4.4.2.4 Knee joint aspiration

1. Indications

1.1 Diagnostic[2]

- Sepsis (septic arthritis).
- Traumatic effusion.
- Gout: Monosodium urate crystals.
- Hemarthrosis due to damage to the cruciate ligaments and meniscal tears.
- Diagnosis of nontraumatic joint disease by synovial fluid analysis.
- Diagnosis of ligamentous or bony injury by confirmation of the presence of blood in the joint.
- Establishment of the existence of an intra-articular fracture by the presence of blood with fat globules in the joint.

Synovial fluid analysis may provide vital data in establishing the diagnosis[3], whether the diagnosis is noninflammatory, inflammatory or septic[12].

1.2 Therapeutic[2]

- Relief of pain of an acute hemarthrosis or tense effusion. The performance of an arthrocentesis may permit examination of the joint. Furthermore, the effects of hemosiderin and proteolytic enzymes on the joint are detrimental[18].

- Local instillation of medications like steroids in different types of arthritic disease for example rheumatoid arthritis, osteoarthritis and psoriasis. This is done as an adjunct to systemic medical therapy.

- Drainage in acute arthritis is a medical emergency[15]. The reason for this is not only due to the pain suffered, but also due to the potential of joint destruction. The three most likely causes for joint destruction are bacterial infection, crystal-induced arthritis and hemarthrosis.

2. Contraindications

- Presence of infection in the tissue overlying the joint. The potential of contaminating the joint should be weighed against the consequence of not recognizing an already septic joint[15].
- Bleeding disorders.
- Patient suffering from a systemic disease.
- Aspiration of a Baker's cyst.

- Contraindications for intra-articular corticosteroid injection[12]:

Absolute:	Cellulitis in the area of placement. Suspected or proven septic arthritis
Relative:	Minimal relief following a trial of injections. Underlying coagulopathy. Recent intra-articular fracture. Evidence of surrounding joint osteoporosis.

3. Step by step procedure

- With attention to sterile technique and careful observation of anatomical landmarks, knee joint aspiration can be as safe and painless as a normal venipuncture.

- The following are four basic principles for intra-articular injection:

1. Make an accurate diagnosis.
2. Revise local anatomy knowledge before injecting.
3. Use aseptic technique.
4. Use the correct size needle.

Step 1. Aseptic technique is crucial. Wash the area with soap and sterile alcohol. It is not necessary to gown up or to go to theatre.

Step 2. Explain the rationale of the procedure to the patient[2]. The use of local anesthesia can make the procedure less painful, but is usually not necessary.

Step 3. Position

- Position the patient on a bed with the knee in the fully extended position. The result is relaxation of the quadriceps muscle and patellar tendon which greatly facilitates needle placement. Relaxation of the quadriceps muscle is essential, as a tense muscle will clamp the patella down into the patellar groove, blocking entry of the needle. Position the patient on a bed. With a large tense effusion, the knee is most comfortably held in a mild flexion

position. Put a pillow under the knee for support.

Step 4. Landmarks[1]:

- Identify the surface anatomy and bony landmarks by inspection and palpation. Carefully palpate the bony margin of the patella, which can be moved freely before the needle is inserted. Palpate the medial surface of the patella, just below the superior border of the patella and insert the needle approximately 1cm medial to the medial patellar edge.

Step 5. Needle direction

- A 20- or 21-ga needle (18-ga to aspirate thick effusion)[12] is used.
- The needle is directed between the posterior surface of the patella and the intercondylar femoral notch avoiding the undersurface of the patella. Although touching of the patella with the needlepoint may occur and does not do harm, this is very uncomfortable for the patient[16].
- Slight negative pressure is kept on the syringe while advancing the needle.
- Synovial fluid is often found after just 1 cm of penetration. Deep advancement of the needle is thus unnecessary. Avoid obvious superficial blood vessels.

Step 6. If a steroid injection is to be given after aspiration, all the fluid should not be aspirated, in order to keep the joint space open and keep the needle in place for injection of the steroid.

Step 7. Patients are allowed to walk from the office, but need to limit activities for the first 24 hours.

Alternative approaches

- **Medial retropatellar approach**: An 18-ga needle is inserted at the midpoint or superior portion of the patella approximately 1 cm medial to the anteromedial patellar edge just proximal to the joint space between the femur and tibia[16].
- **Lateral approach**. The knee can also be entered anterolaterally. However, the space between the patella and the femoral surface is considerably narrower on the lateral side. For the lateral approach, palpate the superior lateral aspect of the patella and insert the needle 1cm superior and lateral to this point [17].
    - Apply gentle pressure on the contralateral side to pool the fluid in the area of aspiration.

- Direct the needle under the patella at a 45° angle to the midjoint area[12].
- If in doubt, examine the opposite unaffected joint to understand the optimal entry site[2].
- One hand can be placed on the medial aspect of the patella slightly displacing the patella laterally and therefore increasing the gap between the patella and femur on the lateral side[10].
- Zuckerman *et al* [12] strongly prefers a lateral approach because it avoids injury to the saphenous nerve. Placement of the needle through muscle is also not necessary for this may cause bleeding. Pfenninger[17] also favors the lateral approach for easier access.

Brown's approach [4]:

- Another method for arthrocentesis is described by Brown[4] in the flexed knee. The needle is directed in the midline through the patellar tendon, ½ inch distal to the lower pole of the patella, through the fat pad and onto the intercondylar notch.

Posterior approach:

- A posterior approach is never advisable, due to the popliteal vessels and nerve posterior to the knee joint.

- **Suprapatellar approach:** The needle can be introduced into the suprapatellar bursa superior and just lateral to the patella in the presence of a very large effusion[10]. The needle is introduced above and to the lateral side of the patella. Aiming down and medially procede with the needle under the posterolateral aspect of the patella. Aspirate as the needle is advanced. The free hand is used to tip the patella laterally and apply pressure on the suprapatellar pouch.

- **Infrapatellar approach:** This approach should rather be avoided according to Zuckerman *et al* [12] because of the close relation to the patellar fat pad, which if injected may result in fat necrosis.

4. Materials

- 18 or 20-21 ga needle
- 20cc syringe
- Drapes
- Aseptic solution and gauze.
- Sterile gloves

5. Anatomical pitfalls

5.1 Diagnosis of knee effusion

The following are physical signs of a knee joint effusion:

- The hollows alongside the kneecap disappear, and a suprapatellar bulge may appear.
- Patellar tap. This is performed by ballottment of the patella on the joint. The left hand performs pressure from the suprapatellar bursa, while the right index and middle fingers tap the patella against the underlying femur. The knee should be in extension.
- Synovial thickening may indicate synovitis.
- Bony prominences like osteophytes appear in osteoarthritis.
- The temperature over the knee may be slightly higher than the other side.
- A small effusion is best defined by the bulge test. Fluid is stroked by the palm of the right hand from the medial side starting at the tibial condyle, upwards into the suprapatellar bursa. The left hand is placed with the thumb on the patella controlling the fluid in the suprapatellar bursa. A bulge at the medial patellar gutter, confirms a small effusion. This should be distinguished from movement of the patella or movement of soft tissues by the controlling thumb on the patella.

5.2 Surface anatomy

- The needle is inserted at the midpoint or superior position of the medial patellar edge, approximately 1 cm medial to the medial patellar edge.

5.3 Synovial joint fluid[4]

- A normal joint contains at most a few drops of synovial fluid, just enough to lubricate the articular surfaces and cartilage. There is always some joint fluid present, but only 1-2 ml may be able to be aspirated. Fluid in the normal knee averages 1 ml. The knee can easily accommodate 50-70 ml of fluid.
- Synovial fluid is basically a dialysate of plasma, to which hyaluronate is added. Synovial fluid has the function of nourishing the avascular articular cartilage and lubricating the joint surfaces[3]. The high viscosity is due to the hyaluronic acid.
- The anteromedial approach is recommended if there is little excess fluid[16]. There is more space between the patella and the femoral condyle on the medial side.

5.4 Quadriceps muscle

- A tense quadriceps tendon will greatly hinder needle placement. The reason for this is that a contracted quadriceps muscle clamps the patella down in the patellar groove.

5.5 Knee capsule[10]

- No defined complete capsule exists, but rather a thick ligamentous sheath

compromising mainly of tendons or expansions of them.

- According to Fullerton[11] the capsule of the knee joint with the ligaments, tendons and fascia form a complete investment around the joint except at those places where communications with bursae exist. This investment is very thin above the patella, only represented by a layer of synovial membrane. A septic arthritis may actually break through the synovial membrane into the fascial planes of the thigh.
- The borders of the knee capsule are:

  - Anterior: The capsule is continuous with the muscles. Tension can therefore be changed with muscle movement. The capsule is formed by fused fibres of the rectus femoris and vastus medialis and lateralis muscles, with superficial fibres crossing anterior to the patella to the ligamentum patellae. The medial and lateral retinacula attach to the anterior border of each tibial condyle. Expansions of the iliotibial tract descend over the anterolateral aspect of the knee joint to the lateral tibial condyle.

  - Posterior: True capsular fibres are found posteriorly, attaching inferior to the proximal part of the tibia and superior to the condyles on the femur. It is strengthened by the oblique popliteal ligament and the arcuate popliteal ligament.

  - Medial: True capsular fibres arise from the medial collateral ligament. They are strengthened by the expansions of the semimembranosus tendon, which also attaches to the medial meniscus and the medial proximal part of the tibia.

  - Lateral: The lateral capsule is separated from the lateral collateral ligament and strengthened by fascia from the fascia lata .The tendon of the popliteus muscle lies between the capsule and the lateral collateral ligament.

5.6 Synovial membrane

- The synovial membrane is attached to the articular cartilage margin over the femur and tibia. The joint cavity is large and communicates with the suprapatellar bursa[1].

- The synovial membrane is the largest and most complex in the body. A large surface is exposed to potential bacterial toxin absorption, should infection occur[11].
- The synovial membrane has diverticulae, folds, recesses and communications with bursae. This makes it very difficult to drain thoroughly.

- The synovial membrane involves the suprapatellar bursa as well as an extension along the course of the popliteus muscle tendon between the lateral collateral ligament and lateral meniscus of the knee joint.

- The cruciate ligaments form a septum, dividing the synovial pouch in the intercondylar notch. The cruciate ligaments are therefore outside the knee joint.

5.7 Bursae[1]

- **Suprapatellar bursa:**
  - The suprapatellar bursa extends under the quadriceps muscle for a distance of about 7 cm above the superior border of the patella. This upward protrusion also extends considerably on the lateral sides.
  - A knee effusion is first evident as a loss of the medial and lateral dimples around the patella. A large effusion presents like a horseshoe swelling of the suprapatellar bursa and to either side of the patella. Fluid may also collect predominantly posteriorly as a popliteal cyst, which should not be aspirated.

- **Infrapatellar bursa:**
  - The infrapatellar bursa has a superficial and deep part. The superficial part is most commonly involved during infrapatellar bursitis (clergyman's knee). The deep infrapatellar bursa is posterior to the patellar tendon and anterior to the tibial tuberosity.

  - Confusion exists on the position of the deep infrapatellar bursa. LaPrade[5] in a cadaver based study (n=50), demonstrated that the deep infrapatellar bursa has a consistent anatomic location. The bursa is located directly posterior to the distal third of the patellar tendon, just proximal to its insertion on the tibial tuberosity. No communication was shown with the knee joint in this study. The bursa was found to be partly compartmentalized, with a portion of the retropatellar fat pad dividing the bursa in an anterior and posterior compartment. Doherty *et al* [10] also states that the deep infrapatellar bursa is separated from the knee joint synovium by a fad pad. Fullerton[11] confirmed this already in 1916 by stating that the bursa between the patellar tendon and the tibial tuberosity, should not be confused with the actual knee joint. There is no communication.

  - LaPrade[5] suggests a recommended route to the deep infrapatellar bursa along the lateral edge of the patellar tendon just proximal to the tibial tubercle.

  - Injection for clergyman's knee (infrapatellar bursitis): The injection is made directly into the inflamed area, introducing the needle from the medial side and directing it anterior to the patellar tendon into the superficial part of the infrapatellar bursa which is commonly involved during infrapatellar bursitis.

- **Prepatellar bursa:**
  - Prepatellar (housemaids knee) and infrapatellar bursitis (clergyman's knee), occur due to recurrent pressure or trauma during kneeling. It is not the same as an

effusion of the knee joint. The prepatellar bursa does not communicate with the knee joint. It is present in 90% of people, is subcutaneous and covers the lower half of the patella and the superior half of the patellar tendon[10].

- Injection for housemaid's knee: One should make sure that the patellar tap sign is absent, showing that the fluid is outside of the joint. The injection is made directly in the area, anterior to the patella.

- **Popliteus bursa:**
  - This bursa is found around the popliteus tendon intra-articularly.
- **Anserine bursa**
  - This bursa is found under the anserine pes.
- **Semimembranosus bursa**
  - This bursa is found between the head of gastrocnemius and semimembranosus. When communicating with the knee joint it is referred to as a Baker's or popliteal cyst. This may rupture presenting with sudden upper calf pain. It is important to distinguish this from deep vein thrombosis by means of a venogramv [8].

5.8 Cruciate ligamanents[10]

- The anterior cruciate ligament originates anterior on the intercondylar area of the tibia, to insert posterior on the medial surface of the lateral condyle of the femur. It prevents anterior displacement of the tibia, as well as hyperextension.

- The posterior cruciate ligament originates posterior on the intercondylar area of the tibia, to insert anterior on the lateral surface of the medial condyle of the femur. It prevents posterior displacement of the tibia, as well as hyperflexion.

- The anterior drawer test is used to test for integrity of these ligaments. With the knee in 90° flexion, the examiner pulls the leg forward with both hands. The anterior cruciate ligament prevents backward displacement of the femur on the tibial plateau. The anterior cruciate ligament is tested in the neutral position. Anterior drawer movement in the neutral position is called the anterior drawer sign and reflects a torn anterior cruciate ligament. The tibia slides forward on the femur when pulling the tibia.

- The posterior drawer test is used when a posterior cruciate tear is suspected. Compare the two knees in a 90°-flexion position to see if there is posterior subluxation of the tibia. If there is subluxation, the anterior drawer test will correct this position. This is therefore called the posterior drawer sign.

- A hemarthrosis may point to a cruciate ligament injury, frequently involving concomitant meniscal tears in up to 70% as seen on MRI[13].

5.9 Cutaneous nerves

- The knee joint is supplied by various nerves, including branches of the femoral nerve, common fibular nerve, tibial nerve and obturator nerve[10].

- The saphenous nerve may be injured when using a medial approach[12]. The saphenous nerve is a branch of the femoral nerve running in relation to the great saphenous vein on the medial side of the knee joint.

5.10 Patella

- Various abnormalities of the patella exist, which may influence the surface anatomy for needle placement:

    - Patella alta – a high and small patella.
    - Patella baja – a low patella.
    - Bipartite patella – a small gap in the patella is present. It is usually bilateral.
    - A patellar plica (synovial fold) may be present especially on the medial side[6].

5.11 Joint cavity

- The joint cavity extends beyond the articular ends of the bones into numerous extensions of the synovial membrane[11]. One extension, the suprapatellar bursa extends under the quadriceps muscle for a distance of about 7cm above the superior border of the patella. This upward protrusion also extends considerably on the lateral sides. Therefore, a penetrating wound involving the distal third of the circumference of the thigh within 7cm of the patella, would almost undoubtedly involve the knee joint. This is also the reason why the joint can be aspirated from this level.

- There are rare cases where the suprapatellar bursa does not communicate with the knee joint cavity.

- Fullerton[11] refers to the opening of the suprapatellar bursa and the knee joint cavity. Apparently this opening is quite small.

- The communication of the suprapatellar bursa with the knee joint is confirmed on MRI of knees with effusions[14]. Effusions appeared to be present within the suprapatellar bursa, intercondylar notch and posterior recesses. MRI cannot distinguish between hemorrhagic and non-hemorrhagic effusions.

6. Complications (anatomically relevant)

Complications of knee joint aspiration (arthrocentesis) are rare[3].

6.1 Unproductive arthrocentesis

- Although an arthrocentesis is a relatively straightforward procedure performed in the office setting, failed taps are relatively common due to multiple causes as reported by Roberts *et al* [7]. The authors demonstrate these causes by means of MRI:

1. There may simply be no effusion at all, provided that the needle moves freely into the joint space.

2. Especially in obese patients, but even in patients of average weight, a small triangular fat pad at the medial aspect of the patella, may be confused with an effusion.

3. A chronically inflamed synovium may undergo fat replacement and thickening. This condition is referred to as lipoma arborescens[9]. This is a rare intra-articular condition with villous lipomatous proliferation of the synovium in the knee joint, especially the suprapatellar bursa. This can easily obstruct the needle during a knee joint aspiration.

4. The presence of a medial plica (e.g. patellar plica) [6] acting like a valve may obstruct the lumen of the needle. Owen[8] also explains failure to aspirate fluid from the knee by this mechanism.

   Several folds, pleats, bands or shelves of synovial membrane may exist in the knee joint. The term plica is used to describe some of these remnants of synovial tissue development. During development of the knee, the lateral and medial compartments as well as the suprapatellar bursa of the knee are separated by thin membranes[6]. These membranes later involute and the knee becomes a single cavity. A plica is a remnant of embryonic synovial septum that persists, and has an incidence of approximately 20% in the general population.
   They are classified to be infrapatellar, suprapatellar and mediopatellar (in order of frequency), depending on the membrane from which they come.
   The suprapatellar plica rarely completely divides the suprapatellar bursa from the rest of the knee joint, but leaves an opening of variable diameter. The medial suprapatellar plica is the most common plica, extending to the medial wall of the joint.
   The mediopatellar plica also lies along the medial wall of the joint.
   The infrapatellar plica stretches from the intercondylar notch to the infrapatellar fat pad, sweeping through the anterior part of the joint space.
   All these plicae may block the needle during aspiration of the knee joint[6].

5. Highly viscous fluid may be difficult or impossible to aspirate through relatively small needles. It may actually be impossible to obtain any fluid from either the medial or lateral side. A maneuver to overcome this may be to ask a second operator to

compress the fluid from three sides of the knee. If the lateral approach is used, this means applying pressure from the medial, inferior and superior sides with both hands[7].

6. Obstruction of the needle lumen by particles in the synovial fluid, especially seen in a rheumatoid effusion.

7. Leversee[16] reports that normal synovial membrane may block the withdrawal of fluid. This can be overcome by twisting the needle, reaspirating or by injecting some fluid back into the joint to clear the needle.

6.2 Unsuccessful entrance to the knee joint:

- Unsuccessful aspiration from the medial side, should be followed by a lateral approach. Roberts *et al* [7] concludes that although surface anatomy markings make a medial approach easier, the lateral approach is more likely to produce fluid in difficult aspirations. This finding is based on the fact that more free synovial fluid was imaged on the lateral side on MRI studies[7]. They therefore recommend the use of the lateral approach for training purposes.

- The knee may be impossible to enter from both medial and lateral sides due to a flexion deformity, large osteophytes, or patellar ankylosis. In these cases, the needle may be placed between the condyles of the femur adjacent to the patellar tendon[2].

- The knee may also be entered with the knee in flexion. This is particularly useful if the patient is confined to a wheelchair. The point of entry is below the lower border of the patella, above the tibia and just lateral (or medial) to the patellar tendon.

6.3 Infection

- Skin bacteria may be introduced into the joint space during the procedure. The possibility of initiating such an infection is enhanced when the overlying skin is not properly cleaned and when sterile technique is not adhered to[2].

6.4 Injection of drugs into a vein or artery

- This should be prevented by aspirating before injecting.

6.5 Tendon rupture

- This complication usually occurs after multiple injections. To reduce the possibility of tendon rupture, injection should never be given intratendinuosly. No ligaments are in danger when the recommended route of needle insertion is adhered to. The anterior approach in the flexed knee may however injure the anterior cruciate ligament.

6.6 Damage to articular cartilage

- Damage to the articular cartilage may be avoided by careful aspiration and needle advancement. Too deep advancement may possibly damage the articular cartilage[10].

6.7 Marked discomfort

- Marked discomfort is experienced when the needle hits periosteum.

6.8 Obstruction of fluid flow

- If the flow of fluid becomes intermittent or stops, this may be due to:
    - Obstruction by synovial membrane.
    - Blockage by fibrin or debris.
    - Displacement of the needle outside the joint cavity.

- If the fluid stops flowing, one can squeeze the soft tissue area around the suprapatellar region to further empty the suprapatellar bursa of fluid.

- A small amount of fluid can be injected back in the joint to clear the needle. If this does not help, the needle should be withdrawn and placed again.

6.9 Complications associated with steroid injections

- Soft tissue atrophy, periarticular calcification and tendon rupture have all been associated with steroid injection.
- Long term effects include osteonecrosis and ligamentous laxity resulting in joint instability[12].
- The joint should therefore not be injected more than three times in one year. However, there is no evidence base for this frequency rate.

6.10 Post aspiration care

- Temporarily support with tubigrip of the quadriceps muscles is necessary after a knee joint aspiration as well as exercises to prevent wasting of the quadriceps muscles.

6.11 Bleeding

- Bleeding is a very rare complication except in patients with a bleeding diathesis.

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4.4.3 Surgical procedures

4.4.3.1 Cesarean section

1. Indications

In labor:

- Fetal or maternal distress.
- Prolongation of the first stage of labor – usually due to a combination of factors like arrested cervical dilatation due to malpositioning of the fetal head, excessive soft tissue resistance and minor degrees of disproportion.
- Cephalopelvic disproportion after a trial of labor.

Not in labor:

- Fulminating pre-eclampsia.
- Placenta praevia.
- Malpositions and malpresentations of the child.
- Breech presentation.
- Failed induction.
- Failed instrumental delivery.
- Prolapsed cord.
- Abruptio placentae.
- Previous repair of a vesicovaginal fistula or prolapse.
- Previous classical cesarean section.
- Previous uterine injury or surgery such as hysterotomy and myomectomy.
- To minimize the hypoxia associated with labor and the trauma of delivery to the fetus, as in the case of a premature fetus, especially when presenting as a breech or one affected by growth retardation.
- Cardiac disease – indicated in cases of uncorrected aortic coarctation.
- Previous vaginal surgery.
- Pelvic tumors.
- Cervical carcinoma.
- Active maternal genital herpes simplex virus.
- Fetal trombocytopenia.
- Fetal macrosomia.

2. Contraindications

- Lack of practitioner training [13].

3. Step by step procedure

Lower segment cesarean section

Step 1. Preparation

- Place a urinary bladder catheter.
- Clean and paint the whole abdomen, perineum and upper thighs with antiseptic solution (povidone-iodine, chlorhexidine or hexachlorophene) and drape in a standard way.
- A large bore intravenous line should be in place
- Type specific blood should be available as well as a recent hemoglobin level.

Step 2. Position

- Position the patient in a left lateral tilt and slight Trendelenburg position (5°). This maneuver ensures that the gravid uterus does not press on the inferior vena cava[26] and partially on the abdominal aorta and therefore cause a fall in cardiac output and placental perfusion[25, 27]. This is known as the supine hypotensive syndrome.

Step 3. Anterior abdominal wall incision

a) Midline:

- Indications for midline incision: Acute fetal distress, prolapsed cord, hypovolemic shock, prior midline incision and obesity.

- Perform a vertical midline incision extending 2.5 cm below the umbilicus to the upper border of the symphysis pubis. It should not extend over the symphysis pubis, for this will result in a tender scar.

- Coagulate or ligate bleeders from the superficial epigastric vessels.

- Open the rectus sheath through the line alba.

- Open the peritoneum in the upper third of the incision. This avoids injuring the bladder, which may be at a higher position than expected due to the gravid uterus.
- The peritoneum should be grasped with a nontoothed forceps or hemostat and inspected and palpated to exclude the presence of bowel or bladder.

- In obese patients, with thick preperitoneal fat, identification of the obliterated urachus (median umbilical ligament and fold) will help to identify the peritoneum.

Disadvantages:

- The midline incision may be associated with a bad scar.
- The incidence of wound dehiscence is higher.

b) Pfannenstiel incision[15]:

- The skin incision is made following a semilunar natural skin line. The average incision begins and ends 2-3 cm below and medial to the anterior superior iliac spines. The incision is made two fingerbreadths above the symphysis pubis.

- Incise through the fatty (Camper) and membranous (Scarpa) layers of the superficial fascia, as well as the anterior rectus sheath.

- Dissect the anterior rectus sheath off the underlying rectus muscle superiorly for approximately 8 cm and inferiorly to the level of the symphysis pubis.

- Care must be taken to coagulate and ligate bleeders from the superficial epigastric vessels.

- Separate the muscle bellies in the midline with simple finger dissection.

- Incise the peritoneum vertically with scissors to gain access to the peritoneal cavity. Be careful not to injure bowel, omentum or bladder.

Disadvantages[16]

- A Pfannenstiel incision may be too slow for an emergency section. This is due to the subaponeurotic dissection of the rectus sheath taking time.
- Postoperative hematoma is not uncommon and the space is usually drained.
- A Pfannenstiel incision does not strictly follow Langer's lines. It may result in guttering when the patient stands.

Step 4. Packing

- Use two large taped gauze swabs to pack the lateral recesses of the wound and attach the tapes each to an artery forceps. No free swabs should be used.

Step 5. Detect uterine torsion

- Identify the round ligaments of the uterus and identify any rotation of the uterus.

Dextrorotation is commonly found. It is important to correct rotation to avoid incision into the large vessels near the base of the broad ligament, which will result in vigorous bleeding.

- Identify the uterine vessels, by feeling for the round ligament, which is situated anteriorly near the superior portion of each side of the uterus.

Step 6. Incising the visceral peritoneum overlying the lower segment of the uterus and pushing the bladder down

- Identify the vesico-uterine reflection.

- Lift the loose peritoneum over the lower segment of the uterus with a dissecting forceps, assisted by using the Doyen retractor, which can be moved from side to side.

- Strip the lower peritoneal flap downward with the bladder for about 5 cm. This maneuver results in the development of a potential space between the bladder and the lower uterine segment and the creation of a bladder flap.

- Be careful in a patient who had a previous cesarean section, due to the adhesion that may be present. The risk of injuring the bladder is higher.

Step 7. Opening the uterus

- Confirm the lie and presentation of the infant before opening the uterus.

- Confirm the lower segment of the uterus by palpation and identify the area where the incision is to be made. This should be done in the lower segment of the uterus over the head of the infant at its widest possible diameter.

- With the scalpel, cut a small transverse incision of about 2cm in the midline into the uterine muscle. Cut down to the amniotic membrane until it bulges in the wound.

- Be careful to avoid too low an incision which may result in bladder injury. A too low incision will be very short due to the downward converging lateral walls of the uterus. There is also a danger of tearing into the broad ligament causing vigorous bleeding.

- Any bleeding venous sinus should be controlled by applying a Green Armytage spring clamp.

- Extend the incision laterally to both sides with curved scissors. Use the index and middle fingers of the opposite hand to lift the uterine wall while using the scissors to avoid cutting the child's ear, which may be just below. A 10-12 cm incision for a term baby is required. The incision is curvilinear, extending upward at the edges to prevent tearing into the broad ligament and ureteral injury.

- If required, one of the lateral edges can be elongated superiorly to form a J incision. A T-incision should not be made for it heals poorly.

- The incision may also finally be enlarged by inserting the index fingers into the incision and stretching the incision from side to side. The whole width of the uterine incision should however not be made by crude tearing of the uterine wall, which will result in uncontrolled tearing with possible uterine vessel laceration[31] and inaccurate repair of the uterine wall.

- Vertical uterine incisions should be avoided, because of the associated incidence of uterine rupture in following pregnancies as well as iatrogenic premature delivery.

- Be careful not to incise the infant. Continuous suction of the incision is essential to clear the field of blood for safe incision.

- Open the amniotic membranes if they have not already ruptured and administer continuous suction to clear the field of blood and amniotic fluid.

Step 8. Extracting the fetus and placenta

a) Head presenting:

- Insert the hand between the anterior uterine wall and head of the infant and elevate the head into the incision. This will cause flexion of the head and therefore a smaller diameter going through the uterine incision.

- Make sure the occiput and not the sinciput is lifted towards the incision.

- If the head is deeply engaged in the pelvis, an assistant is asked to lift the head vaginally.

- As the occiput is in the incision, the assistant should apply fundal pressure to deliver the head.

- From this point the delivery continues as with a normal vaginal delivery.

- Hook the finger in the nearest axilla and deliver the shoulder and arm. Repeat the same on the other side.

- Completely extract the infant and clamp the cord.

- Suction the nasal and oral passages after delivery of the head.

- Apply fundal pressure to deliver the rest of the body.

- Doubly clamp the cord.

- Use of forceps:

    - o Hook the chin forward and apply the obstetric forceps, with the pelvic curve of the blades facing towards the symphysis pubis.
    - o Dislodge the head from the uterus by gentle rocking movements.

- Administer ergometrine intravenously to reduce the amount of bleeding, from the uterine incision as bleeding may start after the stretching of the uterine muscle is eased.
- Remove the placenta by traction on the cord, or by manually shearing it from its uterine attachment if necessary. Remove all the membranes, and vernix caseosa. Clean the inside of the uterus with a towel to remove remnants of the membranes.

b) Breech presenting:

- Delivery is done according to the normal breech extraction procedure.

Step 9. Application of Green Armytage clamps

- Control bleeders with the Green Armytage clamps. Apply them to the lateral angles of the uterine incision and lower margin of the incision.
  This margin may retract and make identification difficult in the presence of a pool of blood. The lower margin can be identified in these circumstances by slipping a finger from a lateral angle of the incision to get hold of the lower margin of the uterine wall incision.

- With serious bleeding from a lateral angle of the wound, lift the lateral part of the uterus with two fingers behind the broad ligament. This makes the site of the vessels easier to visualize and compresses the vasculature for clamping.

Step 10. Stitching the uterus

- The uterus can be left in situ or delivered onto the anterior abdominal wall of the mother for better exposure. When returning the uterus into the abdominal cavity, the uterus should be inspected for bleeding from the uterine vessels which may have kinked temporarily while the uterus was outside the abdominal cavity[40].

- The uterus is closed in two layers of continuous running sutures.

- First place a figure of eight stitch in each corner of the uterine incision.

- Use chromic 1.0 catgut with a round-bodied needle. A cutting needle should not be used for it can cut the deeper layer that has already been inserted.

- Insert the first stitch in the lateral angle of the uterine incision on the far side of the surgeon. Space the stitches so that they control the bleeding sinuses that were clamped by the Green Armytage clamps.

- Take care not to injure the bladder.

- The upper edge is usually much thicker and the unstitched part will be sutured during the second layer. Keep a firm pull on the suturing material when suturing this layer. Insert the suture in a slightly oblique direction.

- Stitch the second row by picking up all the unstitched muscle on the upper edge of the uterus and shut the inner row of sutures. When completed, tie the second catgut to the free end of the first catgut strand.

- Further spots where blood oozes may be stitched with finer catgut by taking one transverse bite below the bleeder and one above the bleeder in a Z-shaped stitch.

- The uterine stitches should be put in more firmly than usually. The reason for this is the fact that the uterus involutes quickly with subsequent loosening of the sutures within hours after the operation.

Step 10. Closing the abdomen

- Both the visceral and parietal peritoneum can be left unsutured[18]. Hull *et al* [41] has demonstrated reduced need for postoperative analgesia and faster return of bowel function when both peritoneal layers are left unsutured. Leaving the peritoneal layers unsutured also significantly reduces operating time. Peritoneal defects demonstrate indistinguishable healing with no scar by 5 days[19].

- Make sure all free blood and clots are removed, the packs are removed and all instruments counted.

- Inspect the uterine tubes and ovaries for pathology and make sure the paracolic gutters and recto-uterine pouch is clean.

- Close the abdomen in three layers, suturing the rectus sheath separately with a continuous suture, as well as the superficial fascia and fat and finally the skin.

- Insert a subcutaneous suction drain in cases where adequate hemostasis was

not established especially in the case of a Pfannenstiel incision.

Alternative: Misgav Ladach method[16]

- This method uses the Joel-Cohen incision of the abdominal wall and follows the principle of surgical minimalism. Manual manipulation is used where possible instead of surgical instruments to injure the tissues as little as possible.

Method

1. Make a horizontal 17 cm incision through the skin, 3 cm below the line on the plane of the anterior superior iliac spines.
2. Deepen the incision in the midline through the fat to the rectus sheath in a short transverse cut of 2-3 cm. Do not free any subcutaneous tissue. This means the subcutaneous blood vessels and nerves stay intact and the midline is virtually bloodless.
3. Make a small transverse incision in the sheath.
4. Enlarge the transverse incision of the sheath underneath the subcutaneous tissue by sliding scissors (one blade under the cut sheath and one above).
   The incision is above the level of pyramidalis, therefore the rectus muscle moves freely over the fascia.
5. Separate the fascial borders and the rectus muscle by pulling caudally and cranially using two fingers.
6. Pull the rectus muscles apart. This is done by both surgeon and assistant inserting their index and middle fingers in the midline between the muscles and then pulling with balanced increasing force to make a big enough opening. This displaces the vessels and nerves under the subcutaneous tissue.
7. Stretch the parietal peritoneum with the index finger and enlarge the hole with the fingers in a caudal and cranial direction. Enlargement in a caudal and cranial direction causes the peritoneum to open transversely saving the bladder from injury. By using the fingers there is less danger of injuring the bowel.
8. Identify the lower segment of the uterus and the superior border of the bladder.
9. Make a transverse incision over the visceral peritoneum 1 cm above the bladder with a scalpel. Avoid blood vessels and go far enough to the lateral side using a retractor for the bladder to give better visibility.
10. Push the visceral peritoneum and bladder down.
11. Make a small transverse incision in the lower uterine segment using a scalpel or finger.
12. Stretch the hole to either side using thumb to steady and the left index to separate the uterine fibers. Open more to the right than the left for the uterus is usually rotated to the right in late pregnancy
13. Place two fingers below the head. The assistant applies fundal pressure while the fingers guide the head through the uterine opening.
14. Manually deliver the placenta. Give 10 units oxytocin or 0.5 mg ergometrine. Manual removal makes the third stage quicker and prevents unnecessary bleeding.
15. Bring the uterus out of the abdominal wound and massage manually to stimulate

contraction to minimize bleeding.

16. Clean the inside of the uterus with a towel to remove remnants of the membranes.
17. Grasp the center of the caudal part of the uterine cut with a Green Armytage forceps and repair the uterine wall with a one layer continuous locked stitch. Start at the edge of the cut nearest to you and use long length chromic catgut. Take large enough bites from the upper and lower edge to secure hemostasis. Take care to stay away from the bladder when taking bites from the lower edge. Sometimes a second layer may be necessary or a cross-stitch for a bleeder. One layer suturing is quicker to perform and healing is better with fewer sacculations. Stitching of the uterus is only for hemostasis and not so much for mechanical strength, because with retraction the sutures loosen within hours after the operation.
18. Check for proper hemostasis.
19. Remove clots in the abdomen, but do not put packs in the intraperitoneal cavity for mopping. Minimal interference with the bowel is necessary for early alimentation.
20. Visceral and parietal peritoneum can be left unstitched. This prevents adhesion formation. A new peritoneum will form. Stitching of the peritoneum leads to ischemia stimulating a repair response with adhesions.
21. Identify the rectus sheath and fascia at both corners and at the lower and upper cut edges. Start stitching at the end nearest to you from the inside in to the outside out to bury the knot inside the fascia. Use a continuous stitch (Vicryl 1.0).
22. Close the skin with mattress sutures and pinch the skin edges together with non-toothed forceps for 5-10 minutes.
23. Start oral fluids immediately and get the patient out of bed as soon as possible after the anesthetic has worn off.

Advantages[17]:

- Darj *et al* [17] showed in a prospective randomized trial, that the Misgav Ladach method compares as follows with the Pfannenstiel method:
  - Operating time was significantly less with the Misgav Ladach method (12.5 minutes compared to 26 minutes with the Pfannenstiel method).
  - The amount of blood loss was significantly less in the Misgav Ladach method (448 ml compared to 608 ml of the Pfannenstiel method).
  - Significantly less analgesic was needed after the Misgav Ladach method.

- Less traumatic for the mother and the mother has quicker postoperative recovery.
- Less febrile reactions.
- Shorter period before bowel function reappears. No use of bowel packs or towels in the peritoneal cavity is important for quicker recovery of bowel function[22].
- Fewer peritoneal adhesions and less scarring.
- It causes less bleeding in the abdominal wall.
- Can be used for an emergency section as well.
- Because the incision is higher than the Pfannenstiel incision, no subaponeurotic dissection is necessary and therefore less bleeding[21]. The incision heals better than a midline vertical incision because it is horizontal. There is also less risk of

herniation[20].

- The subcutaneous tissue is not disrupted except in the midline[16]. Hemostasis, electro-coagulation or tying off of blood vessels with resultant localized ischemia is not necessary. This also decreases the risk of infection.
- There is less risk of keloid formation[16], a complication with specific relevance in Africa.
- Amniotic fluid left behind in the peritoneal cavity brings no risks and is actually bacteriostatic[23].

4. Materials

- Laparotomy tray
- Doyen universal retractor
- Green-Armytage spring clamps
- Suction

5. Anatomical pitfalls

5.1 Embryology

- The female genital tract is formed by the paired Mullerian ducts (paramesonephric ducts). The caudal ends usually fuse to form the uterus and the rostral part descends to become the uterine tubes. Fusion may fail to happen, which may result in two separate hemi-uteri. A bicornuate uterus is more common. A notch forms in the rostral part with a septum protruding into the lumen of the uterus. Spencer[56] reports a case where a child's head was wedged into a horn of a bicornuate uterus with a pressure wound forming in the neck due to the septum.

5.2 Anterior abdominal wall

5.2.1 Subcutaneous tissues

- Johnson *et al* [12] describes the subcutaneous fascia in a study performed with CT and MRI on 20 patients as follows: There is a circumferential subcutaneous fascial plane dividing the subcutaneous fat into a single superficial fat compartment and a single deep fat compartment. The superficial fat compartment remains relatively constant in thickness, but the deep compartment varies in thickness, being thickest in the lumbar region and thinnest laterally. The subcutaneous fascia passes superficial to the linea alba, without fusing with it.

5.2.2 Anterior abdominal wall muscles:

- **External abdominal oblique muscle**: This muscle runs in an oblique medial and inferior course and forms part of the anterior rectus sheath around the rectus abdominis muscle.

- **Internal abdominal oblique muscle**: This muscle runs in an oblique medial and superior course and forms part of the anterior and posterior rectus sheath around the rectus abdominis muscle except in its lower part where it lies anterior to the rectus abdominis muscle.

- **Transversus abdominis:** This muscle runs in a transverse course and contributes to the posterior rectus sheath above a point midway between the umbilicus and pubis (arcuate line). Below this point the muscle contributes to the anterior rectus sheath. The lower limit of the transverse abdominis fascia forming part of the posterior rectus sheath is therefore called the arcuate line. Below this line, the posterior rectus sheath is absent and the transversalis fascia, extraperitoneal fat and parietal peritoneum form the posterior relations of the rectus abdominis muscle.

- **Rectus abdominis:** This muscle attaches on the pubic crest inferiorly and superior on the thoracic cage. It has three to four fibrous insertions, one at the level of the umbilicus, one midway between the umbilicus and the upper insertion and the third midway between the umbilicus and the lower insertion on the pubic crest. The fibrous insertions are attached to the anterior rectus sheath, which limits its retraction.

5.2.3 Blood supply of the anterior abdominal wall

- The abdominal wall is supplied by the superior and inferior epigastric arteries for most of its medial part and the lateral part by the musculophrenic and deep circumflex iliac arteries.

- There is a rich collateral circulation.

- The superior epigastric artery is a branch of the internal thoracic artery. It descends posterior to the midportion of the rectus abdominis muscle, and anastomosis with the inferior epigastric artery.

- The inferior epigastric artery branches from the external iliac artery at the midinguinal point and runs superiorly along the postero-lateral portion of the rectus abdominis muscle. The artery runs medially towards the midline and forms the lateral border of the inguinal triangle (Hesselbach's triangle).
  It is unlikely to be damaged during a Pfannenstiel incision. The epigastric vessels are at risk during rectus abdominis splitting incisions, which are not advised for cesarean section.

- The deep circumflex iliac artery branches form the external iliac artery at the same point as the inferior epigastric artery and courses behind the inguinal ligament along the iliac crest to anastomose with the musculophrenic artery from above.

- The musculophrenic and deep circumflex iliac arteries can be injured if a transverse

incision is extended too far laterally.

5.2.4 Linea alba

- The linea alba is the insertion point of the fasciae of all three anterior abdominal muscles in the midline.

- The linea alba is relatively bloodless therefore wound healing in the midline is associated with more scar tissue formation.

5.2.5 Nerve supply of the anterior abdominal wall

- The anterior abdominal wall is supplied by the seventh to eleventh intercostal nerves, the subcostal nerve and the iliohypogastric and ilioinguinal nerves (both from L1).

- The nerves run in the plane between the internal abdominal oblique and transversus abdominis muscles and supply all the anterior abdominal wall muscles.

- The nerves enter the rectus sheath, run posterior to the rectus abdominis muscle and more or less at the midpoint of the muscle pass anteriorly through the muscle to supply the muscle and the overlying skin.

- A vertical incision lateral to the midline either lateral to the rectus abdominis muscle or through the muscle will injure the nerves and denervate the structures medial to the incision. The result is atrophy of the rectus abdominis muscle at that level with a greater risk of hernia formation.

5.3 Lower segment of the uterus

- The lower segment of the uterus progressively increases in width and length as pregnancy advances. It also decreases in thickness. The lower segment is found posterior to the bladder. The bladder should therefore be pushed downward to expose the lower segment for incision.

- Kerr[50] describes the advantages of the lower segment incision of the uterus in anatomical terms:
    - The wall of the uterus is thin in this area, especially if labor has been in progress for some time. It is often not more than 5 mm in thickness.
    - The uterine wall consist of fibromuscular tissue with the fibrous tissue being much more abundant.
    - The lower segment is less vascular.
    - As there is less bleeding the uterine wound surfaces can be more accurately approximated.
    - The effects of retraction are less active in this segment compared to the superior segment.
    - The wound is covered with bladder and peritoneum and is therefore

extraperitoneal. This limits adhesion formation.

- The wound in the lower segment is not stretched during a subsequent pregnancy and the risk of uterine rupture is much lower than a classical vertical midline incision of the uterus. Uterine rupture does however occur during prolonged labor.

- The myometrium in the fundus consist of 65-70% of smooth muscle and only 25% in the upper cervical segment[47]. Connective tissue increases proportionately toward the cervix. The cervix consists of about 80% collagenous tissue[48].

5.4 Position of the uterus

- The uterus is frequently dextrorotated, which result in a midline position of the left round ligament as well as anteromedial movement of the base of the broad ligament with the large vessels on the left and the left ureter lying anteriorly.

5.5 Peritoneum

- Both the visceral and parietal peritoneum should be left unsutured to reduce the risk of adhesions and to save time. The peritoneum soon heals by forming a new peritoneal layer [18, 19].

5.6 Bladder and ureters [14, 42]

- As a result of the enlargement of the uterus, the bladder rises out of the pelvis and into the abdomen. Therefore the relationship of the bladder, urethra and ureters to other structures changes[52].

- In a non-pregnant patient, the ureter normally lies 1.5-2cm lateral to the cervical isthmus and passes beneath the uterine artery and then medially towards the trigone of the bladder.

- In a pregnant patient the ureter is much closer to the uterus and cervix due to the development of the lower segment of the uterus. The trigone is also elevated due to the uterine enlargement and has a convex shape instead of the normal concave shape. The ureteral orifices are therefore displaced laterally. Due to uterine dextrorotation, the left ureter is drawn anteriorly.

- These factors make the bladder and ureters more susceptible to injury during cesarean section.

- The anatomy returns to its prepregnancy position at about 6 weeks after delivery.

- Hydronephrosis and hydroureter are commonly seen during pregnancy. This may be due to mechanical obstruction by the gravid uterus and the physiological effects of progesterones and prostaglandins. Hydronephrosis and hydroureter are more

commonly found on the right. This may be explained by the dextrorotation of the gravid uterus and ureteral compression by engorged right ovarian vessels. Intravenous pyelography shows that the ureter distal to the pelvic brim is not dilated. Therefore a mechanical explanation of anatomical compression on the ureter on the level of the pelvic brim seem appropriate.

5.7 Uterine artery[49]

- The uterine artery arises from the anterior division of the internal iliac artery. It runs medially superior to the endopelvic fascia and crosses the ureter (with the ureter inferior to the artery) about 2-3 cm lateral to the uterus. It gives off an inferior branch, which anastomoses with the vaginal artery. The superior branch anastomoses with uterine branches of the ovarian artery. The uterine artery is found at the base of the broad ligament on the lateral sides of the lower segment of the uterus.

- During pregnancy the artery elongates and undergoes hypertrophy. Therefore the diameter of the lumen increases. Due to increased elastic fibers in the arterial wall it is more flexible and may vary from its normal position. The ovarian arteries on the contrary do not undergo these changes.
  The ovarian veins however become dilated to accommodate the increased circulatory load of the gravid uterus.

- O'Learly *et al* [49] describes a method to ligate the uterine arteries in the case of severe bleeding. This is easier to perform than internal iliac artery ligation, requiring less dissection.

5.8 Langer's lines[38]

- Langer's lines in the abdominal skin are almost transverse. Therefore, transverse incisions of the abdomen wall like a Pfannenstiel incision tend to be the most cosmetic.

5.9 Inferior vena cava and abdominal aorta

- Compression on the aorta will cause uterine hypoperfusion and compromises the acid-base status of the fetus. Compression or partial obstruction of the inferior vena cava may reduce venous return to the heart, causing a fall in maternal cardiac output and arterial blood pressure. This is known as the supine hypotensive syndrome.

- Positioning in the left lateral tilt position is even more important when regional anesthesia is used due to vasodilatation of the veins of the lower extremity and a further decrease in venous return to the heart. Studies showed a clinically and biochemically more favorable status of the fetus during left lateral tilt[27].

- Downing *et al* [27] measured blood flow in 20 pregnant women with strain gauge plethysmography in the supine, right tilt and left tilt positions in both the upper and

lower limbs. There was no change in the perfusion of the upper limb in all the positions. However, perfusion to the lower limb significantly increased in both the right and left tilt positions and decreased again when turning to the supine position.

- The biochemical status of the newborn is improved when the supine position is avoided during Cesarean section.

- Kerr *et al* [26] demonstrated that respiratory changes were not transmitted from the thorax to the inferior vena cava in the supine position in patients late in pregnancy. These cyclical changes were however seen in the lateral tilt position.
  He also demonstrated a high venous pressure in the inferior vena cava in the supine position. Radiological studies revealed that in 10 of the 12 cases examined there was complete obstruction of passage of contrast medium at the level of the bifurcation of the inferior vena cava. The other 2 were partially occluded. The venous return passed via the lumbar veins and veins surrounding the spinal canal to the azygos veins.

- In the lateral tilt position, some degree of compression of the inferior vena cava was seen. The compression is evenly distributed along the length of the inferior vena cava as far as the fundus of the uterus.

- Kerr[26] therefore concludes that inferior vena cava occlusion is the rule rather than the exception in the supine position. The collateral circulation via the vertebral and azygos venous systems is responsible for the venous return in the supine position.

- Obstruction of the inferior vena cava at the level of the entry of the renal veins will cause increased renal venous pressure.

5.10 Round ligament[29]

- The round ligament helps to identify the uterine vessels. It is situated on the anterior and superior portions of each side of the uterus.

6. Complications (anatomically relevant)

6.1 Incidence

- Nielsen *et al*[7] showed in a prospective study in 1984, involving 1319 patients, an 11.6% intraoperative complication rate for cesarean sections. Elective cesarean sections had a lower complication rate (4.2%) compared to emergency cesarian sections (18.9%). The most frequent complications are blood loss and infection.

- Nielsen *et al* [7] classifies complications as minor and major complications. The minor complications are: blood transfusion necessary due to bleeding, minor lacerations on the lower segment of the uterus and minor injuries to the infant such as a minor laceration of the ear. Major complications are: injury to the urinary bladder, vaginal

and cervical tears, lacerations of the corpus uteri and those into the broad ligament, bowel injury and injury to the infant with noticeable morbidity.
Nielsen found no major complications in the elective group.

6.2 Risk factors for major complications

The following are risk factors for major surgical complications during emergency cesarean sections:

- The station of the presenting part of the infant in relation to the ischial spines. The lower the presenting part the higher is the risk for complications. The complication rate in cases where the presenting part was below the plane of the ischial spines was as high as 60%.
- Labor prior to surgery.
- Low gestational age less than 32 weeks. A higher incidence of technical problems can arise in extracting the preterm infant from the uterus. The uterine wall is usually thick in these cases.
- Rupture of membranes prior to surgery.
- Previous cesarean section.
- Experience of the surgeon.

6.3 Infection [2, 7, 9]

- There is an increased risk of infection after cesarean section with rupture of the membranes .The length of membrane rupture and the length of labor prior to surgery influences the risk of infection. The longer the membranes are ruptured and the longer the patient is in labor prior to surgery, the higher the risk.

- Less experienced doctors have higher rates of postoperative infections.

- The diagnosis of endometritis is made in the presence of a body temperature of 38 degrees or higher on two successive readings at an 8-hourly interval with uterine tenderness and foul smelling lochia [8, 15].

- Wound infection is the most common complication in cesarean section with the following risk factors: Duration of ruptured membranes prior to operation, duration of labor prior to operation, anemia and obesity[8]. Wound infection is diagnosed on the basis of purulent drainage from the incision site with or without fever.

- Farrell *et al* [45] found in a series of 457 cesarean sections, that the only significant risk factor for endometritis was a primary cesarean section. The risk of a primary cesarean section developing endometritis is greater than a repeat section. Labor, rupture of membranes and the use of internal fetal-maternal monitoring were not found to be significant risk factors. They report a 23.8% incidence of endometritis.

- Prophylactic antibiotics are indicated for women with previously ruptured

membranes. Other high-risk indications for prophylactic antibiotics are: long period of labor, multiple examinations and internal fetal monitoring.

- Amniotic fluid is spilled and the subsequent wet drapes may be contaminated. Therefore it is advisable to paint the anterior aspects of the thigh with antiseptic solution.

- Abdominoperineal shaving increases the risk of infection.

- There is always a higher risk of infection from the danger of upward infection from the vagina[50].

- Ott[55] studied the factors related to postpartum infection. Internal monitoring had little effect on the development of postpartum endometritis. Postpartum anemia, increased time between rupture of membranes and delivery, and patients with a high risk (increased parity and age, early membrane rupture, medical and legal complications) have a higher incidence of postpartum endometritis.

6.4 Extension of the transverse uterine incision

- Extension of the uterine incision carries the risk of injuring structures at the base of the broad ligament like the uterine vessels and ureter. This is avoided by making a central incision into the uterine wall of about 2 cm through to the amniotic sac. Then the incision is extended laterally to both sides with scissors guided by two fingers in the uterine cavity. This is ideally done before rupture of the membranes to allow for better visualization. The extension is done laterally and slightly superiorly to avoid the lateral uterine vessels. The finger spreading technique tends to tear in an inferior direction and is therefore more likely to extend into the uterine vessels.

- Extending the incision by lateral tearing will cause a downward concave tear due to the circular muscles in the lower uterine segment that are directed downwards. There is no control over the tear at all with the risk of injuring the large parametrial veins. Attempts to control this bleeding may result in tying the ureter.
Jovanovic[31] reports such a case, as well as a case where 36 units of blood had to be transfused. Another patient had a hysterectomy to save her life.

- In the case of a low-birth weight infant or big baby from a nonlabored uterus where a large incision is necessary, Jovanovic[31] reports that it is best to make an upward curved transverse incision over the lower segment of the uterus.

6.5 Injury to blood vessels

- The fascia that covers the uterine surface should not be incised or damaged when incising the visceral peritoneum overlying the lower segment of the uterus. Vigorous bleeding may occur if this is done at a point during the operation where it should be bloodless. The peritoneum should therefore be picked up with forceps and

cut with scissors rather than using a knife against the uterine surface.

- It is important to identify any torsion of the uterus before performing the lower segment incision of the uterus. Dextrorotation is commonly found, and if not corrected, can result in extending the incision into the large blood vessels near the base of the broad ligament. This is more likely with the surgeon standing on the right side of the patient. Incising these vessels may result in vigorous bleeding.

- Injury to the uterine artery is associated with vigorous bleeding. The artery needs to be ligated in the broad ligament as well as the ovarian-uterine anastomosis just below the attachment of the ligament of the ovary.

- **Vigorous bleeding from the angles of the uterine incision.**

  The problem with this complication is limited exposure of the angles of the uterine wound.

  With serious bleeding from a lateral angle of the wound, the lateral part of the uterus should be lifted with two fingers behind the broad ligament. This makes the site of the vessels easier to visualize and compresses the vasculature for clamping. This maneuver also avoids injury to the ureters and bladder.
  Care should especially be taken during the lower segment incision that lateral extension of the incision does not occur, due to the close relation of the uterine vessels.

- **Internal iliac ligation**

  Vigorous bleeding may occur during cesarean section. Internal iliac artery ligation has been described as a method to stop the bleeding. Evans *et al* [53] reports on 18 patients where the procedure was performed. The three main collateral vessels are the iliolumbar, middle sacral-lateral sacral and superior rectal-inferior rectal arteries. However, due to the variability of the pelvic vasculature in individual patients, ligation of the internal iliac artery may have serious consequences due to insufficient collaterals. Evans[53] describes a case of pelvic and perineal ischemia in one patient. The procedure is also not effective in placenta accreta and uterine lacerations.
  A Hysterectomy is the procedure of choice in patients who are hemodynamically stable.

6.6 Complications of the Pfannenstiel incision[38]

- Dead spaces are created by the dissection of layers of fascia and muscles during this incision. Therefore more bleeding occurs. A subcutaneous drain is often necessary.

- The incision takes relatively more time to complete.

- Transverse incisions may result in nerve divisions. The iliohypogastric and

ilioinguinal nerves may be injured in a wide Pfannenstiel incision. This will result in loss of sensation over the suprapubic region (iliohypogastric nerve) and over the labia majora (ilioinguinal nerve). The ilioinguinal nerve also supplies the conjoint tendon (inferior fibers of the internal oblique and transversus abdominis muscles). This may predispose to the development of an inguinal hernia.

6.7 Injury to the bladder [15]

Eisenkop *et al* [5] reports an incidence of 0.3% of bladder injuries and 0.09% of ureteral injuries in 7527 cesarean sections.

- This is more likely to happen in patients with previous cesarean sections when the visceral peritoneum overlying the lower segment of the uterus is opened and stripped downwards. Eisenkop[5] reports that dissection of the bladder off the lower uterine segment was the most common cause of bladder injuries, especially in the presence of scar tissue from previous surgery. Meticulous sharp dissection is therefore necessary in a case of previous cesarean sections. The bladder is separated from the lower segment of the uterus to better visualize the lower segment of the uterus and to get the ureters out of the field. This should not be done too aggressively in order to avoid injury to the bladder.

- Bladder integrity can be tested intraoperatively by injecting methylene blue dye to distend the bladder and evaluate its integrity.

- With a previous cesarean section, the peritoneum should be incised close to the umbilicus in a midline incision to avoid injury to the bladder.

- A too low incision over the lower segment of the uterus, may result in the uterine muscle disappearing below the bladder. This may lead to subsequent inclusion in a suture of the bladder or even the ureters during subsequent suturing of the uterine wall.

- Extension of the uterine incision may lead into the bladder.

- The bladder can easily be injured during the suturing of the lateral angles of the uterus when the bladder was not separated properly from the lower segment of the uterus.

- The bladder should be catheterized. An empty bladder provides better exposure and decreases the risk of bladder injury.

- Signs of bladder injury: A red vascular appearance of the muscularis of the bladder, urine leaking from the dome of the bladder and a visible Foley's bulb. Hematuria may be indicative of bladder wall trauma.

- Bladder perforation should be dealt with immediately to avoid continuous

urine leakage and to avoid enlargement of the perforation. The most important prognostic indicator for morbidity is the time of recognition of the injury [5].

- Method: Apply Allis clamps on either side of the defect and inspect the trigone and ureteral orifices. Suture the bladder in two layers. First the submucosa and intermediate muscularis layers with continuous 3-0 chromic catgut. Then the rest of the muscularis and serosa with the same suture. Test the bladder integrity by gentle distention of the bladder. Adequate bladder drainage should be secured for at least 7 days.

- Urinary fistula formation should be avoided by early detection and repair of bladder injuries[7].

- Faricy *et al* [52] confirms that bladder injuries are associated with failure to empty the bladder preoperatively, inadequate bladder flap reflection and vaginal incision instead of lower uterine segment incision.

- Complications if bladder injury is not recognized during surgery include: vesicovaginal fistulae, calculi due to penetrating non-absorbable suture material and menouria due to a vesicovaginal fistula[52].

6.8 Injury to the ureters

- This is a very rare complication with a rate of 0.09% reported by Eisenkop[5].

- Ureteral obstruction, ureterovaginal fistulae and ureterouterine fistulae have been reported[51].

- The cause of ureteral injury is usually due to extension of the uterine incision laterally towards the base of the broad ligament or by hemostatic sutures that are placed at the angles of the uterine incision[5]. Ureteral injuries are associated with large infants or in cases of breech or transverse lie where difficulty is experienced during delivery.

- If a ureteral injury is suspected, a urologist should be consulted. The following procedures can be done to assess ureteral patency:
    - Intraoperative or postoperative pyelography.
    - Diagnostic cystotomy with intravenous injection of dye and direct observation of efflux of dye from the ureteral orifice.
    - Diagnostic cystotomy with passage of catheters in the ureter through the ureteral orifice.

6.9 Injury to the bowel[29]

- The bowel may be injured while entering the peritoneal cavity through the parietal peritoneum. Therefore, the peritoneum should be elevated by a non-toothed forceps

or hemostat in the superior third of the peritoneum. The peritoneum should be inspected and palpated to ensure that no bowel or omentum or even bladder is at risk of being injured when the peritoneal cavity is entered.

- More care should be taken if the patient had a previous cesarean section. The risk of adhesions of the bowel or omentum to the anterior abdominal wall is higher.

- Bowel injuries involving the bowel lumen, may lead to fecal contamination of the peritoneal cavity with resultant peritonitis and possible abscess formation.

- Bowel may be injured with the scalpel blade, clamps during surgery or with a suturing needle during abdominal wall closure.

- The risk of bowel injury is increased when the incision needs to be enlarged and when blind attempts are made to control bleeding.

- The following principle should be followed when dealing with adhesions: Gentle blunt dissection with filmy adhesions and sharp dissection with thick adhesions.

- If bowel injury is suspected, the different layers of the bowel involved should be assessed. Small bowel serosa tears may be sutured with 4-0 absorbable suture. If the muscular layer is also involved, a single layer of interrupted 4-0 nonabsorbable suture may be used, at right angles to the longitudinal direction of the bowel. If the lumen has been entered, approximate the muscular layer with interrupted 4-0 absorbable suture and the serosal layer with nonabsorbable 4-0 silk[29].

6.10 Uterine rupture after previous cesarean section.

- Merrill *et al* [1] has shown that 49% of 526 patients with a previous cesarean section delivered vaginally with low morbidity. Unfavorable factors tending to increase the risk of scar rupture are sepsis following the operation and the implantation of the placenta beneath the scar in a subsequent pregnancy.
- The clinical signs of abruptio placentae in a woman with a previous cesarean section should always raise concern about a possible uterine rupture[10].

- The diagnosis of uterine rupture may be difficult due to the fact that large amounts of blood can collect in the broad ligament and extraperitoneal spaces[44]. The diagnosis should always be on the list when an obstetric patient presents with shock.

- The lower segment uterine scar is less likely to rupture compared to the classical cesarean section scar [11]. Rupture of a lower segment uterine scar happens during labor and is essentially a dehiscence of the wound with minimal bleeding. Rupture of a classical scar may however result in serious bleeding for the placenta usually overlies the scar.

- Miller *et al* [39] reports that 0.6 % of women with one previous cesarean section had a

uterine scar rupture, 1.8% of women with two previous cesarean sections and 1.2% with three or more previous cesarean sections. Uterine rupture was therefore three times more common with two or more previous cesarean sections. Miller *et al* [39] concludes that trial of labor is acceptable in the majority of women with previous cesarean sections.

6.11 Extracting the head of the fetus with uterine tearing

- The hand may be used to extract the fetal head, by scooping the head out of the pelvis and then through the uterine incision. The uterine incision is stretched with the head of the fetus and the hand of the surgeon. This may cause tearing of the uterine incision laterally with subsequent bleeding from the dilated veins in relation to the broad ligament.

- Using the hand in the case of a small head may be easy, but the use of a forceps puts less stress on the uterine incision in the case of a bigger head.

- The surgeon should be very careful not to flex the wrists when the hand is between the inferior edge of the incision and the fetal head. This maneuver will cause the incision to tear laterally into the broad ligament or even downward into the vagina.

6.12 Problems with fetal extraction

- The child's head may be impacted in the pelvis. In this event, the table should be put in the Trendelenburg position, and the assistant should pull the fetal shoulder upwards or if this does not help, dislodge the fetal head by means of a vaginal examination.

- If the fetal arm presents the arm should be put back into the uterine cavity. The arms should never be pulled.

- The head can also be rotated to the transverse position and then the head lifted out manually by lateral flexion of the neck.

- With a head high in the uterus fundal pressure may be applied or a vacuum extractor may be used.

6.13 Low Apgar scores

- The interval between opening the uterus and delivery of the infant is important for neonatal outcome. During general anesthesia, induction-to-delivery intervals of more than 8 minutes and uterine incision-to-delivery intervals of more than 3 minutes, are associated with significantly more cases of neonatal acidosis and low 1-minute Apgar scores. During spinal anesthesia, only the uterine-to-delivery interval of more than 3 minutes is important in fetal outcome[32]. The patient needs to be draped before the induction during general anesthesia.

6.14 Pulmonary embolism [3, 4, 7]

- Moldin[4] reports on pulmonary embolism being one of the most common causes of maternal mortality after cesarean section.

- Preventative measures like early postoperative ambulation, elevation of the extremities and stockings can be used[3]. Prophylactic drug therapy may be considered in high-risk patients.

6.15 Amniotic fluid embolism[4]

- Together with pulmonary embolism, amniotic fluid embolism was the principle cause of death of the cases reported in Moldin *et al's* study[4]. In his study 8 patients died from causes directly associated with the cesarean section out of a total of 63 075 cesarean sections performed over 7 years.

6.16 A too low incision

- A too low incision over the lower segment of the uterus may result in the uterine muscle disappearing below the bladder. This may lead to a subsequent inclusion of a suture of the bladder or even the ureters.

- Due to the downward converging of the lateral walls of the uterus, a too low incision may be too short in width with possible difficulty in extracting the head and tearing of the broad ligament which causes vigorous bleeding.

6.17 Inaccurate suturing of the uterine wall

- This may be the result of initial tearing of the uterine aperture with the index fingers laterally after the initial small transverse incision in the lower segment of the uterus. Apart from uncontrolled tearing into the broad ligament, the surfaces of the tear are ragged and result in inaccurate suturing of the uterus.

- The strength of the uterine scar depends on the accuracy with which the suturing of the uterus is done when approximating the anatomical margins of the uterus.

6.18 Complications related to suturing of the uterus

- The bladder may be included in the sutures if the bladder has not been properly displaced from the lower segment of the uterus

- Dilated veins in relation to the broad ligament may be injured if the incision was made too far laterally or was torn during delivery of the fetal head.

- The upper edge of the uterine incision may be mistakenly sutured to a

transverse retraction ring appearing from the posterior uterine wall, and not to the lower edge of the uterine incision.

6.19 Infant injuries[43]

- Most injuries are mild and self-limiting. Rubin[33] reports an incidence of 2 to 7%.
- Soft tissue injuries are most common including tissue bruising.
- The following factors may play a role:
    - Too small abdominal and/or uterine incisions,
    - Impatience during delivery and the amount of manipulation necessary during the delivery.
    - Facial bruising may occur during use of a forceps.
    - The use of a vacuum extractor may cause caput and rarely a cephalohematoma.
- **Fetal skin lacerations** are caused by incision during entrance into the uterine cavity. This complication is more likely in the presence of oligohydramnios. Adequate visualization is necessary in the operating field to avoid incising the infant's skin. The ear of the child may be situated just below the lower segment of the uterus and can be injured when performing the lower segment incision. Therefore, when extending the lower segment incision laterally with the scissors, the opposite finger should lift the uterine wall to avoid injuring an ear just below the surface. Continuous suctioning while entering the uterine cavity is essential to have a good field of vision.
  Fetal skin lacerations usually only require 'Steri-Strips'.
- **Skeletal complications** are the same as for vaginal delivery and are associated with breech deliveries.
    - Humerus fractures can occur due to manipulation of the arm. Haste should be avoided during displacement.
    - Clavicular fractures can occur with raised arms.
    - Femur fractures are not common. Long bone fractures usually occur during extraction. Fractures may be green stick fractures, complete or through the diaphysis or epiphyseal plate.
    - Temperomandibular dislocations may occur during the Mauriceau-Smellie-Viet maneuver in breech deliveries.
- **Brachial plexus palsy** can occur on the opposite side of the neck (lateral extension) due to lateral flexion of the neck during extraction of the head through an insufficient incision or in the presence of a contraction ring or raised arms. Injury of the brachial plexus may vary from individual nerve injury to avulsion of nerve roots[34]. Erb's palsy has also been reported. This occurs at the junction of the 5th and 6th cervical

nerve roots also referred to as Erb's point. Lower brachial plexus injuries were described by Klumpke [34]. Greenwald *et al* [34] reports an incidence of 2/1000 births. Most cases had a good prognosis with early recovery.

- **Spinal cord trauma** can occur in breech presentations with a hyperextended head[35].

- **Intra-abdominal organ injury** may occur to the spleen, liver and also kidneys or adrenals if inappropriate pressure is exerted on the abdomen during extraction. The mortality rate of a ruptured spleen or liver is high[36]. The child will present with shock and abdominal distension. Cullen's sign of bluish discoloration of the umbilicus is a recognized sign of intraperitoneal bleeding [36].

- **Depressed skull fracture.** Skajaa *et al* [54] reports a depressed skull fracture of a child born by cesarean section. The cause was digital impression on the parietal bone during delivery by the doctor. He also speculates that the impaction of the fetal head against the promontory, ischial spines or the symphysis pubis may weaken the bone during prolonged labor.
  Although rare, these fractures may be accompanied by intracranial hemorrhage.

6.20 Laceration of the cervix and vagina[7]

- Especially during an emergency cesarean section, the lower segment of the uterus can be mistaken with the vagina.

- Vaginal incision may happen especially if the patient has been pushing in the second phase of labor. Bryan *et al* [46] reports two cases of inadvertent entry into the superior part of the vagina. The incision may then be thought to be through the lower segment of the uterus, but actually enters the upper vagina. There is a high risk of associated bladder injury and secondary fistula formation, either vesicouterine or vesicovaginal fistulae.
  Due to the extension of the incision, the cardinal ligaments of the cervix, the ureters and descending branch of the uterine artery may be injured as well.

- In women with a history of prolonged second stage of labor, entry into the vagina during the uterine incision should be avoided by making the incision just above the reflection of the vesicouterine peritoneum. The muscles of the uterus in the lower segment are more transversely oriented compared to the more longitudinal directions of the vaginal musculature. This may also help to distinguish the lower segment of the uterus from the vagina.

6.21 Incisional hernia and postoperative wound disruption

- Greenall *et al* [20] has shown in a randomized clinical trial comparing the abdominal midline incision with a transverse incision, that the midline incision has a higher incidence of incisional hernias and tends to burst more easily than transverse abdominal incisions. There is less tension on the edges of the transverse abdominal incision like a Pfannenstiel incision compared to a midline incision.

- Using the Pfannenstiel incision minimizes this complication. Mowat *et al* [28] showed that vertical incisions have an eightfold increase in wound dehiscence compared to transverse incisions.
  Patients with wound disruptions and infection usually have a longer hospital stay. Therefore the risk of thromboembolism is considerably increased.
  The risk of wound dehiscence is higher in the presence of prolonged rupture of the membranes. The transverse incision should be used in these patients.

6.22 Pseudo-obstruction of the colon[24]

- This complication is characterized by an unobstructed colon which is adynamic. The cecum and transverse colon rapidly dilates and eventually may lead to perforation of the cecum. The cecal perforation occurs due to the increased pressure in the bowel and the large diameter of the cecum. This may be a fatal condition if not diagnosed early.

- Rapid abdominal distention without pain, tenderness or vomiting is the first clinical symptom. Symptoms of obstruction occur later. A gas-filled colon especially in the cecum and an ascending colon with a cut off sign at the hepatic or splenic flexures, as seen on a plain abdominal X-ray, are diagnostic.

- Colonic decompression by a nasogastric tube and cecostomy should be performed.

- The pathogeneses of the complication may be explained by an imbalance between sympathetic and parasympathetic innervation. Sacral (S2,3,4) parasympathetic involvement is likely to be implicated. Hence the cut off sign at the splenic flexure where the parasympathetic innervation of the colon changes from vagal (CN X) to sacral (S2,3,4). The gravid uterus applies pressure on the sacral plexus and therefore on the hypogastric parasympathetic plexus as well.

6.23 Superficial hematoma formation

- Hematoma formation in the superficial fascia of the abdominal wall is a common complication. This can be prevented by suturing the superficial tissue layer separately especially in women with a thicker fatty layer. Fine 2.0 catgut can be used for this purpose.

- Pfannenstiel incisions have a higher tendency for hematoma formation, due to the division of multiple layers of fascia and therefore the formation of potential spaces[29]. A subcutaneous drain is often necessary.

- During a Pfannenstiel incision care should be taken to ligate the superficial epigastric vessels. This will help avoid subfascial hematoma formation.

6.24 Meconium granuloma formation[30]

- Blood and amniotic fluid may result in meconium granuloma formation. This can be prevented by using laparotomy packs in each paracolic gutter to absorb these fluids. Spillage of meconium during cesarean section may produce a foreign body granulomatous response resulting in adhesions and abdominal pain. This is a rare condition. Freedman *et al* [30] reported two cases.

6.25 Nausea and vomiting

- Patients under regional anesthesia may experience nausea and vomiting due to stretching of the peritoneum when the laparotomy packs are inserted or taken out.

6.26 Injury to the femoral nerve[37]

- The retractor may damage the femoral nerve during pelvic surgery due to prolonged pressure.

- Salzberg *et al* [37] reports that a transverse incision is a predisposing factor. With a Pfannenstiel incision, the retractor can be placed more laterally and therefore increases the risk of injuring the nerve. Patients with thin anterior abdominal walls have a higher risk of femoral nerve injury.
  The retractor usually injures the femoral nerve about 4 cm superior to the inguinal ligament. The retractor blade can either directly injure the nerve or compress the psoas major muscle and the femoral nerve against the pelvic wall with resultant ischemic damage to the nerve.

- The femoral nerve comes form L2,3.4 and runs in a groove between the iliacus and psoas major muscles. It then runs under the inguinal ligament and enters the femoral triangle.

- Femoral nerve injury may result in paralysis of knee joint extension, wasting of the quadriceps muscle, an absent knee jerk reflex and weakness of hip flexion. These symptoms may range from motor function loss to paresthesias in the cutaneous distribution of the femoral nerve to the anterior aspect of the thigh and the medial surface of the leg.

- Injury to the femoral nerve should be prevented by using appropriate retractors, which do not impinge on the psoas major muscle. Pads can also be placed between the retractor blades and the pelvic wall.

- The absence of the femoral pulse may indicate that too much pressure is placed on the external iliac artery and the femoral nerve.
  A too long incision should also be avoided to keep the retractors away from the nerve.

6.27 Injury to the genitofemoral nerve[37]

- Injury to this nerve presents with pain in the inguinal region with radiation to the genitalia and the upper medial aspect of the thigh. The mechanism of injuring this nerve is the same as for the femoral nerve.
- The genitofemoral nerve comes from L1 and L2 and is mainly a sensory nerve. It pierces the psoas major muscle, runs on the muscle and divides in a genital and femoral branch near the inguinal ligament. The femoral branch innervates the skin over the femoral triangle and the genital branch enters the deep ring of the inguinal canal. It accompanies the round ligament of the uterus in the inguinal canal and supplies the skin of the mons pubis and labium majora.

6.28 Unexpected placenta directly beneath the incision[40]

- Discovery of an anteriorly positioned placenta is usually made while entering the uterine cavity if an ultrasound did not reveal this before the operation. Heavy bleeding may occur. The placenta may be displaced laterally or the incision may be done through the placenta. Therefore there may be fetal blood loss as well. When there is difficulty in extracting the fetus, the cord can be clamped prior to delivery. Resuscitation should commence as soon as the baby is delivered. Maternal hemodynamic function should be supported.

6.29 Formation of fibrous post-operative adhesions

- This complication is common after laparotomies and is caused, as shown by Ellis[19] in animal studies by tissue ischemia and not serosal damage. These adhesions are actually vascular 'grafts' from viable structures in the area providing blood supply to host tissues to remain viable.

- The peritoneum should therefore not be sutured. Suturing of the peritoneum creates ischemic tissue at the suture line and therefore initiates adhesion formation at the sites of reperitonealization. The peritoneum heals by differentiation of a new mesothelium from underlying connective tissue cells.

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4.4.3.2 Appendectomy

1. Indications

- Appendicitis
  Appendicitis has a peak incidence in early adulthood. A review of 2000 patients showed a 1.3:1 male to female ratio[30].

2. Contraindications

- An appendectomy should not be performed in the presence of one of the differential diagnoses. These include acute mesenteric adenitis, acute gastroenteritis, urinary tract infection, ureteral stone, pelvic inflammatory disease, ovulation, pleuritis or consolidation of the lower lobe of the right lung, Henoch Schönlein purpura, testicular torsion, acute epididymitis and seminal vesiculitis, Meckel's diverticulitis, intussusception, perforated peptic ulcer and cecal carcinoma or diverticulitis.

3. Step by step procedure

Step1. Prepare the patient for theatre making sure the patient is properly hydrated and preexisting cardiac and respiratory problems are addressed.

Step 2. Identify McBurney's point [14]. This point is situated at the junction of the lateral and middle third of the line between the superior anterior iliac spine and the umbilicus.

Step 3. Surgically prepare the skin of the anterior abdominal wall and the right thigh.

Step 4. McBurney's incision

- The incision is made obliquely for about 8-10cm, crossing a line from the anterior superior iliac spine to the umbilicus at right angles through McBurney's point. The incision extends one third above and two-thirds below McBurney's point[14]. McBurney stresses the importance of an incision of proper length: "Incisions should be long enough to allow complete and safe work to be done, and it is most unscientific and harmful to encourage

those of limited experience to believe that a special measure of good goes with a special length of incision"[14]

- This incision should be used in cases of acute appendicitis without perforation and peritonitis. In the case of a perforated appendix with generalized peritonitis a midline incision or paramedian incision is required due to the need of abdominal lavage and drainage in all abdominal quadrants.

- The McBurney's incision can be extended medially for lower abdominal pathology, but for upper abdominal pathology, the wound should be closed and a midline laparotomy performed.

Alternative: Lanz incision. This incision is made 1-2 cm medial to the anterior superior iliac spine and continued medially in a slight curve, which is convex inferiorly. The advantage of this incision is that it can be extended medially through the rectus sheath or laterally by division of the abdominal muscles[29] for other intra-abdominal pathology, whereas the McBurney's incision is poor in that regard.

Step 5. Incise the external abdominal oblique aponeurosis in the line of the skin incision, which is in the line of its fibers.

Step 6. Split the internal abdominal oblique and the transversus abdominis muscles in the line of their fibers to expose the peritoneum. The fibers of the transversus abdominis muscle become aponeurotic lateral to the point of the fibers of the internal oblique.
These muscles should be separated without cutting them, thus avoiding nerve injury.

Step 7. Insert the Langenbeck retractors beneath both muscles.

Step 8. Pick up the peritoneum with two artery forceps's and make sure there is no underlying bowel that may be injured.

Step 9. Incise the peritoneum in a craniocaudal direction.

Step 10. Insert the Langenbeck retractors beneath the peritoneum and pull them perpendicular to the line of incision.

Step 11. Take swabs of any purulent fluid before suctioning it.

Step 12. Identify the cecum.

Step 13. Identify the appendix by rotating the cecum until the base of the appendix can be seen. The teniae of the cecum can also be followed to the base of the appendix. To expose the base of the appendix, the cecum should be drawn in order: inferiorly, anteriorly and superiorly.

Access the appendix. It can be easily picked out, when lying in the pelvis. It may be difficult to identify a retrocecal appendix.

Step 14. Grasp the mesoappendix with a forceps or the appendix with a Babcock tissue forceps.

Step 15. In the case of an immobile cecum bound down by peritoneum, it may be necessary to mobilize the cecum by incising the peritoneum on the lateral side of the cecum. This will also give access to a retrocecal appendix. It may be necessary to extend the wound upwards to allow mobilizing the cecum.

Step 16. Gradually mobilize the mesoappendix and transect the vessels in the mesoappendix.

Step 17. Identify the appendicular artery. It usually runs in the free edge of the mesoappendix. The artery should be doubly tied off as well as the smaller vessels towards the base of the appendix. These vessels at the base of the appendix may be difficult to ligate and can be controlled by diathermy.

Step 18. Clamp the fully mobilized appendix, approximately 5mm from the base and reapply the forceps 7-8 mm further distally. A 1.0 chromic catgut ligature is tied to the crushed area.

Step 19. Transect the appendix with a scalpel on the cecal side of the forceps. Discard the appendix with the forceps.

Step 20. It is not necessary to bury the stump, and it is not advised to bury the stump routinely. Williams *et al* [29] report on 700 appendectomies where the stump was left unburied. The stump as well as the base on the cecum should be clearly viable.

Step 21. Suction any fluid from the pelvis and right paracolic gutter. Pass a gauze swab on a forceps through these areas to clean them properly.

Step 22. Inspection of the abdominal organs

- If the appendix appears normal, first inspect the other abdominal organs before the normal appendix is removed. There may possibly be a contraindication for removal of the appendix, for example the risk of fistulae forming in the presence of Crohn's disease[47].
- Inspect the cecum, proximal ascending colon and the distal ileum.
- Inspect the ileum from the ileocecal valve for a possible Meckel's diverticulum at about 20-70 cm from the ileocecal valve[24].
- The presence of mesenteric adenitis may be seen in the ileal mesentery.
- With a head down tilt and packing of the ileum, the pelvic organs in the female can be inspected.

Step 23. Close the peritoneum with continuous suture of catgut under direct vision.

Step 24. As soon as the retractors are removed the abdominal muscles fall together. Use interrupted sutures of catgut to approximate the internal oblique and transversus abdominis muscles. It is advisable to close the tranversus abdominis aponeurosis and transversalis fascia separately to help prevent subsequent possible hernias[22]. The sutures should not be too tight and therefore cause strangulation of the muscles.
Due to the different directions of the muscular fibers, it forms a grid, which provides strength to the anterior abdominal wall.

Step 25. Close the external oblique aponeurosis with continuous catgut from end to end.

Step 26. Close the skin with mattress sutures of monofilament nonabsorbable material.

Advantages of McBurney's incision[14]:

- Except for incising the skin, there is very little bleeding.
- Muscular and tendinous fibers are separated and not incised. This means that after the operation, the fibers fall in place and approximate the edge where they were separated.
- No nerves are usually injured.
- The incision can be enlarged if necessary by continued separation of muscular fibers inferiorly and superiorly as high as the iliac crest.

4. Materials

- Standard laparotomy pack.

5. Anatomical pitfalls

5.1 Embryology

- A transient appendix appears on the embryonic midgut in week five and disappears soon after that.

- The appendix develops in the eighth week of life as a protuberance of the developing cecum. During subsequent development of the cecum the appendix is displaced towards the ileocecal valve. Its final position is on the posteromedial wall of the cecum inferior to the ileocecal valve[29].

- Duplication of the appendix is rare as reported by Bluett *et al* [12] and Collins[11]. Waugh[13] differentiated between three types: 1) appendix with two separate luminae and a common muscular wall, 2) two completely separated appendices originating

from the cecum, 3) a normal appendix with an atypical one. The current accepted classification is that of Wallbridge[27]:

- Type A is a single based appendix with duplication of the appendix from a single cecum.
- Type B anomaly consists of two separated appendices coming from a single cecum.
  - Type B1 is two appendices appearing on either side of the ileocecal valve and in Type B2, a normal appendix appearing from the normal site and a rudimentary appendix from the cecum along the lines of one of the teniae at a varying distance from the first.
- Type C anomaly has a double cecum, each with its own appendix.

- Embryology of duplication of the appendix[12]: If fusion of the transient appendix-like structure with the normal appendix occurs, a type A duplication develops. Type B1 results from improper differentiation of the cloaca. If the transient appendix-like structure does not disappear, without fusion with the normal appendix, a type B2 duplication develops. Partial twinning of hindgut structures with duplications of other structures as well explains the type C duplication.

- Triplications of the appendix can occur, as well as an accessory appendix without communication to the cecum, helical appendix[39], intramural appendix and an appendix-umbilicus fistula[4].

5.2 Appendix

- The appendix arises approximately 1.7 cm from the terminal end of the ileum[8], its base at the union of the teniae. This is at the posteromedial border of the cecum.

- The three teniae converge at the base of the appendix. This is a useful landmark for identification of the appendix during surgery. After joining each other at the base of the appendix, the teniae form a continuous muscular layer on the outside of the appendix[4]. At the orifice of the appendix, muscle fibers branch from the teniae to form a mesh of muscle fibers. The same happens at the apex of the appendix[4].

- The appendix is not a vestigial organ, but part of the lympho-epithelial tissue in the gastrointestinal tract[2]. It actively participates in the secretion of immunoglobulins, especially IgA. It forms part of the gut-associated lymphoid tissue (GALT) system. Removal of the appendix has however not been associated with any manifestation of immune compromise[30].

- Lymphoid tissue is present in the appendix from about 2 weeks after birth. The lymphoid tissue increases throughout puberty and then stays stable for the next decade. After that there is a steady decrease of lymphoid tissue. After 60 years of age there is virtually no lymphoid tissue left and the lumen of the appendix can actually be obliterated.
- The orifice of the appendix can be partially covered by an inconstant mucosal fold,

sometimes referred to as Gerlach's valve[4].

- Length: Most appendices are 6-9 cm in length. Short forms (5cm) and long forms (35 cm) exist[7]. The luminal diameter is between 1 and 3 mm[29].

- Several variations of origin are seen as classified by Treves[9]:
    - Type 1: A fetal type with a funnel-shaped origin. This type is only found in 2-3% of adults.
    - Type 2: The appendix originates from the cecal fundus.
    - Type 3: The appendix originates posteromedially out of the cecum (most common).
    - Type 4: The appendix originates directly beside the ileal orifice.

- The muscular wall of the appendix has horizontal fibers allowing for minimal passive expansion of the lumen.

- Diverticula can be found on the appendix[4].

5.3 Surface anatomy

- Charles McBurney[14] described the point of maximum tenderness in appendicitis as a finger finger placed on the anterior abdominal wall, one-third the distance between the anterior iliac spine and the umbilicus.

- Karim *et al* [25] states that McBurney's point does not mark the site of the base of the appendix in many patients.
  They studied 51 barium enemas, and determined the position of the lower pole of the cecum and base of the appendix relative to bony landmarks in the supine position. They found that 70% of the appendices were situated inferior to the horizontal line joining the anterior superior iliac spine on the left and the right.
  By two lines, the horizontal line between the anterior superior iliac spine and the right midclavicular line, Karim *et al* [25] described four quadrants namely the iliac, inguinal, umbilical and pelvic quadrants. He then related the position of the base of the appendix to these quadrants. The base of the appendix was located in the iliac quadrant in 15%, the inguinal quadrant in 11%, the umbilical quadrant in 15% and the pelvic quadrant in 59%.

- The base of the appendix and inferior pole of the cecum lies more inferior and medial than previously thought according to Karim *et al* [25]. He therefore concludes that an appendix incision should be done in the inguinal and pelvic quadrants. This may however increase the risk of nerve injury as described by Arnbjörnssen[35].

- Therefore, careful palpation of the point of maximal tenderness is important prior to surgery.
- Schumpelick *et al* [4] describes three surface anatomy points for the origin of the

appendix[4]. The origin of the appendix projects either on McBurney's point, Lanz's point (right third point of the interspinal line) or Kümmell's point (right side somewhat below the umbilicus).

5.4 Appendix positions.

- The five typical locations of the tip of the appendix are in order of frequency:
  - 1. Retrocecal- retrocolic either free or fixed,
  - 2. Pelvic or descending,
  - 3. Subcecal, passing downward and to the right,
  - 4. Ileocecal, passing upward and to the left anterior to the ileum,
  - 5. Ileocecal, posterior to the ileum.

- Wakeley[5] reports the position of the appendix in his study of 10 000 autopsy cases as follows:
  - Retrocecal in the retrocecal recess (65%),
  - Descending pelvic (31%),
  - Transverse retrocecal (2.5%),
  - Ascending paracecal, preileal (1%),
  - Ascending paracecal, postileal (0.5%).

- Buschard *et al* [40] described the position of the appendix as either anterior or posterior in relation to the cecum. Anterior positions are the preileal, postileal, promontoric (subileal), pelvic and subcecal positions. Posterior positions include the paracecal and retrocecal positions.

- More recently, O'Connor *et al* [43] studied the locations of the appendix in vivo on 129 patients. The findings were different from Wakeley's autopsy findings. O'Connor demonstrated that the retrocecal position of the appendix was actually the most common location, but occurred in only 33% of instances. In the other two thirds of cases, the appendix tip projected freely into the peritoneal cavity. There results are: preileal (4%), postileal (8%), subileal (15%), pelvic (19%), subcecal (11%), paracecal (10%), retrocecal (33%).

- According to O'Connor *et al* [43], Wakeley [5] included in the category retrocecal appendices that were in a position just lateral or inferior to the cecum although they were lying free. All these positions could develop as a result of torsion of the appendico-cecal junction during embryological development. Wakeley [5] proposed that the appendix is carried posterior to the cecum by helicoidal torsion. His reported figure of 65% retrocecal positions is thus higher.

- In an earlier report, Wakeley[46] reports his intraoperative findings in 120 patients. He found the retrocecal position in 35% of cases. This is similar to the O'Connor *et al* 's[43] data. Maisel[45] reports a retrocecal position of the appendix in 26.7% of cases in a South African based study.

- The retrocecally positioned appendix may be mobile. Buschard *et al* [40] reported that 40% of the 56.7% retrocecally positioned appendices were mobile. The rate of extraperitoneally positioned appendices is therefore lower, and O'Connor *et al* [43] reports it to be in the range of 20-35%.

- Knowledge of the position of the tip of the appendix is important for two reasons. Firstly it is important for finding the appendix during surgery, but secondly the different positions also influence the symptoms of appendicitis.

- Specifically the retrocecal position of the appendix requires a more extensive dissection often involving cecal mobilization[40]. However, if the tip of the appendix is free, the dissection is much easier. This is especially the case in laparoscopic techniques that have been suggested for appendectomies.

- The base of the appendix at the site of the confluence of the teniae coli on the base of the cecum is a constant position. However, the position of the tip may vary greatly[30]. The appendix may be fixed or non-fixed. The appendix in the pelvic position is usually non-fixed.

5.5 Mesentery [4, 8]

- The mesentery of the appendix is derived from the posterior side of the mesentery of the ileum, attaching to the cecum and the proximal appendix. It contains the appendicular artery within its free border.

5.6 Appendicular artery

- The appendicular artery arises from either the ileal branch or a cecal branch of the ileocolic artery. It is usually single but may be double. The artery runs posterior to the terminal ileum and enters the mesoappendix close to the base of the appendix.

- From the main appendicular artery, many small branches supply the appendix along its length[9]. These vessels enter the subserosal space, divide again and run in the muscularis propria into the submucosa to anastomose with the venules[28].

- The base of the appendix may be additionally supplied by a small branch or branches of the anterior or posterior cecal artery[1]. If the stump of the appendix is insufficiently ligated, these may cause severe bleeding[7].

- The ileocolic artery is a branch of the superior mesenteric artery, which supplies the midgut, of which the appendix forms part[4].

- The appendicular artery is a terminal artery. Therefore perfusion of blood cannot be increased, so that ischemic damage may develop[10].
- The anterior cecal artery[4] runs in the superior ileocecal fold on the ventral side of the

cecum and usually does not reach the appendix.

- The inferior ileocecal fold extends from the antimesenterial border of the terminal ileum and spreads over the ventral side of the appendix. There are no blood vessels in this fold. Therefore it is often referred to as the 'bloodless fold of Treves'.

- The ileocolic artery[4] runs in the angle between the cecum and the terminal part of the ileum and divides into several branches:
    - Ileal branche supplying the terminal part of the ileum,
    - Anterior cecal artery supplying the anterior aspect of the cecum,
    - Posterior cecal artery supplying the posterior aspect of the cecum,
    - The colic ramus running superiorly (ascending colic ramus) and supplying part of the ascending colon,
    - The appendicular artery running posterior and very rarely anterior to the terminal part of the ileum to the mesentery of the appendix.

- According to Lippert *et al* [6], the appendicular artery originates in 35% of cases from the ileal branche, in 28% from the division of the ileocolic artery, in 20% from the anterior cecal artery, in 12% from the posterior cecal artery, in 3% from the ileocolic artery of cases and in 2% from the ascending colic ramus.

- The appendicular vein[4] accompanies the appendicular artery in the mesentery. After joining the cecal veins it becomes the ileocolic vein draining into the superior mesenteric vein, which drains into the portal venous system[29].

5.7 Lymphatic drainage[1, 4]

- Lymph nodes are situated in relation to the arteries supplying the appendix. Nodes are found in relation to the appendicular, ileocolic and superior mesenteric arteries, draining to the celiac nodes and cisterna chyli.

- Lymph vessels of the body and tip of the appendix drain to the posterior ileocolic nodes and the base of the appendix to the anterior ileocolic nodes.

- The amount of lymphoid tissue has a role in the development of acute inflammation of the appendix. The incidence of appendicitis peaks in the second and third decades of life. There is a steady decrease of lymphoid tissue towards the age of 60 years after which virtually no lymphoid tissue is left.

5.8 Lumen

- The luminal diameter is between 1 and 3 mm[29].

- Obstruction of the lumen by fecoliths seems to be the main reason for acute appendicitis. Fecoliths are found in 40% of acute appendicitis, 65% of gangrenous appendicitis without rupture and 90% of perforated gangrenous appendicitis[4].

Collins[11] found the presence of fecoliths in a study involving 50 000 cases to be 38.8%. He also found the presence of unusual foreign bodies like metal screws and toothpicks in 1.3% of cases.

- The appendix secretes 2-3 ml of mucous daily. Normal secretion of the appendiceal mucosa continues after occlusion of the appendicular lumen, with resultant rapid distention. This can continue until gangrene and perforation occur. The process may be rapid due to the fact that the appendiceal lumen capacity is only about 0.1 ml[30]. This leads according to the law of La Place (T=P x r/2, T=wall tension, P= intraluminal pressure, r= radius), to increase of intraluminal pressure due to the appendiceal wall's inability to stretch[15]. Even only 0.5 ml of mucous secreted, leads to an increase of pressure of approximately 45mmHg[16]. This explains why the appendix can perforate within hours of the onset of appendicitis. Therefore hospitalization is essential in patients with suspected appendicitis.

- Vascular congestion leads to mucosal impairment and further bacterial invasion of deeper layers of the appendix. Infarction occurs in the area with the poorest blood supply (antimesenteric border) with consequent perforation.

5.9 Histology[29]

- The appendix has the following structure, similar to the colon: serosa, muscularis propria (outer longitudinal and inner circular layer), submucosa, muscularis mucosa and large intestinal mucosa. Lymphoid follicles are found in the submucosa.

- With increasing age, there is increasing fibrosis, which is evident after 40 years of age. Also the amount of lymphoid tissue diminishes.

5.10 Innervation of the appendix

- The appendix is supplied by autonomic nerves. The sympathetic nerves come from the superior mesenteric plexus and the parasympathetic nerves from the vagus nerve.

5.11 Pain during appendicitis[4]

- The dull midline pain is due to distension of the bowel, which stimulates the nerve endings of visceral afferent pain fibers.

- Continued distension leads to occlusion of the capillaries and venules, while arterial inflow continues resulting in vascular congestion. Vagal stimulation due to the distension leads to nausea and vomiting and vague abdominal midline pain due to midgut distribution. Localization of the pain takes place when the inflammatory process has involved the parietal peritoneum, causing the characteristic shift of pain from the umbilical region to the right iliac fossa. The parietal peritoneum in the region of the cecum and appendix is supplied by segmental nerves also supplying the anterior abdominal wall (T12, L1). Localization usually takes place within 4-6 hours.

This is the classical presentation.

- Cutaneous hyperesthesia over the spinal nerves T10, T11 and T12 areas on the right may be present in acute appendicitis. This may be the first presenting sign according to Kozar *et al* [30], and is experienced as pain when gently picking up the skin in the area between the index finger and thumb. In very rare cases this can be confused with the early onset of Herpes Zoster of the same nerve roots.

- Cramping pain may occur due to peristalsis, which is stimulated by the distention.

- Due to anatomic variations in the position and dimensions of the appendix, there are variations in the sequence and position of the pain as well.
  Kozar *et al* [30] gives a few examples:
  - A long appendix with the inflamed tip in the left iliac fossa may cause localized pain the left iliac fossa.
  - A retrocecal appendix may present with back pain or flank pain.
  - A pelvic appendix may present with suprapubic pain.
  - A retroileal appendix may cause testicular pain, thought to be secondary to irritation of the testicular neurovascular bundle.

5.12 Vagal stimulation[30]

- Vomiting occurs in 75% of patients with appendicitis. Anorexia is a very constant symptom in appendicitis. Both are due to vagal stimulation.
  The sequence of symptoms is very important in the diagnosis of appendicitis. 95% of patients first complain of anorexia, followed by abdominal pain and then vomiting. If the vomiting occurs before the abdominal pain, the diagnosis of appendix is probably less high on the differential diagnosis list.

5.13 Examination

- Physical palpation of the abdomen with a tender right iliac fossa over McBurney's point is the principal positive sign in appendicitis. This indicates peritoneal irritation with or without the presence of local rebound tenderness.

- Vital signs are usually normal in the presence of uncomplicated appendicitis. Fever, tachycardia and leucocytosis are due to absorption of bacterial toxins and necrotic tissue.

- Patients feel most comfortable lying supine with the right thigh drawn up to some degree. This position relaxes the peritoneum and provides some relief of pain.

- Muscle resistance starts with voluntary guarding and as peritoneal irritation progresses, involuntary reflex rigidity develops.

- The appendix position also influences the physical signs, for example:

- A retrocecal appendix may have fewer positive signs on the anterior abdominal wall during palpation, and more in the flank region.
- A pelvic appendix may present with no signs on the anterior abdominal wall at all. However the diagnosis is made on rectal examination. As the examining finger pushes against the peritoneum of the rectovesical pouch, pain is experienced locally and in the suprapubic region.

- Rovsing's sign – Pain is experienced in the right iliac fossa, when the left iliac fossa is palpated. This is a sign of peritoneal irritation.

- Psoas sign – This test is done by lying the patient supine on the edge of the bed and then slowly extending the right thigh. This action stretches the iliopsoas muscle and will illicit pain in the presence of appendicitis. The appendix is closely related to the psoas muscle.

- Obturator sign – This test is performed with the patient supine and with the right thigh flexed and internally rotated. This will stretch the obturator internus muscle and discomfort will be felt if the appendix is in close relation to the muscle as it would be in the pelvic position of the appendix.

- A mass in the right iliac fossa may be a periappendiceal abscess or loops of bowel around an inflamed appendix.

5.14 Anterior abdominal muscles[2]

- The external abdominal oblique muscle is aponeurotic because this muscle loses its muscle fibers below the spino-umbilical line. The internal abdominal oblique and transversus abdominis muscles are muscular at the level of incision. These muscles are split in the direction of their fibres by means of blunt dissection.

- The abdominal muscles are supplied by segmental nerves from T7 to T12 and L1. In the region of the incision during an appendectomy, the T12 and L1 nerves are in possible danger. The nerves run in the neurovascular plane between the internal oblique and transversus abdominis muscles in an inferior and medial direction. The classical McBurney's incision [14] made in a similar direction over McBurney's point is unlikely to injure the nerves.

5.15 Extraperitoneal fat[2]

- This layer is variable in patients and is seen just before entering the peritoneal cavity.

5.16 Cleavage lines[2]

- An incision made in the direction of the cleavage lines (Langer's lines) as is the case with a McBurney's incision, tend to result in less scaring and dehiscence than incisions made across these lines.

5.17 X-ray Anatomy[30]

- A plain X-ray of the abdomen is rarely helpful in the diagnosis of appendicitis. An abnormal gas pattern is often seen but this is a nonspecific finding. Rarely a fecolith may be seen on an X-ray.

- A chest X-ray may be important in excluding right lower lobe pneumonia. Pain may be referred to the right iliac fossa and may present as acute appendicitis.

5.18 Ultrasound anatomy[3]

- The appendix can be demonstrated by compression ultrasonography. A normal appendix is demonstrated as an easily compressible blind-ending tubular structure originating from the cecum, with an anteroposterior diameter of 5 mm or less[44]. The appendix is compressed between the anterior abdominal wall and the iliopsoas muscle.

- The anteroposterior diameter of the appendix is measured with maximal compression. A positive scan for appendicitis is regarded as a non-compressible appendix with an anteroposterior diameter of 7 mm[44]. Demonstration of a fecolith is diagnostic of appendicitis. These ultrasonographic signs should be interpreted when acute pain is present in the right iliac fossa.

- A retrocecal appendix may be difficult to visualize from the anterior approach. Scanning directly posterior to the cecum via a lateral flank approach is necessary.

- A dilated uterine tube may mimic the appearance of an appendix. The uterine tube does not have as prominent an echogenic submucosal ring as the appendix. A transvaginal ultrasound is necessary to rule out a hydrosalpinx[44].

- Ultrasound diagnosis of appendicitis has a sensitivity of 78 to 96 percent and specificity of 85 to 98 percent.

- False positive scans can be due to inflammation surrounding the appendix, dilated uterine tubes that are confused with the appendix, inspissated stool that is confused with a fecolith, or an uncompressible appendix due to a thick fatty layer in the anterior abdominal wall in obese patients.

- False negative scans can be due to demarcation of the disease process to the tip of the appendix, a retrocecal appendix, a dilated appendix that is confused with small bowel or a compressible appendix due to perforation.

- Surrounding structures like the pelvic organs should also be evaluated especially if the ultrasound examination fails to diagnose appendicitis.

5.19 CT Anatomy[20]

- The appendix appears as a thin-walled tubular structure on CT scan and is seldom visualized during routine CT examinations. The reason for this is the variation in the size of the appendix, the presence of surrounding periappendiceal fat and the demonstration of the contrast-filled terminal ileal loops[21]. It is surrounded by mesenteric fat. The diameter of the appendix should not exceed 6 mm. Contrast filling of the appendix is best visualized after rectal administration of contrast. The inflamed appendix appears as either a fluid filled distended structure or a small collapsed tubular structure[21]. Circumferential wall thickening may be observed. Periappendiceal inflammation, fecoliths, appendiceal abscesses and mucocele can also be detected.
  Appendicoliths appear as solid ring-like densities on CT.

- Kozar[30] reports that CT should be primarily used if an appendiceal abscess is suspected and to help decide whether percutaneous drainage is feasible. It also helps to identify the nature of the abscess, whether the abscess is small, well-localized or complex. Small abscesses may only require intravenous antibiotics, well-localized abscesses may be drained percutaneously and complex ones require surgical drainage.

- CT scanning should not delay operative treatment when clinically indicated.

5.20 Appendicitis in pregnancy[30]

- The incidence of appendicitis in pregnancy is 1 in 2000 pregnancies. Acute appendicitis is more common in the first trimester.

- The appendix is gradually displaced laterally and superiorly from McBurney's point as the uterus enlarges. At 8 months it may be located as high as the right hypochondrium. This makes the diagnosis of appendicitis problematic.

- Fetal mortality increases markedly in the event of appendix rupture. There should be a high index of suspicion in the cases of abdominal pain during pregnancy.

- Guarding and rebound tenderness are difficult to assess due to the lax abdominal wall.

6. Complications (anatomically relevant)

6.1 Ruptured appendix

- Delayed operative treatment in appendicitis increases the risk of rupture of the appendix. Rupture occurs along the antimesenteric border of the appendix and usually distal to the point of lumen obstruction.
  A fever greater than 39 degrees, and white blood cell count of more than

18,000/mm³ is highly suggestive of a ruptured appendix.

- About 16% of patients presenting with a history of appendicitis have a ruptured appendix[30]. This is approximately 20% in children and as high as 49% in patients over 80 years.

- Mortality rates for the elderly are reported to be 15%.

- Rupture of the appendix gives rise to infection which is usually contained in the right iliac fossa but may spread to cause generalized peritonitis.

- Diagnosis of a ruptured appendix is important for the treatment differs from an unruptured appendix. An initial midline incision is necessary for a pre-operatively diagnosed ruptured appendix. The diagnosis of a ruptured appendix may be difficult and CT may be helpful.

6.2 Peritonitis, intra-abdominal abscesses and septicemia

- These complications usually occur after rupture of the appendix.

- The mortality rate is determined by age and whether the appendix ruptured before surgery.

- Abscess formation is greatly reduced by intravenous antibiotics. Abscesses are more likely to occur in generalized peritonitis and inadequate cleaning of the abdomen before closure. The most common cause is where a devitalized part of the appendix was not removed or where a fecolith was left behind[29].

- Abscesses can occur anywhere in the abdomen, but specifically in the following locations:
    - Pelvis. The pelvis is the commonest site for abscess formation[29]. Patients present with a swinging fever, deep pelvic pain and diarrhea. The abscess can be diagnosed with a rectal or vaginal examination and may be drained via these routes as well.
    - Appendiceal fossa.
    - Recto-uterine space.
    - Subhepatic space.
    - Between loops of intestine.
    - **Subphrenic abscess** – This can be explained by the communication between the paracolic gutter to the right of the ascending colon, the hepatorenal space (right subhepatic space or Morrison's pouch) and the subphrenic space on the right. The right colic flexure has no ligament like the phrenicocolic ligament on the left attaching it to the diaphragm. Therefore there is a direct communication between the mentioned gutters and subphrenic spaces on the right.

- Septicemia may lead to cardiovascular and respiratory failure.

6.3 Inability to locate the appendix

- The appendix may be difficult to find during surgery. It may be overlooked or even congenitally absent. The retrocecal appendix may be difficult to find as it may be hidden in peritoneal folds or be attached to the posterior parietal peritoneum.

- Agenesis of the appendix is extremely rare. Collins studied 50 000 cases, and found four cases of agenesis[11].

- The clinical significance of double or triple appendices as classified by Waugh[13] and Wallbridge[27] is that if a patient presents with typical symptoms of appendicitis but had a previous appendectomy, this should be included in the differential diagnosis. Anatomic anomalies of the appendix can make the diagnosis of appendicitis difficult. In cases of a diffuse clinical picture, especially in young and elderly patients, the spectrum of anatomic and embryological anomalies must be kept in mind.

- The location of the appendix has been reported to be very variable. This is usually the case in malrotation or situs inversus and even a thoracic appendiceal position has been reported associated with a diaphragmatic hernia[18].

- The appendix can also be found in the cecal wall beneath the serosa[19], which may necessitate incision of the cecal wall to remove the appendix. If no appendix is found during surgical exploration, a palpable thickening of the cecal wall may be the appendix.

- Izimbergenov[26] reports on a subhepatic position of the appendix. Treves[9] also observed in a study of 100 dissections a position of the tip of the appendix in actual contact with the inferior surface of the liver in 4 cases. In one of the four the tip of the appendix was in direct contact with the gallbladder. Treves[9] also found an appendix with an extensive mesentery lying across the midline with the tip on the left psoas major muscle.

- Du Toit[31] reports on a case of situs inversus viscerum where the appendix is situated in the left iliac fossa. Situs inversus viscerum has an incidence of 1 in every 6-8000. Although the viscera are on the opposite side, components of the nervous system are not the other way round. Pain in an acute appendicitis on the left side, is therefore still initially found in the peri-umbilical area and falsely projected to the right iliac fossa, after which the pain will be locally experienced in the left iliac fossa over the peritoneal irritation[48].

- These positions should be kept in mind during surgical exploration.

6.4 Bacterial contamination of the peritoneal wall

- One study has demonstrated that invagination of the stump of the appendix significantly reduces the incidence of bacterial contamination of the peritoneal cavity[17]. Williams however report on 700 appendectomies where the stump was not buried without any adverse effects.

6.5 Wound infection

- Wound infection is regarded as a minor complication and usually occurs in the subcutaneous tissues. Dehiscence of a McBurney's incision is rare. Intravenous antibiotics including an antibiotic with an anaerobic spectrum, significantly reduces this complication.

- Williams *et al* [29] points out that this complication can be minimized by a 'no-touch' technique, adequate exposure of the operating field and gentle handling of the anatomical structures.

6.6 Differential diagnosis[30]

- The differential diagnosis is dependent on a) the anatomical location of the inflamed appendix, b) the stage of the process and c) the age and sex of the patient.

- The differential diagnosis of appendicitis is an anatomical diagnosis in the sense that pathology of surrounding anatomical structures in the abdomen can present almost in the same way as acute appendicitis.

- The preoperative diagnosis of appendicitis should be more or less 85% correct to avoid unnecessary operations. However an accuracy rate of more than 90% should also raise concern, for this means that patients with an atypical presentation will not receive prompt operative intervention.

6.6.1 Acute mesenteric adenitis

- Acute mesenteric adenitis is most commonly confused with appendicitis, especially in children. Usually an upper respiratory infection is present or there is a recent history of such an infection. Pain is more diffuse and not sharply localized. Generalized lymphadenopathy is usually present.

6.6.2 Acute gastroenteritis

- Acute viral gastroenteritis can be differentiated from appendicitis by the presence of acute watery diarrhea, nausea and vomiting. Hyperperistaltic cramps are usually present and localizing pain and signs are absent. The abdomen is relaxed between cramps. Salmonella gastroenteritis may present with acute abdominal pain often localized and associated with rebound tenderness.

6.6.3 Urinary tract infection

- Pyelonephritis on the right may simulate the signs of a retroileal appendicitis. These patients also have chills, costovertebral angle tenderness and pus cells, blood and bacteria in the urine.

6.6.4 Ureteral stone

- The stone may be lodged in the vicinity of the appendix. Usually the pain is referred to the scrotum, labia majora or penis. Hematuria is present and leukocytosis absent. Intravenous pyelography confirms the diagnosis.

6.6.5 Pelvic inflammatory disease

- If confined to the right tube pelvic inflammatory disease presents in a similar way as appendicitis. Nausea and vomiting are not prominent. There is acute tenderness of the cervix on vaginal examination and a purulent vaginal discharge may be present.

6.6.6 Ovulation

- Ovulation may result in the spill of a small amount of blood and fluid from the Graafian follicle. This may cause brief abdominal pain and may be confused with appendicitis especially if ovulation is from the right ovary. History taking of the menstrual cycle will reveal that the pain is present at the midpoint of the menstrual cycle and therefore also referred to as mittelschmerz.

6.6.7 Pleuritis or consolidation of the lower lobe of the right lung

- Pain may be referred to the right iliac fossa and can be confused with appendicitis. It is therefore important in the clinical examination to also evaluate the chest.

6.6.8 Henoch Schönlein purpura

- Abdominal pain is prominent, but is associated with joint pain, purpura and nephritis.

6.6.9 Testicular torsion, acute epididymitis and seminal vesiculitis.

- These conditions may also mimic appendicitis. Seminal vesiculitis can be diagnosed by palpating an enlarged tender seminal vesicle on rectal examination.

6.6.10 Meckel's diverticulitis

- The signs and symptoms are very much the same as acute appendicitis. The operative treatment is the same and can be done through a McBurney's incision.

- A Meckel diverticle[24] is found in 2% of people, It usually presents at the age of two

with a brick-red stool because the diverticulum usually contains various types of cells, such as acid-producing cells causing local ulceration and hemorrhaging. The diverticulum occurs 2 feet (60 cm) from the ileocecal valve on the ileum, which is the middle of the midgut. The diverticulum may be 2 inches (5 cm) long. This rule of two's is not necessarily always applicable. The diverticulum is found on the antimesenteric border of the bowel.

6.6.11 Intussusception

- Intussusception usually occurs in children under two years, whereas appendicitis is very uncommon in this age group.

6.6.12 Perforated peptic ulcer

- If the gastroduodenal contents spread to the right iliac fossa it may mimic acute appendicitis. Usually there are epigastric signs as well.

6.6.13 Cecal carcinoma or diverticulitis

- Cecal carcinoma or diverticulitis may be confused with an appendiceal abscess especially in patients older than 50 years.

6.7 Hematuria

- Hematuria may be found in appendicitis due to its close relationship to the right ureter.

6.8 Pyogenic liver abscess[32]

- Spread of the infective focus via the venous drainage of the appendix to the portal venous system in the abdomen, may result in liver abscesses. This complication was frequently encountered in the pre-antibiotic era with an incidence of 10-30%.

- Hematogenous spread of infection occurs via the portal venous system. Liver associated abscesses may also develop due to direct spread via the paracolic gutter lateral to the ascending colon to the hepatorenal space and the subphrenic space to the bare area of the liver. It may also be due to an inflamed appendix which is located in the right hypochondrium due to lack of cecal descent or with an unusually long appendix.

- Pylephlebitis or portal pyemia (endophlebitis of the portal venous system) due to appendicitis was also more common in the pre-antibiotic era. This endovascular infection has a high mortality.

6.9 Cecal fistula

A fistula may form due to sloughing of part of the cecum.

6.10 Hemorrhage[33]

- The ligature of the appendicular artery may slip and cause serious bleeding either intraperitoneally or intraintestinally.

- Rectal bleeding has also been reported. Sandmarks[34] describes as case of a 17-year-old patient who presented with severe rectal bleeding and low Hb 7 days after appendectomy. A second laparotomy revealed that the catgut ligature on the appendix stump slipped off. Bleeding from the appendix stump occurred into the cecum.

- Hessert[41] found that in 5% of cases an arterial branch running from the cecum extramurally to the appendix supplies the base of the appendix. The presence of this artery may increase the risk of postoperative hemorrhage from the appendix stump. Great care should be taken to secure ligation of the blood vessels supplying the base and proximal part of the appendix.

6.11 Femoral nerve injury

- A femoral nerve injury following appendectomy has been reported[36]. Kourtopoulos[36] reports a case where due to an unusual position of the appendix, bleeding from the epigastric vessels was found. Subsequent efforts to stop the bleeding caused the femoral nerve being caught in one of the sutures, with a typical femoral nerve injury involving both sensory and motor functions of the nerve in the thigh.

- The femoral nerve runs in the groove between the iliacus and psoas muscles and underneath the inguinal ligament lateral to the femoral artery.

- Injury to the nerve usually occurs in low abdominal incisions where self-retaining retractors are used.

6.12 Appendicitis following appendectomy[37]

- Francis[37] reports on a case where a patient developed appendicitis after having an appendectomy several years ago. The patient developed acute appendicitis in the appendix stump, which was 1 cm in length. It is therefore important to remove the entire appendix. The appendix should be ligated at the ceco-appendicular junction. The appendix may be bound to the cecum by a peritoneal fold or adhesion. The base of the appendix may also be obscured by inflammation. There are blood vessels supplying the proximal third of the appendix coming from the wall of the cecum. The appendix stump is therefore viable although the appendicular artery was ligated.

Ligation at the ceco-appendicular junction is therefore important to devascularise the proximal appendix.

6.13 Intussusception of the appendiceal stump[38]

- Ileocolic intussusception is a very rare but potentially fatal complication after appendectomy. Wolfson[38] reports on a case where a hemicolectomy was done due to ileocolic intussusception with the appendiceal stump as the leading point of intussusception. The diagnosis is difficult due to the postoperative state.

6.14 Intestinal obstruction

- Intestinal obstruction may develop in the long term due to slowly resolving peritonitis, loculated abscesses and adhesion formation.

6.15 Inguinal hernia

- This late complication rarely occurs in a McBurney incision[35].
  Damage to the segmental nerve supply of the abdominal muscles may eventually lead to the development of hernias.

- Arnbjörnsson[35] studied 826 patients with inguinal hernias and found that 43 had previously undergone an appendectomy. A right inguinal hernia developed in 35 of the 43 cases, left inguinal hernia in 6 and a bilateral inguinal hernia in 2 cases. The ratio of right-sided to left-sided inguinal hernias in the post appendectomy patients was 6:1, compared to 2:1 in those patients who did not had a previous appendectomy. This is a significant difference. Gue[22] found exactly the same ratio in a retrospective study of 701 patients. The most likely cause is injury to the nerves supplying the abdominal muscles and paralysis of the valve of the internal inguinal ring.

- Lytle[42] describes the anatomy of the internal inguinal ring: ' The internal ring is "U" shaped; composed of thickened transversalis fascia, is suspended by its two pillars, medial and lateral to the posterior aspect of transversus abdominis muscle. The curve of the "U" lies at or just above the lower border of the aponeurosis of the transversus muscle. This aponeurosis forms the floor of the ring and is supported in front by the internal oblique muscle.' This forms an efficient valve, which closes with increased intra-abdominal pressure. Injury to the nerve supply of or the transversus abdominis muscle itself may damage the valve action of the internal inguinal ring.

- All the muscles in the inguinal region receive their nerve supply from the iliohypogastric and ilioinguinal branches of L1.

- The ilioinguinal nerve emerges about 1.5 inch medial and inferior to the anterior superior iliac spine and is not in particular danger of injury during a McBurney's incision. However, the iliohypogastric branch is found approximately 2.5 cm (1 inch)

above the ilioinguinal nerve and runs inferiorly and medially in the neurovascular plane between the internal oblique and transversus abdominis muscles. It crosses a line drawn from the umbilicus to the anterior superior iliac spine approximately 5 cm superior to the anterior superior iliac spine.

- A McBurney's incision runs parallel to the nerves. The nerves are in danger if the fibers of the internal oblique are cut. Therefore they should be separated by blunt dissection. The same should be done with the transversus abdominis muscle and posteriorly lying transversalis fasica[22].

- Incisions below the level of the anterior superior iliac spine should be avoided. The ilioinguinal and iliohypogastric nerves may be damaged. Arnbjörnsson[35] and Gue[22] suggest that incision below the horizontal line from the anterior superior iliac spine to the rectus abdominis muscle should be avoided. This is due to the fact that the segmental nerves pierce the anterior abdominal muscles at this level and run in an inferior and medial direction.

- Gue[22] states that the higher incidence of inguinal hernia's on the right after appendectomy may be due to protrusion of peritoneum through the incomplete approximation of the transversus abdominis muscle and transversalis fascia. Separate suturing of the transversus abdominis aponeurosis with the transversalis fascia should therefore be performed.

- Injury to the ilioinguinal nerve may lead to paralysis of the conjoint tendon, which may lead to an indirect inguinal hernia.

- Leech *et al* [23] however has shown in a retrospective study including 549 patients, that right inguinal hernias are not associated with appendectomies. [22]

6.16 Herpes Zoster

- In very rare cases this can be confused with the early onset of Herpes Zoster of the same nerve roots.

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4.4.3.3 Ectopic pregnancy surgery (Salpingectomy, Salpingo-oophorectomy)

1. Indications

- Ruptured ectopic pregnancy.

  Settings where high technology equipment is not available, patients with ectopic pregnancies often present in a hemodynamically unstable condition with a low hematocrit.

- Incidence: In parts of Africa, one in every 40 pregnancies may be tubal[10].

2. Contraindications

- An oophorectomy should be avoided unless the blood supply to the ovary has been seriously compromised[1].

3. Step by step procedure

Surgical treatment of ectopic pregnancies can be classified as either conservative or as an emergency lifesaving procedure in the case of a ruptured ectopic pregnancy.

- Conservative treatment involves the extraction of the ectopic pregnancy with as little damage to the uterine tubes as possible. Conservative treatment involves laparoscopic techniques of performing a linear salpingostomy and extraction of the ectopic pregnancy or salpingectomy [3]. Other treatment modalities include a linear salpingotomy, segmental excision and fimbrial expression as well as medical treatment with methotrexate[9].

- The vast majority of ectopic pregnancies in first world countries are currently, with the aid of advanced diagnostic modalities like transvaginal ultrasound and laparoscopy, diagnosed as unruptured ectopic pregnancies[6]. Therefore, various conservative and nonsurgical modes of management are available. This means that the uterine tube is kept intact.

- Nonsurgical management involves the systemic administration of drugs, which stop

the growth of trophoblastic cells. These drugs can also be administered via laparoscopic or ultrasonographical route directly into the ectopic pregnancy[6].

- Conservative treatment of ectopic pregnancies, require a hemodynamically stable patient, an unruptured uterine tube, an accessible tube and the desire for future fertility[7]. Hankins *et al* [15] also adds the presence of an ectopic pregnancy in the ampulla with a size of less than 5 cm and an easily accessible route without extensive adhesions.

- This form of treatment is not in the scope of this paper, which deals with the emergency surgical treatment of a ruptured ectopic pregnancy. The aim in hemodynamically unstable patients is to control the bleeding site as soon as possible[1]. This most often needs a salpingectomy with or without oophorectomy. During rupture of an ectopic pregnancy, the vasculature of the tube is disrupted and can bleed vigorously.

Salpingectomy

Step 1. Ensure that the patient is hemodynamically stable by having two high flow peripheral lines in place and blood either administered or on standby.

Step 2. Perform a standard lower abdominal laparotomy. A Phannenstiel incision can be performed, but usually takes more time to perform. In an emergency situation it is better to perform a vertical midline incision. This also allows alternative surgical procedures that may be necessary[1].

Step 3. Identify and then elevate the affected uterine tube with an Allis or Babcock clamp.

Step 4. Inspect the other uterine tube and ovary and make sure they are normal. If not, a special effort should be made to spare ovarian tissue on the affected side.

Step 5. Grasp the mesosalpinx with two clamps starting from the fimbrial end and advancing to the base of the uterine tube at the cornu. Avoid the tubal pregnancy. Cut between the clamps. A cautery may also be used, which has the advantage of sealing the small vessels. Do not perform a cornual resection. The advantage of performing a cornual resection is that it reduces the risk of a subsequent ectopic pregnancy implant. However, the disadvantage is that it weakens the myometrial wall and may lead to a uterine rupture in a subsequent pregnancy.

Step 6. Ligate the pedicles with 2.0-delayed absorbable suture.

Step 7. Clamp the tube at the intramural portion. After cutting the tube use a figure eight suture to close.

Step 8. In the case of an intramural pregnancy, a corneal wedge resection needs to be done. An incision is made in the cornu and a small wedge of tissue is removed with the tube at the base of the incision. The round ligament may be used to cover the surgical site and support the uterus.

Salpingo-oophorectomy

An ipsilateral oophorectomy is sometimes necessary. The decision to perform an oophorectomy should be reserved for those patients where the blood supply to the ovary has also been seriously affected[1]. Attempts are currently made to preserve as much ovarian tissue as possible for future fertilization techniques[15].

Step 1. Perform a standard lower abdominal laparotomy.

Step 2. Grasp the uterine tube and the ligament of the ovary with a clamp.

Step 3. Open the peritoneum (broad ligament) lateral to the ovary and uterine tube as well as the suspensory ligament of the ovary. Extend the incision superiorly and inferiorly. Take care to avoid damaging the ureter.

Step 4. Identify the ureter. Check the position of the ureter closely with all further clamping and suturing.

Step 5. Seek an avascular area in the broad ligament with the finger and create a large enough hole to place the clamps.

Step 6. Clamp the suspensory ligament of the ovary with two clamps and incise through the ligament. Ligate the ligament with a free tie and then with a suture ligature placed distally to the free tie. Use delayed absorbable suturing material. Make sure the ureter is away from the structures.

Step 7. Place a curved clamp adjacent to the uterus on the uterine tube and the ligament of the ovary. Excise the specimen.

Step 8. Ligate with a free tie followed by a suture ligature distal to the free tie.

Step 9. Close the peritoneum with continuous suturing of delayed absorbable suture. Take care to avoid the ureter. The two pedicles can be buried in the broad ligament.

4. Materials

- Laparotomy tray
- Equipment for blood transfusion and possible autotransfusion

5. Anatomical pitfalls

5.1 Possible locations of an ectopic pregnancy

- Ectopic pregnancy refers to all places apart from the normal place for development of the pregnancy (έκτοπος = out of place). It therefore includes all sites of implantation outside the uterus and the abnormal sites of implantation inside the uterus like the cervix and corner of the uterus or so-called angular pregnancy.

- The following sites for ectopic pregnancy occur in order of frequency:

    - Ampulla or infundibulum
    - Isthmus
    - Interstitial portion of the uterine tube
    - Peritoneum of the broad ligament, bowel, omentum, mesentery (primary abdominal pregnancy)
    - Ovary
    - Cervix

- Jarcho[11] documented the frequency of ectopic pregnancies according to the site of implantation in over a 1000 cases:

Ampulla and infundibulum:	65.5%
Isthmus	25.0%
Interstitial portion of the uterine tube	4.2%
Abdominal	1.6%
Entire tube with or without involvement of the ovary	2.3%
Ovary	0.5%
Broad ligament	0.5%
Cornu	0.3%
Rudimentary horn	0.1%

- Niles *et al* [26] reports that over 50% of cases involved the distal third of the uterine tube.

- More recently Hankins *et al* [15] reports that 95% of ectopic pregnancies implant in the uterine tube (91% in the ampulla and 4% in the isthmus), 2.5% occur in the cornu of the uterus and 2.5% in other locations like the ovary (0.5%), cervix (0.1%) and abdomen (0.03%).

5.2 Uterine tube

- The uterine tube has the following parts: Ampulla, infundibulum, isthmus and cornu. An ectopic pregnancy may be found in any of these sites.

- The most common site for a tubal pregnancy is the ampulla of the uterine tube[4].

Approximately 65.5 - 85% of tubal pregnancies attach to the ampullary region of the uterine tube, and 15 - 25% attach to the isthmus (proximal portion)[7 11]. The ectopic pregnancy is located in the lumen of the uterine tube, within the wall of the tube or in both[4].

- The left and right uterine tubes are involved with equal frequency[10].

5.2.1 Ampulla

- The ovum attaches to the columnar epithelium of the ampulla of the uterine tube and affects the muscular tissue, connective tissue and blood vessels. The blood vessel walls are eroded by the trophoblast, similar to the intervillous space formation in the uterus. There is no support from muscles or deciduas as is the case in the uterus. The ectopic pregnancy can therefore easily rupture. It can also be aborted or in very rare cases develop in later months. Tubal abortion means that the ectopic pregnancy is expelled from the uterine tube leaving a damaged tube behind.

- Rupture or perforation of the ampulla of the uterine tube occurs as a rule between week 6 and 10 from the last menstrual period (LMP).

- Rupture may take place into the peritoneal cavity or extraperitoneally into the layers of the broad ligament. Intraperitoneal rupture is more common and bleeding is more serious. With extraperitoneal rupture the bleeding is limited by the layers of the broad ligament. Myerscough [10] however describes a case of severe bleeding of an extraperitoneally ruptured ectopic pregnancy with blood spreading to the level of the umbilicus.

- A large quantity of blood can be lost into the peritoneal cavity in a short time, with a patient collapsing.

- Myerscough[10] however reports that the rupture of the tubal wall is a gradual erosion with recurrent episodes of bleeding and possible syncope as well as lower abdominal pain.

5.2.2 Isthmus

- An ectopic pregnancy in the isthmus of the uterine tube usually perforates early between the second or third week. It may occur before a menstrual period is missed.

- The isthmus part of the tube is less distensible and the muscular wall less developed. Therefore rupture occurs early with sudden collapse and shock.

5.2.3 Interstitial part of the uterine tube (cornual pregnancy)

- Ectopic pregnancies rarely occur in the interstitial part of the uterine tube.

Myerscough [10] reports one case in a series of more than 200 ectopic pregnancies. The gestational sac may extend to the uterine cavity or into the tube.

- Rupture may occur into the uterus but more commonly into the peritoneal cavity. It is accompanied by vigorous bleeding. This may occur on a later stage in the second trimester. It closely resembles an angular pregnancy or a pregnancy in a rudimentary horn.

- The interstitial part of the uterine tube is 1cm in length and is surrounded by myometrium.

- There is more extensive trophoblastic invasion, with increased vascularity. The diagnosis is often delayed and has a higher maternal morbidity and mortality[15].

- Excision of these ectopic pregnancies often necessitates the resection of a portion of the myometrium as well.

5.2.4 Ovarian pregnancy

- True ovarian pregnancies have been reported[10]. Rupture occurs at a relatively early date although full term ovarian pregnancies are described. Spiegleberg[17] defined the ovarian pregnancy according to the following criteria:

    1) The uterine tube and fimbriae should be intact on the affected side,
    2) The gestational sac should be located on the ovary,
    3) The ovary should be connected to the uterus by the ligament of the ovary and
    4) Ovarian tissue should be found in the wall of the gestational sac.

5.2.5 Abdominal pregnancy

- Primary attachment of the ovum in the peritoneal cavity is rare and abdominal pregnancies are usually due to a pregnancy being aborted or ruptured from the uterine tube and subsequent development in the peritoneal cavity.

- After rupture the ovum usually dies, but may nestle itself in the abdomen in surrounding structures like the omentum and mesenteries and continue to grow as an abdominal pregnancy.

- Iffy[13] describes a case of primary implantation in the rectouterine pouch.

- Healy[14] describes a case of primary abdominal pregnancy with the placenta attaching to the cecum.

- Hosking[12] describes a case where the placenta stayed in the tube, the cord ran through the ostium with an abdominal pregnancy reaching 2.3 kg, but the infant died soon after delivery.

- An abdominal pregnancy may also develop between the layers of the broad ligament. As the pregnancy grows the layers of the broad ligament are separated and the peritoneum of the bladder and rectum is dissected by the growing pregnancy and as it develops it forms adhesion with surrounding structures[10].

5.2.6 Heterotopic pregnancies

- A heterotopic pregnancy refers to the simultaneous coexistence of an intrauterine and extrauterine pregnancy. The incidence is reported to be 1 in every 30 000 pregnacies[15].

5.3 Histology

- An ectopic pregnancy may be located within the wall of the uterine tube, especially in the ampullary region of the uterine tube. The pregnancy therefore develops extraluminally[2]. Senterman *et al* [16] however reports on ampullary pregnancies being intraluminal in 56% of cases, extraluminal in 7% and both extra- and intraluminal in 37% of cases.

- In the isthmic region of the uterine tube, ectopic pregnancies are usually located within the lumen.

- In a histopathological study, Pauerstein[4] showed that in 25 consecutive cases, the pattern of spread of the trophoblast and hemorrhage was intraluminal, extraluminal or both of the two. Maternal blood vessels are invaded by the trophoblast soon after implantation. This results in hemorrhage in the uterine tube, often leaking out of the abdominal ostium causing a great deal of destruction of maternal tissues.

- An intraluminal trophoblast sometimes leaves the entire epithelial lining intact, eroding the endosalpinx or persists as discontinuous islands along the periphery of the dilated tubal lumen.

- Extraluminal proliferation of the trophoblast occurs between the layers of the wall of the uterine tube. Initially implantation occurs in the lumen, which is soon followed by penetration into the lamina propria and muscularis.

- The invading trophoblast usually simulates the same responses of the trophoblast invading the decidua of the endometrium[2]. After destroying the epithelium, the trophoblast invades the muscularis. The muscularis usually restricts the growth of the trophoblast up to a point where rupture occurs.

5.4 Mechanism of rupture

- The mucosal layer is usually destroyed and may only involve a small portion of the circumference of the mucosa. Blood vessels in the lamina propria and subserosa are

invaded by the trophoblast cells. The resulting hemorrhage into the lumen and uterine tube wall causes severe damage to the uterine tube.

- The muscularis is usually stretched until only a few fibers of muscle and serosa are left before rupture occurs. Distension of the tube is usually primarily due to an accumulation of intraluminal blood and secondarily due to the expanding pregnancy[16].

- The muscularis is destroyed in more than half of the cases.

- Senterman *et al* [16] reports that the disruption of the tubal wall is usually less severe in an ampullary pregnancy compared to an isthmic pregnancy.

- Timonen *et al* [25] found that ruptured tubal pregnancy was more frequent than unruptured tubal pregnancy in older age groups, possibly because of lowered elasticity of the tissues. They may also postpone seeking medical help, because they may have experienced various kinds of abdominal pains before.

5.5 Mechanism of oval pick-up[4]

- The fimbriae of the uterine tube sweep across the surface of the ipsilateral ovary during ovulation. The ovum has a sticky cumulus mass, which combined with the dense fimbrial network advances the ovum into the infundibulum of the uterine tube. The ovum is therefore picked up from the ovarian surface. This mechanism is so effective, that the ovum can also be picked up from as far down as the rectouterine pouch.

5.6 Ectopic pregnancy - mechanism

- Underlying salpingitis affects the transport of the fertilized ovum through the tube to the uterine cavity and is said to be the most significant risk factor for ectopic pregnancies due to scarring of the uterine tubes. This pelvic infection often involves *Chlamydia* and *Neisseria Gonorrhea*. Niles *et al* [26] however has demonstrated in a histopathological study including 436 cases of ectopic pregnancy, that the histological diagnosis of chronic inflammatory disease was present in only 40% of the cases. Apart from structural defects, he postulates that there may also be a functional disturbance of the uterine tube responsible for ectopic pregnancy.

- Another possible mechanism is delayed oval pick up, where fertilization and early stages of pre-implantation development has already occurred. The fertilized ovum therefore implants in the ampullary region of the uterine tube.

- Another theory by McElin *et al* [5] holds that ectopic pregnancy is due to delayed ovulation and fertilization. This fails to suppress menstruation, which flushes the fertilized oocyte from the uterine cavity into the uterine tubes.

- The following factors increase the incidence of ectopic pregnancies[15]:

  - Pelvic inflammatory disease.
  - Tubal sterilization.
  - Tubal surgery like salpingostomy.
  - Assisted reproductive technologies.
  - Use of an intra uterine contraceptive device (IUCD).
  - Diethylstilbestrol exposure.
  - Use of low dose pregestational agents.
  - Improvements in diagnostic techniques.

5.7 Diagnosis

5.7.1 History and physical examination

- The classic triad of an ectopic pregnancy is: Pain, vaginal bleeding and a palpable adnexal mass after missed menses. After rupture, the patient usually presents in shock.

- The onset of symptoms ranged from one to 27 weeks (counted from the last normal menstruation) in Dorfman *et al's* study[8]. Half of women developed symptoms within eight menstrual weeks and by 12 weeks 75% experienced symptoms related to the ectopic pregnancy.

- **Pain**[7]

  Abdominal pain occurs in 85-100% of women with an ectopic pregnancy. The pain is caused by peritoneal stretching of the expanding uterine tube or from blood in the peritoneal cavity due to rupture or leakage from the uterine tube.

- **Vaginal bleeding**[7]
  After pain, vaginal bleeding is the most common symptom, occurring in 60% of women. Bleeding is dark and continuous and is caused by insufficient hormonal support of the endometrial deciduas and consequent shedding.

- **Adnexal mass**[22]

  This mass can be palpated by vaginal or bimanual palpation. It can be difficult due to patient discomfort. The cervix is extremely tender on examination. There may be some tender resistance in the rectouterine pouch (Pouch of Douglas).
  With localized bleeding, there may be an irregular swelling in the adnexa.

- **Shock**[15]

  Less than 5 percent of women with an ectopic pregnancy are reported to present with hypovolemic shock due to intraperitoneal blood loss. This is the situation in a first

world country.

- **Abdominal signs**

  More typical is the presentation with abdominal pain, guarding and rebound tenderness in the suprapubic region or one or both of the iliac fossae due to blood irritating the peritoneum.

5.7.2 Biochemical tests

- New immunoradiometric assays can diagnose the presence of human chorionic gonadotrophin (HCG) as early as 1 week before expected menses[24].

- Kadar *et al* [9] reports that β HCG levels double every 1.98 days in normal early intrauterine pregnancies. An increase of less than 66% in 2 days (48 hours) is predictive of an ectopic pregnancy.

- Low progesterone levels are also associated with ectopic pregnancy.

5.7.3 Culdocentesis (Culpotomy)

- A culdocentesis is done to obtain a specimen of possible fluid, pus or blood from the rectouterine pouch via the posterior fornix of the vagina.

- This procedure is especially valuable in the presence of a ruptured ectopic pregnancy.

- Culdocentesis is indicated in a patient with a possible ectopic pregnancy where sophisticated diagnostic modalities such as sensitive diagnostic assays and ultrasound are not available or may cause considerable delay before obtained[18].

- Non-clotting blood obtained from a culdocentesis with a positive pregnancy test is 99 percent accurate for ectopic pregnancy and surgical treatment can commence[18].

- A positive culdocentesis is not necessarily associated with a ruptured ectopic pregnancy. Romero *et al* [18] found 62% of patients with a positive culdocentesis but unruptured ectopic pregnancy with slow and intermittent bleeding.

- The differential diagnosis of a ruptured ovarian cyst, ruptured endometrioma or bleeding from elsewhere should be considered. A negative culdocentesis does not rule out an ectopic pregnancy.

- Hematocrit determinations on culdocentesis fluid can differentiate between an ectopic pregnancy and a ruptured ovarian cyst. A hematocrit level of above 12 to 15% indicates an ectopic pregnancy[24].

- A negative culdocentesis does not rule out a hemoperitoneum. A hemoperitoneum may also present without the traditional signs of peritonitis during physical examination. Romero[18] therefore argues that a culdocentesis should not be restricted to patients with physical signs of peritoneal irritation.

- **Anatomy of culdocentesis**

    - The vagina is approximately 9 cm long in an adult female.

    - The posterior vaginal wall is related from superior to inferior by the peritoneum of the rectouterine pouch, the rectum, anal canal and perineal body.

    - The upper 2 cm of the posterior wall of the vagina is related to the rectouterine pouch and is less than 5mm thick in this region.

    - The superior part of the vagina is supplied by branches of the uterine and vaginal arteries, which are both from the internal iliac artery.

    - The rectouterine pouch is formed by reflections of peritoneum and separates the rectum from the uterus and superior part of the vagina.

    - Free fluid can accumulate in the rectouterine pouch in both the upright and supine positions.

    - The pouch may contain small bowel and usually a small amount of peritoneal fluid.

- Contraindications for culdocentesis include an uncooperative patient, a pelvic mass (tubo-ovarian abscesses, appendiceal abscesses, pelvic kidneys), a non-mobile retroverted uterus and coagulopathies.
- Large masses in the rectouterine pouch should be excluded by careful bimanual examination.

- **Step by step procedure**

    - **Step 1.** Perform a careful bimanual examination

    - **Step 2.** Insert a vaginal speculum and open it widely

    - **Step 3.** Grasp the posterior lip of the cervix with the uterine cervical tenaculum. Stabilize the posterior vaginal wall by elevating the cervix

    - **Step 4.** Swab the posterior part of the vaginal wall with a surgical preparation

    - **Step5.** Administer local anesthesia

- **Step 6.** Attach a spinal needle to a 20ml syringe
- **Step 7.** Advance the needle parallel to the posterior blade of the speculum.
- **Step 8.** Penetrate the vaginal wall 1-1.5 cm posterior to the posterior border of the cervix in the midline. Penetrate 2 - 2,5cm[28].
- **Step 9.** Aspirate while the needle is gradually withdrawn.

- **Complications of culdocentesis include:**
  - Rupture of an unsuspected tubo-ovarian abscess
  - Perforation of bowel (not usually associated with high morbidity)
  - Puncture of the uterine wall
  - Perforation of a pelvic kidney
  - Bleeding from the puncture site, especially in the presence of clotting disorders.

5.7.4 Ultrasound anatomy

- Ultrasonographic findings include the absence of a gestational sac in the uterine cavity with endometrial reaction and a mass in one of the adnexae or a demonstration of a gestational sac outside the uterine cavity.

- High resolution vaginal ultrasonography and sensitive assays of β HCG (Human chorionic gonadotrophin) has made early detection of ectopic pregnancies possible and subsequently various conservative techniques to surgically manage ectopic pregnancies without removing the uterine tube and ipsilateral ovary.

- Kadar *et al* [9] has shown that a gestational sac can be visualized by transabdominal ultrasonography with a concentration of HCG greater than 6500 mIIU/ml[9] and 1200 to 1500 mIIU/ml when using a transvaginal probe[23]. The absence of a gestational sac with a positive HCG test above this concentration indicates an ectopic pregnancy. Presence of the gestational sac indicates an intrauterine pregnancy. The absence of a gestational sac with HCG levels below this concentration has diagnostic value.

- Transvaginal sonography can however visualize the gestational sac at lower HCG levels and see the adnexal structures with better resolution. This is because the probe is closer in proximity to the pelvic organs.
  An intrauterine gestational sac can first be seen with a transvaginal ultrasound at 5 weeks gestation[15].

- Fleischer *et al* [19] reports on the ultrasound findings in 47 women with ectopic pregnancy. This is presented in a table modified by Hankins *et al* [15]:

Ultrasonic findings	%
Uterus	
Thickened endometrium	43
Pseudogestational sac	15
Adnexal structures	
Tubal ring	49
With living embryo	21
With embryo and yolk sac	8
With dead embryo	4
With yolk sac	6
Without embryo and yolk sac	15
Corpus luteum	34
Nonspecific adnexal mass	28
Dilated tube	19
Peritoneal cavity	
Clear fluid	47
Particulate fluid	28

The tubal ring produced by the ectopic pregnancy in the uterine tube, represents an unruptured uterine tube.

5.7.5 Diagnostic laparoscopy[15]

Laparoscopy provides a direct visual assessment instrument of the pelvic organs and ectopic pregnancy. Surgical removal of most uncomplicated ectopic pregnancies can be done via this route.

5.7.6 Duplex Doppler techniques

Vascular patterns in the adnexae can be visualized with color flow Doppler and can be seen on the conventional B-mode at the same time. Trophoblastic flow gives a high velocity and low impedance signal. If this pattern is seen separate from the uterus and ovary, it suggests trophoblastic flow of an ectopic pregnancy[15]. Pellerito[20] reports a sensitivity of 95% for diagnosing an ectopic pregnancy with color flow imaging.

5.8 Differential diagnosis[22]:

- Pyosalpinx
- Hematosalpinx
- Retroverted gravid uterus
- Early stage of uterine abortion
- Acute appendicitis
- Gastrointestinal disorders

- Urinary tract infection
- Intrauterine pregnancy

5.9 Uterus[10]

- The uterus may be displaced anteriorly, posteriorly or laterally due to the ectopic pregnancy in the uterine tube. The uterus also changes in size, shape and consistency.

5.10 Multiple ectopic pregnancies

Fujii *et al* [27] reports a case of a rare unilateral tubal quadruplet pregnancy. Unilateral twin and triplet pregnancies are rare as well. The cause of these multiple ectopic pregnancies are thought to be the same as for ectopic pregnancies, being pelvic inflammatory disease, congenital abnormalities, operative trauma and tumors.

6. Complications (anatomically relevant)

6.1 Delayed or misdiagnosis

- Delay or misdiagnosis by clinicians contributed up to 53% of cases of maternal death related to ectopic pregnancy in Dorfman *et al*'s study[8]. In an additional 5% of cases, the diagnosis was made without prompt enough intervention. Eight percent of maternal deaths were associated with both clinician and patient delay. Patient delay is usually due to the mild nature of symptoms, which the patient regards as unimportant.

- The diagnosis of ectopic pregnancy was often confused with gastrointestinal disorders (25%), intrauterine pregnancy (18%), pelvic inflammatory disease (14%), psychiatric disorders (9%), spontaneous abortion (9%), complications of induced abortion (7%) and urinary tract infection (7%)[8].

6.2 Maternal mortality

6.2.1 Acute hemorrhage

- Ruptured ectopic pregnancy is a leading cause of maternal death in the USA. In a study of 86 deaths from 102 100 patients with ectopic pregnancies, 85% of the cases died due to acute hemorrhage[8]. About 70% of those who died from hemorrhage did not have any surgery for ectopic pregnancy. It is clear that early intervention is crucial.

- Most women (75%) died within 12 weeks gestational age of the pregnancy. This shows that most ectopic pregnancy deaths are seen in the first trimester. Ectopic pregnancy deaths seen after 12 weeks were mostly in interstitial, cornual or abdominal locations of the ectopic pregnancy.

- Of all maternal deaths related to ectopic pregnancy, 78% occurred within the fallopian tube distal to the uterine insertion, whereas 22% were situated in the interstitial, cornual or abdominal locations. The implantation site is an important risk factor. Although interstitial, cornual and nontubal implantations are rarely found[11], they accounted for 20% of maternal deaths in Dorfman *et al*'s study[8]. They are therefore two to five times more at risk compared to ectopic pregnancies distal to the cornual junction. The diagnosis is more difficult and due to their increased size and vascularity they present as an extremely dangerous clinical situation when ruptured.

- Abdominal and interstitial implantations were more likely in the same study [8] to become symptomatic later in pregnancy when compared to more distal locations of ectopic pregnancies.

- Dorfman *et al* [8] concludes that timelier diagnosis and treatment by health professionals might have prevented half of the deaths.

6.2.2 Infection

- Dorfman *et al* [8] reports in his study that infection was after hemorrhage the second most common cause of death with an incidence of 5% leading to maternal mortality.

6.2.3 Anesthesia related deaths

- Dorfman *et al* [8] reports that anesthesia related complications were the third leading cause of death in ectopic pregnancies with an incidence of 2%.

6.2.4 Other

- Other causes of death were pulmonary edema, transfusion reaction with cardiac and renal failure, and air embolism due to auto-transfuser malfunction and pulmonary embolism.

6.3 Fertility

- Dubuisson[21] reported on the fertility of 125 women who had a unilateral salpingectomy. Of those with a normal contralateral uterine tube, 50% had a normal pregnancy and 20% a repeat ectopic pregnancy in the contralateral tube. Of those with an abnormal contralateral uterine tube, a quarter had a normal pregnancy or repeat ectopic pregnancy.

- Timonen *et al* [25] reports on 1085 patients treated for ectopic pregnancy. They found that of those treated with radical surgical procedures (77.5%), 49.3 % became pregnant again and 30.4% had normal term pregnancies.

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