostic workup [1][16].

Pre-treatment

In spite of the final diagnosis, the patients must be provided with adequate pain relief. One of possible choices and also the most common one is intravenous Acetaminophen at 15 mg/kg/dose every 6 hours. The medication is well-tolerated, generally available worldwide and does not interfere with the results needed to obtain the final diagnosis [17]. The supply of opiates may result in the loss of the peritoneal sign but does not significantly interfere the final diagnosis [18]. In case of vomiting, the patients need to be given intravenous rehydration.

Classification

Each case of appendicitis can be classified as either complicated or uncomplicated, based on the presence of specific criteria. This classification plays a crucial role in guiding the selection of the appropriate treatment strategy. Complicated appendicitis is characterized by an inflamed appendix accompanied by at least one of the following conditions: gangrene, perforation, intra-peritoneal purulent fluid, contained phlegmon, or intra-abdominal abscess [19]. In the absence of these conditions, the inflamed appendix is classified as uncomplicated.

In cases of children presenting with acute appendicitis, it has been observed that between 30–60% have already developed appendicular perforation by the time they are seen by a surgeon [10][20][21]. Several factors have been identified that increase the likelihood of perforation, including the presence of fever, a prolonged history of symptoms, vomiting, abnormal laboratory results such as elevated leukocyte count or C-reactive protein levels, the detection of free abdominal fluid, and an appendix diameter of 11 mm or greater [22].

Anatomy

The base of the appendix generally maintains a consistent anatomical position, typically located on the posteromedial surface of the cecum, where the three taenia coli converge. In contrast, the position of the appendix tip exhibits considerable variability. It is retrocecal in approximately 28–68% of cases, followed by a pelvic location in 27–53% of instances. Other, less frequent positions include subcecal (2%), anterior or preileal (1%), within a hernial sac (2%), in the right upper quadrant (4%), and in the left upper or lower quadrants, with each of these positions occurring in fewer than 0.1% of cases [23][24].

Pharmacological treatment

First-line pharmacotherapy for appendicitis typically involves the intravenous administration of nonsteroidal anti-inflammatory drugs (NSAIDs), Paracetamol, or opioids, depending on the severity of pain and the patient's condition, regardless of the subsequent treatment approach [22]. In order to achieve an adequate therapeutic effect, it is crucial to administer a broad-spectrum antibiotic to address the variety of potential pathogenic microorganisms that may be involved in the inflammatory process. For instance, while amoxicillin-clavulanic acid is commonly used, it has limited efficacy against Escherichia coli, a predominant bacterial species in the intestines [25]. On the other hand, Ertapenem offers a broader spectrum of activity and can be administered once daily, making it an effective option for treating severe abdominal infections. However, when using such antibiotics, it is important to consider the elevated risk of antibiotic resistance, which poses significant concerns for long-term treatment outcomes [25]. As a widely accepted compromise between effectiveness and risk, a combination therapy of metronidazole and gentamicin is often employed [26].

The use of antibiotics alone has proven to be an effective treatment for uncomplicated appendicitis, with studies showing a success rate of 90.5% in children aged 5 to 15 years [27]. One possible approach involves starting with a 48-hour course of intravenous antibiotics, followed by 3 to 5 days of oral antibiotic therapy [28]. This regimen is specifically suited for uncomplicated appendicitis cases, as they are less likely to involve complications such as perforation. However, in cases of colic appendicitis, the risk of perforation significantly increases, making surgery the recommended course of action to prevent further complications [27].

Operation techniques

The most common treatment method of appendicitis is appendectomy, which is widely considered as safe and effective [7][29]. It can be performed classically or laparoscopically. Both approaches have a long history in medicine, as the first reported case of open appendectomy was in 1735 by Claudius Amyand, while the earliest recorded instance of laparoscopic appendectomy was in 1980 by Karl Semm [10][30].

Open Appendectomy

Once adequate anesthesia is achieved, the child is positioned supine, and the surgical field is disinfected and draped in a sterile manner. Classic appendectomy can be performed through open appendectomy by McBurney's approach for a muscle-splitting incision in the right lower abdominal quadrant [31]. Appendix can be also reached by Lanz incision which is more horizontal compared to more oblique McBurney's. Despite the exact place of the incision, the appendix is localised and taken outside the peritoneum. The mesoappendix is dissected in an antegrade manner from the tip to the base using an absorbable suture. The appendix is ligated at its base and excised. The exposed mucosa of the stump is cauterized. Stump inversion is achieved with a string suture-knot [26].

Conventional Laparoscopic Appendectomy

In laparoscopic operation, the initial supine position of the patient needs to be modified to Trendelenburg and left lateral modification. A 5-mm incision is made along the inferior margin of the umbilicus, and a Veress needle is inserted to establish CO_2 pneumoperitoneum at a pressure of 8–12 mm Hg, adjusted based on the patient's age and body weight. Once pneumoperitoneum is achieved, a 5-mm trocar is introduced through the same incision, allowing the use of a 5-mm laparoscope. In addition to the main incision, two other incisions are made in a triangular pattern, with the base of the triangle formed by the left inguinal region and umbilicus, where trocar sheaths are inserted for instrument access. Laparoscopic appendectomy can be carried out using a three-trocar technique, incorporating both 5-mm and 10-mm trocars. The mesoappendix is dissected using either a harmonic scalpel or thermal fusion technology. The appendiceal base is secured with either an endoloop or polymeric ligating clips. The resected appendix is placed in a disposable retrieval bag and extracted through the 10-mm trocar. Finally, the incision is disinfected, and the skin is closed, while drainage may be placed if there is significant contamination in the pelvic cavity [26][32].

In case of left-side laparoscopic appendectomy, some modifications to the operating room setup and trocar placement are required for a successful procedure. The surgeon and assistant position themselves on the patient’s right side, while the monitor is placed on the left. The reversed laparoscopic view can present a technical challenge for less experienced surgeons, and a right-handed surgeon may need to perform dissection with the left hand. Unlike standard procedures, there is no fixed trocar placement in these cases. Instead, port positioning should be adapted according to laparoscopic surgery principles [33].

An additional advantage of the laparoscopic approach is a possibility of visualizing the whole abdominal cavity. In this case, more anomalies can be diagnosed and occasionally treated. One of such examples is Meckel’s control, especially useful in children. Another example is a simultaneous laparoscopic cholecystectomy and appendectomy, which is a rare but not impossible case to happen [34].

Single-incision laparoscopic appendectomy (SILA)

In an effort to improve outcomes and achieve better cosmetic results, the conventional three-port laparoscopic appendectomy has evolved into a single-incision, scarless procedure by concealing the incision within the umbilicus. The transumbilical approach enables usage of an operative telescope with an integrated working channel. This method allows a grasper to be inserted through the umbilical wound to exteriorize the appendix, which is then resected outside the abdominal cavity. Moreover, a modified version of the single-incision laparoscopic technique has emerged, incorporating a multi-channel port. This approach enables the use of two independent working instruments, allowing the procedure to be performed either intracorporeally or extracorporeally [35][36].

A transverse incision of approximately 5 mm is made at the lower margin of the umbilicus. A CO_2 pneumoperitoneum is established, achieving an intra-abdominal pressure of 8–12 mmHg, comparable to that used in standard laparoscopic procedures. A 5-mm trocar is introduced through the puncture site, followed by routine exploration of the abdominal cavity using additional trocars placed bilaterally near the umbilical ring. To locate the appendix, 5-mm and 12-mm trocars are inserted, and the patient's position is adjusted from left lateral to Trendelenburg. Purulent fluid in the rectal fossa is drained, if present, and the ileocecal region is exposed. The appendix is grasped and elevated with forceps, while the mesoappendix at its base is carefully separated using blunt dissection with vascular forceps. The mesoappendix is then ligated with Hem-o-lok clips and divided using an electrocautery hook, ensuring hemostasis through electrocoagulation. The base of the appendix is doubly secured with Hem-o-lok clips before being transected and extracted through a puncture site near the lateral edge of the right umbilical region. The abdominal and pelvic cavities are carefully inspected for the presence of remaining pus and potential bleeding. Any residual pus is drained, and hemostasis is confirmed. To complete the procedure, the peritoneum, muscle layers at each trocar site and skin incisions are closed with sutures. To reduce postoperative pain, local analgesic injections are given in the wound area [37].

Postoperative treatment

The definitive confirmation of both the diagnosis and classification of appendicitis is determined through histopathological examination. However, clinical treatment decisions

must be made significantly earlier, as histological results typically become available only within two to four weeks post-surgery. Consequently, surgeons must rely on their intraoperative assessment to guide immediate management. Fortunately, in the majority of cases, intraoperative diagnosis aligns well with histological findings, regardless of the surgical technique employed [38].

Based on the perceived severity of the condition, either a single-dose antibiotic regimen or broad-spectrum antibiotic therapy is initiated to prevent complications. If the severity of appendicitis is underestimated during surgery, it can lead to increased morbidity and prolonged hospitalization, emphasizing the importance of accurate intraoperative evaluation [38].

Discharge

A patient diagnosed with uncomplicated appendicitis is typically ready for discharge once they exhibit effective pain management, successfully pass a normal bowel movement and demonstrate the ability to tolerate both oral fluids and solid food without complications. In contrast, for individuals suffering from complicated appendicitis, additional criteria must be met before discharge is considered safe. Along with adequate pain control, normal bowel function, and tolerance to oral intake, these patients must also show no signs of persistent leukocytosis or fever, as their presence could indicate an ongoing infection or unresolved inflammatory process [26].

Discussion on stating the diagnosis

Taking everything into consideration, in stating the diagnosis, the clinical presentation of the patient should be crucial, whereas all the other tests ought to be an addition to the clinical image. In most cases, essential criteria are typical clinical presentation and history, positive ultrasonography description and leukocytosis. In case of any doubts at this point, additional examinations are considered. A significant impediment is the fact that children are more likely to present atypical symptoms [39][40][41]. Nevertheless, the final definitive diagnosis can be stated only by obtaining the histopathologic result of the resected appendix, which is more of a confirmation of previous thesis, since the treatment decisions are already made [6][42]. The

result is considered as positive if transmural neutrophil invasion involves the muscularis layer of the appendix [31].

It is important to note that all the diagnostic methods discussed above assume a physiological location of the appendix, typically in the right side of the abdomen. Although the appendix's exact positioning can vary, appendicitis is rarely suspected when the patient reports pain on the left side. In such cases, gastrointestinal conditions are more likely to be considered, including diverticular disease, mesenteric ischemia, bowel obstruction, and left-sided primary epiploic appendagitis. Additionally, genitourinary disorders such as ectopic pregnancy, ovarian torsion, pelvic inflammatory disease, cystitis, epididymitis, prostatitis, and testicular torsion should also be considered as potential causes of left-sided abdominal pain [43][44][45][46][47].

However, in instances of situs inversus or congenital malrotation of the midgut, left-sided acute appendicitis can still be a plausible diagnosis. These conditions should be considered when evaluating patients, and a thorough history, physical examination, and imaging studies can help identify such rare presentations [33][43][47][48].

Discussion on treatment

Comparing antibiotic treatment to surgery, non-conservative treatment results in shorter hospital stay but also longer postsurgical disability and higher risk of recurrence [18]. Averagely, conservative treatment requires 14.32 hours more spent in hospital but then 13 days less of disability [27]. However, the results may be influenced by the fact that complicated appendicitis cases which require surgical treatment can be initially more severe and progressed.

There are several advantages of the laparoscopic method (LM) compared to the classic method (CM), such as small incision, reduced bleeding, less time needed for the intestines to regain their function, smaller need for painkillers after the procedure and 2 times lower ratio of post-surgical wound infections [2][32]. However, disadvantages of the LM are longer duration of the operation compared to the CM and more cases of intra-abdominal abscesses in some studies [19][49]. On the other hand, some reports state contradictory results following lower risk of postoperative incidence of complications and no significant differences in the

duration of the operation [32]. Furthermore, LM allows the surgeon to assess intra-abdominal structures much more precisely than CM when diagnostic uncertainty arises because of more adequate assessment of the presence of fluid in the peritoneal cavity, potential bleeding and evaluation of the intestine for the presence of a Meckel's diverticulum [43]. The risk of postoperative small bowel obstruction is comparable in both techniques, therefore major risk factors are appendix perforation and the presence of intra-abdominal abscess [50].
There is a clear advantage of the laparoscopic method over the classical appendectomy, and therefore, if possible, should be favored as the preferred approach, nevertheless both techniques should be known to surgeons in case of a need of conversion or patient's contraindications to laparoscopic approach [50].

When comparing Conventional Laparoscopic Appendectomy (CLA) to Single-Incision Laparoscopic Appendectomy (SILA), there is no significant difference concerning operation duration, total hospitalization days and cost, postoperative pain and complications. A remarkable advantage of SILA is definitely the aesthetic effects. The wound is almost invisible as the scar is hidden inside the umbilicus [35].
This approach is more frequently used for uncomplicated appendicitis. However, in cases of complicated appendicitis, particularly when the appendix is in an atypical location or surrounded by dense adhesions, its removal through an umbilical incision becomes significantly challenging [37][51].

Summary

Despite being one of the most popular diseases concerning acute abdomen not only in children but also in adults, the matter is not at all binary in nature. Both diagnosis and treatment may appear challenging even for experienced surgeons. In spite of the long history of acute appendicitis, there is still scope for developing new methods and improving already existing ones.
Clinicians need to be mindful of uncommon anatomical variations and their potential consequences [43]. Final decision as it comes to the operating method should be made based on the appendicitis classification, operating surgeon's experience and available equipment [32].

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