CHAPTER 3
3. ACUTE APPENDICITIS

3.1. INTRODUCTION

Appendicitis is a painful inflammation and infection of the appendix and the primary cause is obstruction of the appendiceal lumen [Sloan et al., 2001]. Appendicitis is a dangerous condition and it usually occurs when the appendix becomes infected and blocked by a build-up of thick mucus, faeces or some foreign object such as parasitical worms. Global statistics show that one in 15 people will develop appendicitis in their lifetime, and people between the ages of 10 and 30 are most prone to the condition. But it may happen to anyone without warning, which is why NASA is considering preventative appendectomies for astronauts before they embark on future space missions [Sethian et al., 2006].

Appendicitis is the most common cause of acute abdominal pain that requires surgical intervention in the Western world [Brooke Jeffrey et al., 1987]. Patients with the disease may present with a wide variety of clinical manifestations, and the diagnosis may elude even the most experienced clinicians [Williams 1983]. The adult appendix is a long diverticulum averaging 10 cm in length that arises from the posteromedial wall of the cecum, approximately 3 cm below the ileocecal valve [Buschard et al., 1973]. The appendix may lie in a retrocecal, subcecal, retroileal, preileal, or pelvic site which influences the clinical presentation [Sivasankar et al., 2009; Foschi et al., 2002; Guidry et al., 1994; Wagner et al., 1996].

3.1.1. Overview of Acute Appendicitis

Symptoms of appendicitis usually include pain in the lower right abdomen, loss of appetite, nausea and or vomiting, with or without fever. There may be mild diarrhea or
constipation. The site of this pain could be higher in appendicitis in pregnancy, or even lower in those with very long appendix. Early symptoms of appendicitis are those symptoms that most people with this condition may recognize and complain of. They include lower right sided abdominal pain of gradual onset, feeling sick, and loss of appetite. Anyone with these three symptoms can be assumed to have appendicitis until otherwise proven [Edema 2005].

The maximum incidence of the disease occurs in the second decade; thereafter, disease incidence declines with age [Addiss et al., 1990, Primesta et al., 1994]. The primary pathogenic event in the majority of patients with acute appendicitis is luminal obstruction [Pieper et al., 1982]. Fecoliths, which result from the inspissations of fecal material and inorganic salts within the appendiceal lumen, are the most common cause of obstruction and are present in 11%-52% of patients with acute appendicitis [Nitecki et al., 1990]. Ultrasound is a widely available and inexpensive modality with the potential for highly accurate imaging in the patient suspected to have acute appendicitis. Although operator skill is an important factor in all ultrasound examinations, it has particular importance in the examination of the patient with right-lower-quadrant pain. Nonetheless, the criteria for the ultrasound based diagnosis of acute appendicitis are well established and reliable [Ozekes et al., 2005]. Ultrasound is also highly useful in identifying an alternate diagnosis [Gaensler et al., 1989].

The specific ultrasound approach to the right lower quadrant should include graded compression ultrasound, a technique first popularized by using high frequency linear probes. It describes the use of uniform pressure on the region of interest by the handheld ultrasound transducer. The patient is also able to provide input as to the point of maximal tenderness, which often is useful in focusing the examination in the correct area [Borushok et al., 1990].
Sonologist starts the examination with a curvilinear transducer appropriate for the patient; the linear transducer is used last, for more detailed images of the gut. Rigorous adherence to the criteria for diagnosing appendicitis is recommended. The inflamed appendix is seen as a blind-ended, tubular structure with a laminated wall that arises from the base of the caecum and it is a peristaltic and non compressible [Jeffrey et al., 1988].

Appendicoliths appear as bright, echogenic foci with clean distal acoustic shadowing. Prior to the actual perforation of the appendix, ischemic and gangrenous change in the appendiceal wall may lead to focal or generalized loss of definition of the wall layers [Borushok et al., 1990]. With perforation of the appendix, the distended appendix may no longer be visualized at ultrasound examination. Although the criteria for the diagnosis of appendicitis are focused on the appendix itself, inflammatory changes in the perienteric fat are often the first and most obvious findings at ultrasound examination. Inflamed fat appears at ultrasound as an “echogenic mass effect”.

It separates the inflamed gut from the surrounding gut and other organs. Phlegmonous change manifests as hypoechoic zones with poor margination within the inflamed fat that blend imperceptibly at its margins with the fatty tissue [Sarrazin et al., 1996]. Liquefaction and abscess formation will manifest as an actual fluid component. Gas bubbles within a collection suggest either perforation or gas-forming organisms. A localized perforation of the appendiceal tip may show gas pockets localized to the perforation site, with disruption of the wall at that point. Sympathetic thickening of the adjacent terminal ileum and ascending colon may lead to the erroneous interpretation of the site of the original problem.
Jeffrey Jr et al., (1988) evaluated high-resolution, real-time ultrasonography with graded compression to evaluate 90 patients with clinically suspected acute appendicitis. Ultrasonographic visualization of a non-compressible appendix is the primary criterion for a diagnosis of acute appendicitis. The overall sensitivity is 89%, the specificity is 95%, and the accuracy is 93%. It is concluded that visualization of a noncompressible appendix with real-time sonography appears to be a sensitive and specific method for the diagnosis of appendicitis in patients with acute pain in the right lower quadrant.

Jeffrey Jr et al., (1988) studied 250 consecutive patients with suspected appendicitis with graded compression sonography. 80 patients have positive follow up and diagnostic criterion for appendicitis is visualization of a non-compressible appendix and dimensions of the visualized appendix. It is concluded that a normal appendix may rarely be visualized with high resolution graded compression sonography. Diagnosis of appendicitis can be made in adult patients with persistent right lower quadrant pain and a visualized appendix greater than 6 mm in diameter. If the maximal outer appendiceal diameter is less than 6 mm, appendicitis has been considered when there is compelling clinical evidence of appendicitis or multiple appendicoliths.

Puylaert (1986) have conducted a study in 60 consecutive patients with clinical signs of acute appendicitis using graded compression sonography. 89% of patients with confirmed appendicitis, ultrasound detected the inflamed appendix. Appendix is not visualized in 100% of the patients without acute appendicitis. Sonographic Murphy is positive in 88% of cases and perforation is detected in 86%. It is concluded that graded-compression ultrasound is the examination of choice if there is doubt whether an appendectomy should be performed.
Rioux (1992) conducted a study to assess the value of sonography in detecting the normal and abnormal appendix in 170 patients with suspected appendicitis. The wall thickness (normal, less than or equal to 3 mm), compressibility of the appendix, and echogenicity of surrounding fat were the primary criteria used to determine the status of the appendix. A diagnosis of appendicitis was made when appendiceal compressibility was reduced or absent, or when the transverse wall thickness was greater than 3 mm. Other signs of appendicitis included decreased echogenicity of the surrounding fat or the presence of a poorly defined hypoechoic round or oval structure, adjacent to the cecum and independent of loops of bowel. Criteria for appendiceal rupture were clear asymmetry in wall thickness with indistinctness of wall layer or the presence of an air or fluid collection around the appendix. Appendix is considered normal if it is not visualized and a normal appendix has been clearly identified in 102 of 125 patients without acute appendicitis. The sensitivity of sonographic examination in detecting appendicitis is 93%, the specificity is 94%, and the accuracy is 94%. The predictive value of a positive test is 86%; that of a negative test is 98%.

It is concluded that normal appendix can be visualized sonographically far more frequently than previously suspected. The wall thickness of the appendix appeared to be a useful index of the status of the appendix and search for normal and abnormal appendix increases the diagnostic accuracy. Lim et al., (1996) studied the diagnostic value of graded-compression ultrasonography for the diagnosis of focal appendicitis confined to the tip. Of 20 patients with focal appendicitis confirmed at pathologic examination, 17 patients (85%) have focal appendicitis correctly diagnosed at ultrasonography. 3 (15%) patients have normal proximal and mid portions and appendicitis has been confined to the tip. Since the length and location of the appendix is variable, they concluded that the entire length of the appendix should be evaluated to avoid false negative examinations.
3.1.2. Existing Methods for Appendicitis Diagnosis

The diagnosis of appendicitis begins with a thorough history and physical examination. Patients often have an elevated temperature, and there will be usually moderate to severe tenderness in the right lower abdomen when the doctor pushes there. If inflammation has spread to the peritoneum, there is frequently rebound tenderness. Rebound tenderness is pain when the doctor quickly releases his hand after gently pressing on the abdomen over the area of tenderness [Sivasankar et al., 2009]. The various existing methods for appendicitis diagnosis are: leukocytes count, urinalysis, abdominal X-Ray, ultrasound, barium enema, computerized tomography scan and laparoscopy.

**Leukocytes Count**

The white blood cell count in the blood usually becomes elevated with infection. In early appendicitis, before infection sets in, it can be normal, but most often there is at least a mild elevation even early. Unfortunately, appendicitis is not the only condition that causes elevated white blood cell counts, and almost any infection or inflammation can cause this count to be abnormally high. Therefore, an elevated white blood cell count alone cannot be used as a sign of appendicitis [Sivasankar et al., 2009].

**Urinalysis**

Urinalysis is a microscopic examination of the urine that detects red blood cells, white blood cells and bacteria in the urine. Urinalysis usually is abnormal when there is inflammation or stones in the kidneys or bladder. The urinalysis also may be abnormal with appendicitis because the appendix lies near the ureter and bladder. If the inflammation of appendicitis is great enough, it can spread to the ureter and bladder leading to an abnormal urinalysis. Most patients with appendicitis, however, have a normal urinalysis. Therefore, a
normal urinalysis suggests appendicitis more than a urinary tract problem [Sivasankar et al., 2009].

**Abdominal X-Ray**

An abdominal x-ray may detect the fecalith that may be the cause of appendicitis, which is obvious in case of children [Sivasankar et al., 2009].

**Ultrasound**

An ultrasound is a painless procedure that uses sound waves to identify organs within the body. Ultrasound can identify an enlarged appendix or an abscess. Nevertheless, during appendicitis, the appendix can be seen in only 50% of patients. Therefore, not seeing the appendix during an ultrasound does not exclude appendicitis. Ultrasound also is helpful to women as it excludes the presence of conditions involving the ovaries, fallopian tubes and uterus that can mimic appendicitis [Sivasankar et al., 2009].

**Barium Enema**

A barium enema is an X-ray test where liquid barium is inserted into the colon from the anus to fill the colon. This test can, at times, show an impression on the colon in the area of the appendix where the inflammation from the adjacent inflammation impinges on the colon. Barium enema also can exclude other intestinal problems that mimic appendicitis, for example Crohn's disease [Sivasankar et al., 2009].

**Laparoscopy**

Laparoscopy is a surgical procedure in which a small fiber optic tube with a camera is inserted into the abdomen through a small puncture made on the abdominal wall.
Laparoscopy allows a direct view of the appendix as well as other abdominal and pelvic organs. If appendicitis is found, the inflamed appendix can be removed with the laparoscope. The disadvantage of laparoscopy compared to ultrasound and CT is that it requires a general anesthetic. There is no test that will diagnose appendicitis with certainty. Therefore, the approach to suspected appendicitis may include a period of observation, tests as previously discussed, or surgery [Sivasankar et al., 2009].

**Computerized Tomography (CT) Scan**

The patients who are not pregnant, a CT scan of the area of the appendix is useful in diagnosing appendicitis and peri-appendiceal abscesses as well as other diseases inside the abdomen and pelvis that can mimic appendicitis [Sivasankar et al., 2009].

Prabhu desai et al., (2008) proposed that artificial neural networks can be useful in diagnosing acute appendicitis. They used a back propagation algorithm and the weights of the connections were altered in an attempt to reduce the mean square error of the whole data set. Sivasankar et al., (2009) proposed that Back propagation Neural Network and Bayesian Based Classifier can be useful in diagnosing Appendicitis. Balu et al., (2011) proposed a method for identification of acute appendicitis using euclidean distance on sonographic image.

Aleksander et al., (1999) proposed a computer model, built on clinical attributes with additional access to the results of certain biochemical tests which performed better then a classifier realized by probability estimates given by a team of physicians, based only upon the clinical attributes. Ikramullah Khan et al., (2005) used an alvarado scoring system which depends on the presence and absence of certain variables and which provides an
accurate guide to whether or not the patient has the appendicitis. Mesut Tez et al., (2008) proved that neuro fuzzy systems can incorporate data from many clinical and laboratory variables to provide better diagnostic accuracy in acute appendicitis.

3.1.3. Historical Background of Appendicitis

The epidemiology of appendicitis poses many unanswered questions. Almost unknown before the 18th century, there was a striking increase in its prevalence from the end of the 19th century, with features suggesting that the side effect of modern Western life. The conservative British medical establishment resisted the novel appendectomy procedure until after the turn of the century, when it was used to save the new king's life. In 1901, the Prince of Wales, Albert Edward, underwent an emergency appendectomy, just two weeks before his scheduled coronation as King Edward VII. Albert Edward successful recovery finally convinced British surgeons that this operation was the only way to save the victims of this "mysterious" new disease. Currently, 7% of the U.S. population will contract appendicitis at some point in their lifetime [King Edward, 2012]. Appendicitis is the most common reason for a child to need emergency abdominal surgery. Young people between the ages of 11 and 20 are most often affected [Health Enc, 2012].

Modern medicine recognizes that appendicitis is primarily a disease of the Western World. They attribute this to the greater amount of fiber in the diet of the Third World. There are no medically proven ways to prevent appendicitis. Although appendicitis is rare in countries where people eat a high-fiber diet, experts have not yet shown that a high-fiber diet definitely prevents appendicitis.

Many residents of the developing world, not wanting to appear "backward", feel obliged to adopt western toilets. This trend is causing health problems that were previously
unknown among squatting populations [Jonathan Isbit, 2007]. The Indian type of toilet is more conducive to complete evacuation than the Western toilet. With the western style closets becoming popular in India, there is a risk of increased incidence of appendicitis.

Unfortunately, western doctors have never made the connection between toilet posture and appendicitis. Their understanding of this disease has advanced little since Frederick Treves performed his famous appendectomy on the Prince of Wales. Ironically, Sir Frederick lost his own daughter to appendicitis. Despite being highly skilled at surgery, he had no idea what causes the disease, or how to prevent it. Now his successors have the opportunity to redeem their profession. By incorporating this new knowledge into their practice, they can help their patients to avoid this deadly disease [Sam Rao Yoga, 2012].

3.2. SONOGRAPHY IN MEDICAL IMAGING

It is noteworthy to mention two researchers in the history of ultrasound and medical imaging and they are: Doctor Karl Theodore Dussik of Austria, who published the first paper on medical ultrasonics in 1942, based on his research on transmission ultrasound investigation of the brain; and Professor Ian Donald of Scotland, who developed practical technology and applications for ultrasound in the 1950s. Subsequent years saw tremendous improvements in ultrasound hardware and software. With advent of B-mode ultrasound and the added advantage of doppler studies increased the diagnostic acumen of ultrasound. Diagnostic ultrasound has recently been widely used in diagnosing various acute abdominal conditions, as well as routine clinical examinations in hospitals.

Medical ultrasonography is a diagnostic imaging technology used to visualize internal organs, their size, structure and any pathological lesions using high frequency sound (in the
megahertz range = millions of cycles per second. Human can only hear in the range of about 30 to 20,000 cycles per second). It is different from x-ray that uses mechanical sound energy rather than radiation to produce images and it provides a thin tomographic slice rather than a flat plane projection, like x-ray or fluoroscopy. It also has the advantage of being real-time rather than static, and it can display not only image, but doppler information as well, useful in assessment of blood flow [Nicholas, 2012].

3.2.1. Sonographic Scan

An ultrasound machine is a non-invasive way to provide valuable medical details compared to traditional tools and diagnostic techniques. In other words, it has greatly helped medicine to become safer and more accurate. Some common functions of the process are discussed here. Ultrasound machines for obstetrics provide invaluable information about a woman’s pregnancy and her growing baby. The ultrasound scanning of uterus can view the baby’s current position, gender and condition. Such procedure can identify the conception date and ensure that the fetus is in healthy development.

3.2.2. Advantages of Sonographic Image

Sonographic images are very well which is particularly useful for delineating the interfaces between solid and fluid-filled spaces. It renders "live" images, where the operator can dynamically select the most useful section for diagnosing and documenting changes, often enabling rapid diagnoses. It has no known long-term side effects and rarely causes any discomfort to the patient, and is relatively inexpensive compared to other imaging modalities [Marc Fine, 2012]. Ultrasound has been used in a variety of clinical settings, including obstetrics and gynecology, cardiology and cancer detection.
The main advantage of ultrasound is that certain structures can be observed without using radiation. Ultrasound can also be done much faster than X-rays or other radiographic techniques [Craig Freudenrich, 2012]. The applications of ultrasound machines include biomedical applications as well as industrial applications. As a matter of fact, it could be considered as the most used equipment either in clinics or hospital these days. Ultrasound is more effective and safe compared to those old techniques practiced in decades past.
[Nicholas, 2012]. Figure 3.1 shows Philips iU22 Ultrasound Machine, Touch screen control, Probes and Systems.

3.3. SUMMARY

Appendicitis is an inflammation of the appendix; and once it starts there is no effective medical therapy. Hence, appendicitis is considered a medical emergency. When treated promptly, most patients recover without difficulty but if treatment is delayed, the appendix can burst, causing infection and even death. Appendicitis is the most common acute surgical emergency of the abdomen. In this chapter, overview of acute appendicitis, various existing methods for appendicitis diagnosis, related work in appendicitis and historical background of appendicitis are highlighted. In addition, sonographic scanner machine and different type of advantages of ultrasound image are explained in detail.