

Trends in the Diagnosis and Management of Pediatric Appendicitis

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Practice Gap

1. Clinicians should be aware of the current approach to the use of imaging in diagnosing appendicitis. (1)
2. Clinicians should understand the current standard of care in the timing of appendectomy as well as the role of initial nonoperative management in perforated appendicitis.

Objectives After completing the article, the reader should be able to:

1. Implement the current recommendations regarding the use of imaging, following the “ultrasound-first paradigm.”
2. Understand the urgent, but not emergent, timing of appendectomy in cases of simple appendicitis.
3. Recognize the option of managing select cases of perforated appendicitis with antibiotics and the role of subsequent interval appendectomy.

INTRODUCTION

Recent substantial changes in surgical care apply to the most common acute pediatric surgical condition: appendicitis. This review focuses on the specific aspects of diagnosis and management of appendicitis that have shifted dramatically. We highlight three areas: the role of imaging in diagnosis; the use of antibiotics to halt progression of appendicitis, allowing for appendectomy in the morning rather than in the middle of the night; and the role for deferral of surgery in certain complex cases of appendicitis. We describe the current approach to these aspects of diagnosis and management and examine the basis for this approach.

HISTORICAL CONTEXT

Clinicians accepted the premise that inflammation of the vermiform appendix caused a common intra-abdominal illness only in the late 1880s, when Reginald

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Fitz at Harvard carefully reviewed 257 autopsy cases and coined the now universally accepted term “appendicitis.” (2) His prescient subtitle for that publication, “With Special Reference to its Early Diagnosis and Treatment,” set the clinical goal for at least a century. The morbidity of complex appendicitis was recognized to be considerable compared to the consequences of simple appendicitis treated by appendectomy in the early stage of the disease before perforation occurred. The means of establishing an early diagnosis of appendicitis was clarified when Charles McBurney, a New York surgeon from that same decade (1880s), observed that the site of maximum tenderness was “in the average adult, almost exactly two inches from the anterior iliac spine, on a line drawn from this process through the umbilicus,” his now eponymous point. (3)

CURRENT PRACTICE

Some features of the management of appendicitis have become standard. For example, open appendectomy with an incision in the right lower quadrant has been replaced with a routine laparoscopic approach for both simple and complex appendicitis. The laparoscopic approach has been linked to a reduced risk of wound infections and bowel obstructions, improved postoperative pain control, shorter duration of hospitalization, and faster return to daily activities. (4)(5) Most appendectomies currently are performed laparoscopically, a rate that has increased from 22% in 1998. (6) Similarly, the broad consensus is that antibiotics should be administered to the child who has simple acute appendicitis before the incision and not continued after the operation. (7)(8) Those who have simple appendicitis often can be safely discharged from the hospital the same day as the operation. (9) The need to continue antibiotics postoperatively when treating *perforated* appendicitis is universally accepted. (10) However, the choice of antibiotic, duration of administration, and potential role for oral medication vary.

Other steps in diagnosis and management of appendicitis are supported by evidence. Because resistance to these practices persists, this review focuses on the evidence. First among these issues is the role for imaging and choice of imaging study, which has been marked with controversy and a string of proposals and counterproposals. For many decades, the decision to operate was made exclusively on clinical grounds and not influenced by imaging studies. Clinical diagnosis is still appropriate for some children.

ESTABLISHING THE DIAGNOSIS ON CLINICAL GROUNDS

Appendicitis is caused by obstruction of the appendix from inflammation in the wall or from a fecalith. At the onset of

the pathophysiologic process, the obstructed hollow organ stretches, causing stimulation of visceral nerves. The child experiences mild mid-abdominal pain, which is referred pain. Because the appendix is part of the midgut, its sensory visceral nerves refer pain to the T10 dermatome. Clinicians are not expected to diagnose the condition at this earliest stage. When inflammation progresses through the wall of the appendix, it stimulates somatic nerves, causing local peritoneal signs. The evolution of localized peritoneal signs (right lower quadrant peritonitis) allows the diagnosis. If the inflammation persists, the appendiceal wall necroses and perforates, causing bacterial contamination of the peritoneum. Bacterial spillage that is contained, either by surrounding bowel or omentum, forms either a phlegmon or an abscess. Uncontained contamination results in diffuse peritonitis and sepsis, which is associated with increased morbidity and mortality.

Clinicians caring for children, especially for the very young, are limited by the lack of clear history and the difficulty in establishing peritoneal signs on physical examination. Distinguishing voluntary guarding, often displayed by an upset child when the abdomen is palpated, from peritoneal signs is the crux of the challenge to the diagnostician. Among the time-honored tricks of the trade to elicit peritoneal signs are determining if the following caused pain: the ride to the doctor’s office, having the child walk and climb onto an examining table, asking the child to jump to see if the jolt elicits right lower quadrant pain, and pressing with a warm stethoscope in the left lower quadrant to determine if that causes right lower quadrant pain (the Rovsing sign). The psoas sign (pain on extension of the right thigh) and obturator sign (pain elicited with flexion and internal rotation of the hip) are employed to unearth the notoriously problematic retrocecal and pelvic appendix, which may not be associated with tenderness to palpation on the anterior abdominal wall.

For decades, a careful history and physical examination were the primary tools in establishing which child warranted an appendectomy (Table 1). These diagnostic measures would be supplemented by a complete blood cell (CBC) count, urinalysis (UA), and only occasionally abdominal radiography. The abdominal radiograph was, until recent decades, the only imaging tool available in aiding the diagnostic process. The relative rarity of a radio-opaque fecalith limited its usefulness. A mildly elevated white blood cell (WBC) count supported the diagnosis of appendicitis but was neither sensitive nor specific. A significantly elevated WBC count was consistent with complex appendicitis but likewise was not a refined tool. UA was widely advocated when a patient presented with possible appendicitis to

TABLE 1. Clinical Findings Suggestive of Acute Appendicitis

| | |
|----------------------|--|
| Chief Complaint | Right lower quadrant pain |
| History | Mid-abdominal pain that migrated to the right lower quadrant |
| Physical Examination | Right lower quadrant tenderness |
| Peritoneal Signs | Pain with hopping; psoas, obturator, Rovsing signs |
| Laboratory | Leukocytosis (mild unless perforated) |

exclude urinary tract pathology. However, its role was confounded by the fact that WBCs or red blood cells are often seen in the setting of acute appendicitis because the inflamed appendix can abut the ureter or bladder.

With a detailed history and physical examination, CBC count, UA, and occasional abdominal radiograph, clinicians differentiated which child warranted an appendectomy. The process was and remains labor-intensive, sometimes aided by a period of “active observation” with serial examinations. The goal is to obtain a prompt diagnosis of appendicitis, early enough in the course of the illness to avoid progression to perforation. Because the process is imperfect, some experts advocated for surgeons to remove unaffected appendices 20% of the time, based on the concept that if the surgeon removed too few unaffected appendices, some patients were allowed to advance to perforation. The rate of negative appendectomies, in fact, did not need to be so strikingly high to avoid cases of perforation. However, those claims and the imprecise nature of the clinical diagnostic process increased the attractiveness of using computed tomography (CT) scan to diagnose appendicitis. Missed diagnosis of appendicitis has been the most common cause of lawsuits against emergency care physicians who treat children, adding incentive to rely on CT scans.

EVOLUTION OF THE CT SCAN IN DIAGNOSING APPENDICITIS

In the 1990s, some radiologists promoted the use of CT scans to determine who did and who did not have appendicitis. Toward the end of that decade, the CT scan was strongly advocated by a group of radiologists at Massachusetts General Hospital (MGH). They initially presented 100 patients (children and adults) with clinically suspected appendicitis who underwent CT scans, which demonstrated a sensitivity of 100% and specificity of 95% for diagnosing appendicitis. (11) Subsequently, MGH

confirmed the benefit of CT scans in reducing negative appendectomies and missed cases of appendicitis. (12) Because ordering CT scans is easy, the use of CT scans is widespread, and these studies seemed convincing, diagnosing appendicitis by CT scan was tempting to pursue. However, a few features of these investigations bear reconsideration.

The group from MGH promoted a “focused” study of the right lower quadrant, acknowledging the need to limit radiation exposure. As use of the CT scan proliferated, the practice of using a limited study was not widely followed. In addition, the MGH authors recognized that the advantages of the CT scan in adults were not evident in their pediatric patients. They noted that this may “reflect the fact that clinical accuracy is generally higher in pediatric patients.” In their studies, the diagnostic acumen of the surgeons who based their judgment on the clinical findings before obtaining imaging was substantially lower than had been demonstrated in separate pediatric series. Furthermore, the standard practice against which the CT scan was compared did not accurately reflect care given to children in pediatric centers. Negative appendectomy rates in many pediatric series were 7% or less, not the 20% reported in the MGH investigation. (13)

Use of the CT scan to diagnose appendicitis became routine. Pediatricians sometimes ordered CT scans before sending children to the hospital or consulting surgeons. Physicians in emergency departments sometimes ordered CT scans before consulting surgeons. Surgeons sometimes supported or promoted obtaining CT scans before seeing the patients. The CT scan held the promise of removing uncertainty from a clinical conundrum. In less than a decade, most children had a CT scan before undergoing appendectomy. The Children’s Hospital in Denver reported that in 1997, 1% of children underwent CT before appendectomy, a rate that increased progressively to 58% in 2001. (14) A study from Children’s Hospital of Boston and Miami Children’s Hospital reported that 78% of children had undergone CT scan before appendectomy in 2002 compared to 14% in 1997. (15)

Use of the CT scan as a standard diagnostic step when acute appendicitis is suspected in children has generated several concerns. The unwanted effect of radiation on future cancer risk is a particular concern in childhood, in part because exposure is cumulative and lifelong and in part due to the increased sensitivity of the young patient to ionizing radiation. Other concerns about the CT scan include the common practice of administering oral contrast, which is both time-consuming to allow the contrast to reach the appendix and noxious to the patient who is suffering an

acute gastrointestinal illness. Also, the often-used intravenous contrast, interestingly not part of the protocol from the studies at MGH, has risks, including allergic reaction and contrast-induced nephropathy. Finally, sedation is sometimes required to obtain adequate images from pediatric patients, which further increases the risk of performing a CT scan, especially in the setting of an acute gastrointestinal illness with the potential for aspiration of gastric contents.

After several years of increasing utilization of CT scans in children, some groups reported no resulting improvement in diagnostic accuracy. “These data suggest that it would be prudent to limit the use of radiographic studies to children who have been examined and in whom the surgeon remains uncomfortable with the diagnosis of appendicitis.”⁽¹⁴⁾ The study from Children’s Hospital of Boston and Miami Children’s Hospital concluded that a clinical guideline based on history, physical examination, and WBC count would allow the selective use of imaging without sacrificing diagnostic accuracy. ⁽¹⁵⁾ A similar clinical practice guideline was implemented in a pediatric emergency department at the Medical University of South Carolina Children’s Hospital, which focused on early surgical involvement in cases of likely simple appendicitis, ultrasonography for patients with equivocal history and physical examination findings, and CT scan only for patients with likely perforated appendicitis. ⁽¹⁶⁾ After guideline implementation, there was a 41% decrease in the use of CT scans (from 90% of children undergoing appendectomy to 48%) and an increase in the use of ultrasonography and the percentage of children undergoing appendectomy without any imaging. There was no increase in the rate of negative appendectomy. These results confirm that decreasing reliance on CT scans is safe and effective when children are in properly trained hands and suggest that a clinical practice guideline can be a useful tool.

Selective use of CT scan should focus on patients in whom the diagnosis remains unclear despite less invasive approaches and patients with particularly advanced appendicitis because the presence of a large abscess can change the therapeutic approach.

ULTRASOUND-FIRST PARADIGM

Influenced by evidence that the diagnosis of appendicitis in pediatrics is not substantially improved by CT scan and concerned about causing future cancers, clinicians have increasingly advocated the use of ultrasonography as the initial imaging test if the diagnosis is unclear and imaging is warranted. The term “ultrasound-first paradigm” has been used to describe this approach (Table 2). ⁽¹⁷⁾ Ultrasonography

is warranted when the patient’s history and physical examination findings are not typical for appendicitis. For example, a child may present with right lower quadrant pain but with a history that is inconsistent with appendicitis. There may be only minimal tenderness on physical examination without peritoneal signs. When the differential diagnosis remains broad after a history and clinical examination, ultrasonography by a dedicated practitioner is a useful tool in helping to diagnose appendicitis. The CT scan should be limited to cases in which the diagnosis remains unclear or in cases of advanced appendicitis with the likely presence of an abscess.

A commonly held myth is that ultrasonography is so inaccurate in identifying appendicitis as to be useless. The basis for this falsehood is twofold. First, experience in adult patients should not be compared to experience with children because ultrasonography is much less effective in visualizing the appendix in larger patients compared with children. To pass through a thick patient, the sonographic device requires a lower-frequency transducer, which results in a less clear image. In smaller patients, higher-frequency transducers can penetrate adequately and provide a more refined image. Furthermore, measurement parameters for the size of the appendix are based on compression sonography, which is more difficult to accomplish in the adult patient. The other reason for the negative reputation of ultrasonography is that not all medical centers are staffed with radiologists and sonographic technicians experienced in performing or interpreting this test for children with possible appendicitis. Dedicated sonographers can perform pediatric ultrasonography with diagnostic accuracy that approaches that of the CT scan.

The literature does not support the myth that ultrasonography is an inaccurate study for children with possible appendicitis. ⁽¹⁸⁾ A rigorous meta-analysis published in 2006 confirmed that although the sensitivity of CT scan is better than ultrasonography for diagnosing appendicitis

TABLE 2. **Ultrasound-first Paradigm: When Imaging is Needed for Diagnosis**

| | |
|----------------|---|
| Safe | No ionizing radiation No sedation No intravenous or oral contrast |
| Accurate | Comparable diagnostic capacity to computed tomography scan |
| Cost-effective | Inexpensive Portable Fast |

in adults, the advantage is strikingly less among children, the population at greater risk from ionizing radiation. (19) The practice in some hospitals is to order a CT scan because ultrasonography does not routinely show the appendix and sonographers are not confident in assessing secondary signs of appendicitis. Centralization of pediatric care to institutions that have skilled ultrasonography services represents an important initiative for visionary planners of health care distribution. A child with possible appendicitis should, if possible, be referred to a medical center that has skilled pediatric ultrasonography available. This practice should substantially reduce the number of CT scans performed for children with possible appendicitis. (20)(21)

Although this imaging conundrum is important, clinicians should remember that the decision to perform an appendectomy often can be made with adequate accuracy without imaging of any type (Table 1). The role of the CT scan can be limited to uncertain cases with unclear ultrasonographic results and to some children who have complex appendicitis in whom an abscess is suspected. Abscess is a circumstance that, if confirmed, is often managed initially with intravenous antibiotics and consultation with an interventional radiologist for a drainage procedure rather than an appendectomy.

TIMING OF APPENDECTOMY

More than 125 years ago, Reginald Fitz established the goal for clinicians managing appendicitis: endeavor timely appendectomy. The widespread understanding has been that appendicitis has relatively limited morbidity if treated by prompt appendectomy before the disease progresses to complex or perforated appendicitis. Perforated appendicitis carries significantly more threat than simple appendicitis. The circumstances of a delayed diagnosis could provide a pretense for possible lawsuits. As a result, appendectomies were performed for decades at all hours of the day and night as emergencies.

When a child presented with complex appendicitis, a period spent providing intravenous hydration and antibiotics was widely accepted. However, in the case of simple appendicitis, the operation was treated as an emergency that must be addressed immediately because of the presumed risk of allowing simple appendicitis to become complex and heightening morbidity.

Well into the antibiotic era, and long after the work of Fitz, this approach of emergent surgery for simple appendicitis has been modified. To spare the strain on resources, when appendicitis is diagnosed at night, a common practice is to initiate intravenous antibiotics and fluids and perform

the operation at a convenient time, typically the next morning. (10) This approach presumes that antibiotics halt the progression of the illness, allowing for a safe operation conducted by a full staff and rested team. (22)(23) The pathophysiologic analogy is an infected hollow organ such as cholecystitis or diverticulitis for which an immediate emergency surgery is rarely appropriate. Multiple children's surgical centers have confirmed the safety of this approach. (24)(25)(26)

Because the purpose of surgery is to prevent perforation, there is no need for emergency surgery if the appendix is already perforated at time of diagnosis. Appendectomy for perforated appendicitis can be performed after administration of intravenous fluids and antibiotics, hours after diagnosis. (27) This long-established practice is now applied to less advanced, nonperforated cases of appendicitis. (10)(24)(26) The accepted approach today is to start intravenous fluid and antibiotics upon diagnosis of appendicitis, which halts disease progression, and to perform the appendectomy hours later, usually in the morning, for both simple and complex acute appendicitis.

ANTIBIOTICS AS TREATMENT FOR APPENDICITIS

Complex appendicitis (a term denoting advanced conditions that include both perforated and gangrenous appendicitis) is suspected when there is some combination of a history of pain lasting more than 3 days, pronounced abdominal tenderness, marked leukocytosis, and a fever. Ultrasonography may reveal an abscess. Obtaining a CT scan is often appropriate when an abscess is either suspected or documented on ultrasonography, with the purpose of evaluation for possible drainage. In those cases with drainable abscesses, treatment with antibiotics and drainage of the collections by interventional radiologists is a sound approach. Once the acute infection resolves, patients have the option of undergoing delayed appendectomy. This approach to perforated appendicitis has been called "interval appendectomy," denoting that an operation is deferred and performed electively after the infection has resolved, typically 2 months later during a subsequent visit to the hospital. There is no consensus on whether eventual appendectomy should be performed in all cases of complex appendicitis that resolve after initial nonoperative treatment. Some children experience recurrent inflammation until the appendix is removed, but most do not. (28)

Treating periappendiceal abscesses with antibiotics and interval appendectomy became a popular approach more than 30 years ago. Affected patients typically reported having pain for about 1 week. Physical examination generally

revealed a soft abdomen and good gastrointestinal function. A course of antibiotics was used to treat the abscesses. Practitioners believed that performing appendectomies in the face of well-defined abscesses would make recovery more complicated for patients and that surgery would make the previously well patients ill. With that background and with the ability to recognize abscesses on CT scans, clinicians have advocated use of the CT scan when complex appendicitis is likely based on the concept that if there is an abscess, antibiotics, sometimes coupled with drainage by an interventional radiologist, is an appropriate therapeutic approach.

When initial nonoperative treatment was established in cases of appendiceal abscesses, the use of antibiotics without immediate surgery and the possibility of an interval appendectomy were applied more broadly in some centers. Some clinicians advocated this approach for all cases of perforated appendicitis, including any seemingly complex case, whether or not an abscess was present or drainable; others advocated against this approach. Morbidity has been compared for groups of patients with presumed complex appendicitis who underwent appendectomy early in the course of treatment and those who did not. Different series have different results, and some studies have found select subsets of patients who seem to benefit from one approach over the other. Some selection process is warranted; antibiotic therapy without immediate surgery for patients with presumed complex appendicitis should be determined on a case-by-case basis. (29)(30)(31)(32)

Recently, a few small trials have shown fair success rates for antibiotics alone in managing simple appendicitis. Larger numbers of patients and longer follow-up are needed to determine the validity of managing simple appendicitis without appendectomy. That practice has not become standard. However, the idea is provocative and may prove to have some applicability. (33)

Summary

- On the basis of class B evidence and consensus, acute appendicitis in children can often be diagnosed clinically with only selective use of imaging. (13)(14)(15)(16)
- On the basis of class B evidence and consensus, ultrasonography is the test of choice when acute appendicitis is suspected but is unclear based on history, physical examination, and laboratory results. (17)(18)(19)
- On the basis of class B evidence and consensus, the use of computed tomography scan should be limited to cases of suspected complex appendicitis with abscess or when there is clinical suspicion for acute appendicitis but ultrasonography results are not helpful. (16)
- On the basis of class C evidence and consensus, children with possible appendicitis ideally should be treated in medical centers that have skilled sonographic personnel. (21)
- On the basis of class B evidence and consensus, simple appendicitis should be treated by appendectomy during normal operating hours. Preoperative treatment with intravenous antibiotics and fluids during the overnight hours halts disease progression and allows for the safest surgery with the benefit of a full and rested staff. (24)(25)(26)
- On the basis of class B evidence and consensus, complex appendicitis with a well-defined abscess can be treated nonoperatively initially, with the option of an interval appendectomy after recovery from the acute infection. (29)(30)(31)(32)(33)

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CME quiz, references, and suggested readings for this article are at <http://pedsinreview.aappublication.org/content/37/2/52>.

Parent Resources from the AAP at HealthyChildren.org

- Appendicitis in Teens: <https://www.healthychildren.org/English/health-issues/conditions/abdominal/Pages/Appendicitis-in-Teens.aspx>
- Spanish: <https://www.healthychildren.org/Spanish/health-issues/conditions/abdominal/Paginas/Appendicitis-in-Teens.aspx>
- Abdominal Pain in Children: <https://www.healthychildren.org/English/health-issues/conditions/abdominal/Pages/Abdominal-Pain-in-Children.aspx>
- Spanish: <https://www.healthychildren.org/spanish/health-issues/conditions/abdominal/paginas/abdominal-pain-in-children.aspx>
- Stomachaches in Children & Teens: <https://www.healthychildren.org/English/health-issues/conditions/abdominal/Pages/Stomachaches-in-Children-Teens.aspx>
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1. A 17-year-old boy presents to your clinic with a 2-day history of constant abdominal pain that has localized over the last 12 hours to the right lower quadrant of the abdomen. On physical examination of the patient's abdomen, direct palpation 2 inches from the anterior iliac spine on a line drawn from this process through the umbilicus causes increased pain. Tenderness at McBurney point represents:
 - A. An abdominal mass palpated in a patient with perforated appendicitis.
 - B. An acute appendicitis.
 - C. An incarcerated umbilical hernia.
 - D. Diffuse peritonitis.
 - E. Intussusception.
2. A 7-year-old child presents with vague mid-abdominal discomfort that eventually migrates to the right lower quadrant. Acute appendicitis is diagnosed. The original mid-abdominal pain is due to:
 - A. Activation of somatic pain fibers.
 - B. Activation of visceral pain fibers.
 - C. Hyperperistalsis.
 - D. Peritoneal irritation.
 - E. Persistent vomiting.
3. A 13-year-old girl comes into the emergency department with a 12-hour history of generalized abdominal pain and anorexia. The abdominal examination displays tenderness to palpation worse in the right lower quadrant with no peritoneal signs. The white blood cell count is $12,000/\mu\text{L}$ ($12 \times 10^9/\text{L}$) with a mild left shift. Which diagnostic study or procedure should be performed initially?
 - A. Abdominal and pelvic ultrasonography.
 - B. Abdominal computed tomography scan.
 - C. Abdominal magnetic resonance imaging.
 - D. Laparoscopy.
 - E. Transvaginal ultrasonography.
4. A 10-year-old child is seen in the emergency department at 10:00 PM and the diagnosis of early acute appendicitis is suspected. Anorexia and mid-abdominal pain began 24 hours before entering the emergency department. The white blood cell count is $12,500/\mu\text{L}$ ($12.5 \times 10^9/\text{L}$) with a left shift. Abdominal ultrasonography reveals a noncompressible tubular mass in the right lower quadrant with a diameter of 9 mm. Standard of care next requires:
 - A. Abdominal computed tomography scan to confirm the diagnosis.
 - B. Immediate emergent appendectomy.
 - C. Intravenous antibiotics and appendectomy the next morning.
 - D. Intravenous antibiotics until symptoms have resolved.
 - E. Intravenous antibiotics with interval appendectomy 6 to 12 weeks after symptoms have resolved.
5. Abdominal ultrasonography is performed on a 9-year-old boy with a 1-week history of abdominal pain who now presents with generalized peritoneal signs. The ultrasonography demonstrates a large mass in the right lower quadrant adjacent to the abdominal wall. There is a fecalith within the mass. Subsequently, an abdominal computed tomography scan is obtained, which reveals a 9×7 -cm fluid-filled mass with an inflammatory surrounding rim that corresponds to the ultrasonographic findings. After antibiotics are administered, the next therapeutic step should be:
 - A. Continued antibiotic therapy with observation.
 - B. Immediate surgical exploration and appendectomy.
 - C. Laparoscopic exploration.
 - D. Pain control and surgical exploration if the symptoms have not resolved in 24 hours.
 - E. Percutaneous drainage of the abscess.

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