

How sick is your appendectomy?

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Introduction

Appendectomy is the removal of the vermiform appendix. The term 'appendectomy' is misleading as it gives no indication of degree of clinical compromise the patient may be suffering leading to the need for this procedure. The patient presenting for appendectomy represents a clinical challenge to the anaesthetist, which requires vigilance in ascertaining the severity of illness in order to allow for good anaesthesia management.

What are the indications for appendectomy?

Appendectomy is indicated in patients presenting with signs of peritonitis suggestive of appendicitis.

What is appendicitis?

Appendicitis is inflammation of the inner lining of the vermiform appendix that eventually spreads to all its components.¹ It is a common cause of abdominal pain and is the leading indication for emergent abdominal surgery worldwide.²

Anatomically, the appendicular orifice is constant in its opening into the base of the caecum, near the ileocaecal valve but its course and tip may be located in numerous positions which may complicate diagnosis during clinical examination.² The appendix is located retroperitoneally in 65% of patients.² It can also be located posterior to the terminal ileum, caecum, ascending colon or liver.¹

In the USA, the incidence is 233/100 000 population with the highest affected being the 10 – 19 year-old group.² It affects men more than women (male to female ratio 1.4:1).²

What are the causes of appendicitis?

Appendicitis is caused by the obstruction of its lumen.¹ The causes of this obstruction may include:^{1,2}

- Lymphoid hyperplasia:
 - Secondary to inflammatory bowel disease (IBD), e.g. Crohn's disease.
 - Infection e.g. gastroenteritis, amoebiasis, respiratory infections, measles, mononucleosis, tuberculosis.

- Seen more commonly in childhood or in young adults.
- Faecal stasis and faecaliths:
 - Seen commonly in the elderly.
 - Faecaliths formed by layering of calcium salts and faecal debris round a nidus of inspissated faecal material within the appendix.
- Parasites:
 - Seen more commonly in Eastern countries.
 - For example: Schistosomes species, pinworms, *Strongyloides stercoralis*.
- Foreign bodies:
 - Shotgun pellet, intrauterine device, tongue stud, activated charcoal
- Neoplasms:
 - Carcinoid, adenocarcinoma, mucocoele

What is the pathophysiology of appendicitis?

The main feature in appendicitis is obstruction of the appendicular lumen although this is not proven in all cases.^{1,2} This obstruction leads to raised pressure within the lumen due to secretion of fluids and mucus, which remain stagnant.¹

Multiplication of bacteria occurs within the appendix leading to recruitment of white blood cells. Pus is formed which further increases the intraluminal pressure.¹ If the obstruction is not relieved, the intraluminal pressure rises above that of the appendicular veins causing venous outflow obstruction.¹ This leads to appendicular wall oedema and eventually ischaemia.¹ Epithelial integrity is lost, allowing bacterial translocation into the appendicular wall.¹ Early on in the disease, aerobic bacteria predominate and as the disease progresses, a mixed infection is more common.² Organisms implicated include *Escherichia coli*, *Peptostreptococcus*, *Bacteroides fragilis* and *Pseudomonas* species. Within a few hours, thrombosis of the appendicular artery and vein occurs which leads to perforation and gangrene of the appendix.¹ Subsequently, a periappendicular abscess may develop or worse still, peritonitis.¹

The engorged appendix stimulates the visceral afferent nerve fibres at T8 to T10 resulting in a vague central or periumbilical abdominal pain.² As the inflammation spreads to the adjacent parietal peritoneum, the somatic nerves are stimulated thus leading to local peritoneal irritation that results in the pain becoming better localised.²

How does appendicitis present?

Fifty percent of patients present with a classic history of anorexia and central abdominal pain followed by nausea, right iliac fossa pain and vomiting.² Diarrhoea and constipation have also been reported.² The duration of symptoms is usually less than 48hrs in the majority of adults, however it can be longer in the elderly and those with perforation.¹ On examination, rebound tenderness and guarding may be elicited. Left iliac fossa pain may be found in patients with a very long appendix or situs inversus.¹

How is appendicitis diagnosed?

A high index of suspicion should be maintained based on the history and physical examination. In experienced hands, the diagnosis of appendicitis can be made with an accuracy of 75 to 80%.²

The following laboratory tests help to confirm the diagnosis and assess the severity of the disease:

- Mild leukocytosis (white blood cell count >10 000 cells/ μ l)
- Mild elevation of serum bilirubin > 1.0 mg/dl is a marker of appendix perforation with a sensitivity of 70% and a specificity of 86%.

Imaging studies, which aid in the diagnosis, include CT scanning, abdominal ultrasound, plain abdominal x-rays and MRI scanning.

In children less than 3 years old, adults older than 60 years and women in the second and third trimester the diagnosis of appendicitis can be challenging. In these cases, imaging may be of great use.

The modified Alvarado scale assigns a score to each of 7 diagnostic criteria as follows:

- Migratory right iliac fossa pain (1 point)
- Anorexia (1 point)
- Nausea or vomiting (1 point)
- Tenderness in the right iliac fossa (2 points)
- Rebound tenderness in the right iliac fossa (1 point)
- Fever >37.5°C (1 point)
- Leukocytosis (2 points)

A low Alvarado score <5 has more diagnostic criteria to rule out appendicitis than a high score \geq does to rule in a diagnosis. Clinical judgment however remains more important in establishing the diagnosis.

What is the differential diagnosis for acute appendicitis?

Several inflammatory and infectious conditions can mimic acute appendicitis.² These include:

- Perforated appendix
- Caecal diverticulitis
- Meckel's diverticulitis
- Acute ileitis
- Crohn's disease
- Gynaecologic and obstetric conditions
 - Tubo-ovarian abscess
 - Pelvic inflammatory disease
 - Ruptured ovarian cyst
 - Mittelschmerz
 - Ovarian and fallopian tube torsion
 - Endometriosis
 - Ovarian hyperstimulation syndrome
 - Ectopic pregnancy
 - Acute endometritis
- Urologic conditions
 - Renal colic
 - Testicular torsion
 - Epididymitis
 - Torsion of the appendix testis or appendix epididymis

How is acute appendicitis managed?

Early diagnosis and prompt operative intervention is essential to avoid morbidity and mortality of acute appendicitis.³ The gold standard of treatment is appendectomy. To avoid delay in diagnosis, many surgeons accept a 10 – 15% negative laparotomy rate.³

Appendectomy can be performed via laparoscopy or open laparotomy. In the USA, 58% of appendectomies are performed laparoscopically. The choice of approach is determined by: confidence in the diagnosis, history of previous surgery, age, gender, body habitus and surgical skills. Laparoscopic approach is associated with a lower rate of wound infection, reduced postoperative pain, shorter hospital stay and faster return to normal bowel function. But this has to be balanced with the higher rate of intra-abdominal abscess, longer operating times and higher costs.

What preoperative preparations are required prior to appendectomy?

Peritonitic abdominal pain for longer than 24 to 48 hours requires the exclusion of sepsis and multi-organ dysfunction.

Physical examination should focus on assessment of the intravascular volume status, shock, multi-organ dysfunction and adequacy of haemodynamic resuscitation. Hypo-

volemic shock can present with hypotension, tachycardia and oliguria. If this state persists without treatment, rapid deterioration and death can ensue.

Investigations should aim to assess degree of multi-organ dysfunction. These include: full blood count, platelet count, serum electrolytes, liver and kidney function tests, blood glucose and ECG. A coagulation profile and blood gas analysis is mandatory where systemic features of sepsis are present. Cultures for blood, urine and peritoneal fluid should be obtained prior to commencing empiric antibiotic therapy. Erect chest x-ray or abdominal x-ray in the left lateral position may aid in diagnosing perforation of the appendix.

Sepsis is defined as the presence (probable or documented) of infection together with systemic manifestations of infection. Severe sepsis is defined as sepsis with sepsis-induced organ dysfunction or tissue hypoperfusion. The diagnosis of sepsis and septic shock can be made using Surviving Sepsis Campaign Guidelines of 2012.⁵ These comprehensive guidelines can be downloaded free of charge from <http://www.sccm.org/Documents/SSC-Guidelines.pdf>

The guidelines use general variables (fever, hypothermia, heart rate, respiratory rate, mental status, oedema and hyperglycaemia) in addition to inflammatory variables, organ dysfunction variables and tissue perfusion variables as diagnostic criteria for sepsis.

Severe sepsis is diagnosed if infection is suspected to have caused any of the following:

- Increased lactate levels
- Reduced urine output
- Acute lung injury with or without pneumonia
- Increased creatinine
- Increased bilirubin
- Decreased platelet count
- INR > 1.5

Preoperative management

Haemodynamic resuscitation

- The aim is to restore adequate oxygen delivery to peripheral tissues. In severe cases of appendicitis with perforation, massive sequestrations of fluid into the peritoneum and gut lumen can lead to hypovolaemia⁴.
- This can be guided by the Surviving Sepsis Campaign guidelines if the diagnosis of severe sepsis or septic shock has been made:⁵
- Arterial lines and CVP should be used to guide resuscitation in patients with haemodynamic instability.
- The Surviving Sepsis Campaign guidelines should be followed for recommendations on the use of inotropes and vasopressors that may be required to offer further support.⁵

Initial Resuscitation

- Protocolised, quantitative resuscitation of patients with sepsis-induced tissue hypoperfusion (defined in this document as hypotension persisting after initial fluid challenge or blood lactate concentration ≥ 4 mmol/l). Goals during the first 6 hrs of resuscitation:
 - Central venous pressure 8–12 mmHg
 - Mean arterial pressure (MAP) ≥ 65 mmHg
 - Urine output ≥ 0.5 ml/kg/hr
 - Central venous (superior vena cava) or mixed venous oxygen saturation 70% or 65%, respectively.
- In patients with elevated lactate levels targeting resuscitation to normalize lactate.

Fluid Therapy of Severe Sepsis

- Crystalloids as the initial fluid of choice in the resuscitation of severe sepsis and septic shock.
- Against the use of hydroxyethyl starches for fluid resuscitation of severe sepsis and septic shock.
- Albumin in the fluid resuscitation of severe sepsis and septic shock when patients require substantial amounts of crystalloids.
- Initial fluid challenge in patients with sepsis-induced tissue hypoperfusion with suspicion of hypovolemia to achieve a minimum of 30 ml/kg of crystalloids (a portion of this may be albumin equivalent). More rapid administration and greater amounts of fluid may be needed in some patients.
- Fluid challenge technique be applied wherein fluid administration is continued as long as there is hemodynamic improvement either based on dynamic (e.g., change in pulse pressure, stroke volume variation) or static (e.g., arterial pressure, heart rate) variables.

- Electrolyte abnormalities should be corrected accordingly.
- Blood transfusion should be administered according to patient's comorbid profile.
- Deranged coagulation should be corrected using fresh frozen plasma and other blood products as required.

Antibiotic administration

- Empirical antibiotic therapy should be commenced as soon as the relevant cultures have been obtained if this does not delay the administration of antibiotics.
- The following list includes the recommended antibiotic regimen for patients with intraabdominal infection as outlined by the Surgical Infections Society based on evidence from trials⁴:
 - **Single agents**
 - Ampicillin/sulbactam
 - Cefotaxan
 - Cefoxitin
 - Ertapenem
 - Imipenem/cilastatin
 - Meropenem
 - Moxifloxacin
 - Piperacillin/tazobactam
 - Ticarcillin/clavulanic acid

- **Combination regimens**
 - Aminoglycoside plus an anti-anaerobic agent (clindamycin or metronidazole)
 - Aztreonam plus clindamycin
 - Cefuroxime plus metronidazole
 - Ciprofloxacin plus metronidazole
 - Third or fourth generation cephalosporins (cefepime, ceftazidime, ceftizoxim or ceftriaxone) plus anti-anaerobe

Critical care organ support if needed

Maintenance of nutrition

Are there any scores that can be used to predict mortality in perforated appendicitis?

The Mannheim Peritonitis index (MPI) is a score used to predict mortality in adult patients with perforation peritonitis. The risk factors that make up the scoring are listed in the table below. It considers duration of peritonitis >24hrs as a major contributing factor mortality with a 7 to 8 fold increase in mortality being noted with delay more than 24 hrs. Hypoglycaemia during hospitalisation has been associated with increased in-hospital mortality. Sepsis, starvation, malignancy and low serum albumin are risk factors for hypoglycaemia, while depleted glycogen stores, impaired gluconeogenesis and increased peripheral utilization could be contributing factors. Renal dysfunction is a marker of mortality.

The MPI score ranges from 0 to 57 and can be applied to any cause of perforation peritonitis to predict the

The Mannheim Peritonitis Index	
Risk Factors	Score
Age > 50years	5
Female sex	5
Organ failure: <ul style="list-style-type: none"> • Renal failure: creatinine >177 mmol/l or urea >167mmol/l or oliguria <20 ml/hr. • Pulmonary insufficiency: pO₂<50 mmHg or pO₂>50 mmHg • Intestinal obstruction/paralysis >24hrs or complete mechanical ileus • Hypodynamic or hyperdynamic shock 	7
Malignancy	4
Pre-operative duration of peritonitis >24hrs	4
Origin of sepsis not colonic	4
Diffuse generalized peritonitis	6
Exudate: <ul style="list-style-type: none"> • Clear • Cloudy, purulent • Faecal 	0 6 12

prognosis of such patients with sepsis. Scores <21 have a low mortality (0–23%) compared to those with a score >29 with a high mortality more than 50%.

What is the perioperative management of a patient presenting for appendectomy?

Appendectomy may be all that is required in otherwise healthy young patients presenting early in the course of the disease. Surgical risk increase with delay in diagnosis and surgery. The choice of laparoscopic or open appendectomy depends on the severity of intra-abdominal pathology.⁴

General anesthesia with endotracheal intubation and positive pressure ventilation is the preferred technique as complete relaxation of the abdominal muscles is required for laparotomy. Invasive monitoring should be established preoperatively for aerodynamically unstable patients. Normothermia should be maintained. Fluid status should be corrected in concert with electrolyte and acid-base balance. Postoperative ICU admission may be suggested by the presence of: advanced age, comorbid illness, delayed presentation, features suggestive of sepsis or organ dysfunction.

Rapid sequence induction is indicated as these patients are at risk for aspiration. Choice of induction agent depends on the haemodynamic status of the patient. Volatile or total intravenous anaesthesia can be used for maintenance in accordance with the patient's haemodynamic responses. In critically ill patients with septic shock, ketamine and midazolam or a high opioid technique using fentanyl may be required. Fluid resuscitation and inotropic support may be required to maintain counteract the hypotensive effect of anaesthesia and ventilation.

The use of non-steroidal anti-inflammatory drugs (NSAIDs) should be avoided in patients with renal or hepatic impairment.

Sepsis is a relative contraindication to neuraxial anaesthesia due to the haemodynamic effects that may predominate. Recent assessment of coagulation status is mandatory. Laparotomy under spinal anaesthesia and epidural anaesthesia is well described in literature.

What are the considerations for postoperative care following appendectomy?

As mentioned earlier, fit young patients may follow an uneventful course if diagnosis and surgery are done early. Pre-operative assessment should guide the anaesthetist in deciding which patients will require intensive care admission postoperatively. The Surviving Sepsis Campaign recommendations of 2012 guide the management of these patients through out the perioperative and postoperative periods.^{4,5}

Fluid management, electrolyte and acid-base monitoring and nutrition are important to outcome of the patient. Ventilator support and inotropic or vasopressor support should be continued in the critically ill patients. The Surviving Sepsis Campaign has very clear evidence-graded recommendations for mechanical ventilation of patients with adult respiratory distress syndrome (ARDS).⁵

Antibiotics should be continued and adjusted according to culture results. Glycaemic control should be maintained in the range of 6 – 10 mmol/L. Enteral feeding should be started as soon as possible unless there is a surgical contra-indication to do so. Intravenous hydrocortisone should only be used in the presence of hypotension that remains refractory to fluids and vasopressors. The recommended dose is 200mg/day in divided doses.

Acute renal failure ensues in 23% of patients with severe sepsis. Renal replacement therapy may be required to manage acidosis, hyperkalaemia or fluid overload. Continuous renal replacement therapy (CRRT) and sustained low efficiency dialysis (SLED) are used in haemodynamically unstable patients.

Prophylaxis against stress ulcers and deep vein thrombosis is recommended.

Conclusion

Appendicitis is one of the most common indications for emergency abdominal surgery. A delay in diagnosis can result in critical illness that poses a great challenge to the anaesthetist. Thorough assessment of all patients preoperatively helps to inform adequate intra-operative anaesthesia management and postoperative intensive care management. The Surviving Sepsis Campaign recommendations of 2012 provide an excellent framework for the management of critically ill patients with acute appendicitis.

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