REVIEW OF LITERATURE

History

Hernias have been a subject of interest since the dawn of surgical history. The history of hernia repair is the history of surgery.[21]

The earliest recorded reference for hernia was in ‘Egyptia Papyrus of Ebers’ 1522 BC. Hippocrates had differentiated between hernia and hydrocele around 400 BC. The former was reducible and the latter transilluminable.[1] The ancient Indian surgeon Sushruta had wrote ‘Sushruta Samhita’ around 400 BC, which includes major abdominal surgeries and surgeries like repair of hernia, anal fistula, fractures with help of sharp surgical instruments like knives and needles.[22]

The history of hernia surgery for groin hernia has gone through many stages of development. These can be divided as -[10]

1. Ancient era (ancient times to the fifteenth century)
2. Era of the start of herniology (fifteenth to seventeenth centuries)
3. Anatomic era (seventeenth to nineteenth centuries)
4. Era of repair under tension (nineteenth to mid-twentieth century)
5. Era of tensionless repair (mid twentieth century to the present)

There have been a number of erudite reviews on the history of hernia and its treatment. The final word on surgery for hernia is yet to be heard. Hernia surgery has gone through a major evolution from the days of the truss and castration to the present day laparoscopic extra peritoneal surgery.

*Five principles of modern hernia repair* developed through these periods of development includes –[10]

- antiseptic/aseptic operation
- high ligation of the sac
- tightening of the internal ring
- reconstruction of the posterior inguinal floor
- tension free repair.

The development of hernia surgery of (1) *ancient era*, (2) *start of herniology era* and (3) *anatomic era* were contributed by many legends in the field of surgery.
Table 1: Time line and contribution of the legendary contributor surgeon of ancient era, start of herniology era and anatomic era [1, 10, 21, 23]

<table>
<thead>
<tr>
<th>Time</th>
<th>Contributor</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancient Era (Ancient time to fifteenth century)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 AD</td>
<td>Celsus</td>
<td>Detailed description of hernia surgery with haemostasis and preservation of the testicles.</td>
</tr>
<tr>
<td>200 AD</td>
<td>Galen</td>
<td>Hernia produced by rupture of peritoneum with stretching of overlying fascia and muscles.</td>
</tr>
<tr>
<td>700</td>
<td>Paul of Aegina</td>
<td>Distinguished between incomplete (bubonocele) and complete (scrotal) inguinal hernia; for complete hernia he recommended ligature of sac with cord and orchiectomy.</td>
</tr>
<tr>
<td>1363</td>
<td>Guy de Chauliac</td>
<td>Distinguished inguinal from femoral hernia; develop 'Taxis' method to reduce hernia in Trendelenberg position.</td>
</tr>
<tr>
<td>Era of the Start of Herniology (Fifteenth to Seventeenth Centuries)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1510-90</td>
<td>Ambrose Pare</td>
<td>Advocated trusses, condemned orchiectomy, operation in incarcerated and strangulated hernia.</td>
</tr>
<tr>
<td>1556</td>
<td>Pierre Franco</td>
<td>Introduced grooved director for incising neck of sac in strangulated hernia without risk of bowel injury.</td>
</tr>
<tr>
<td>1559</td>
<td>Caspar Stromayr</td>
<td>Defined direct and indirect hernias; Stressed importance of high ligation of indirect sac;</td>
</tr>
<tr>
<td>Anatomical Era (Seventeen to Nineteenth Centuries)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td>Littre</td>
<td>Reported Mackel’s diverticulum in hernia sac.</td>
</tr>
<tr>
<td>1731</td>
<td>De Garengeot</td>
<td>Reported appendix in the hernia sac.</td>
</tr>
<tr>
<td>1743</td>
<td>Demetruș deCantemir</td>
<td>Described transabdominal approach for inguinal and femoral hernia.</td>
</tr>
<tr>
<td>Year</td>
<td>Name</td>
<td>Contribution</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1754</td>
<td>Albrecht von Haller</td>
<td>Describe congenital hernia</td>
</tr>
<tr>
<td>1714-1788</td>
<td>Percival Pott</td>
<td>Early surgery for congenital hernia</td>
</tr>
<tr>
<td>1722-1789</td>
<td>Pieter Camper</td>
<td>Described Camper's fascia; ascribed causes of hernia to ‘lifting, bumping, falling’; described etiology of congenital, direct and indirect hernias; describe closure of processus vaginalis</td>
</tr>
<tr>
<td>1752-1832</td>
<td>Antonio Scarpa</td>
<td>Described Scarpa fascia, Scarpa sheath (cremasteric fascia), Scarpa triangle (femoral triangle), Sliding hernia; improvement in hernia repair techniques</td>
</tr>
<tr>
<td>1785</td>
<td>Richter</td>
<td>Described Richter’s hernia - partial enterocele</td>
</tr>
<tr>
<td>1718-1841</td>
<td>Astley Cooper</td>
<td>Described superior pubic ligament of Cooper; cremasteric fascia and transversalis fascia;</td>
</tr>
<tr>
<td>1790</td>
<td>John Hunter</td>
<td>Describe process vaginalis being continuous with tunica vaginalis and may be the cause of some congenital nature of indirect hernias; described gubernaculum testis</td>
</tr>
<tr>
<td>1759-1816</td>
<td>Hesselbach</td>
<td>Defined iliopubic tract; Describe ‘corona mortis’; Described importance of the medial triangle of groin (included the femoral canal) for direct hernia</td>
</tr>
<tr>
<td>1817</td>
<td>Juleus-Germian Cloquet</td>
<td>Post natal closure of processus vaginalis; made observations of the iliopubic tract;</td>
</tr>
<tr>
<td>1791-1870</td>
<td>John Gay</td>
<td>Femoral sheath and canal</td>
</tr>
<tr>
<td>1734-1818</td>
<td>DeGimbermat</td>
<td>Described lacunar ligament; and its division in the treatment of strangulated femoral hernia</td>
</tr>
<tr>
<td>1823</td>
<td>Bogros</td>
<td>Bogros space – triangular space in iliac region</td>
</tr>
<tr>
<td>1888</td>
<td>Eduardo Bassini</td>
<td>The father of ‘modern hernia surgery’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bassini’s technique—“triple layer approximation to the shelving edge of inguinal ligament.”</td>
</tr>
</tbody>
</table>
(4) Era of Hernia Repair under Tension (Nineteenth to Midtwentieth Century)

- Lister introduced antiseptic surgery about 1870, followed by Halsted's introduction of gloves in 1896 and Von Mickulicz translated antiseptic surgery to aseptic surgery in 1904, the scene was set for the techniques of modern hernia surgery to develop.
- Marcy, Steele and Kocher had done sac management through the external inguinal ring. Lucas-Championniere was first to split the external oblique aponeurosis, lay open the inguinal canal, and imbricates the roof during closure. The sac was excised under direct vision down to the internal ring.
- Marcy in 1871, first three of the modern principles of inguinal surgery were used, antisepsis/ asepsis, high ligation of the sac, and tightening of the internal ring. Unfortunately, these procedures failed to achieve the goal of radical cure of inguinal hernia. [10]

Table 2: Time line and contribution of the legendary contributor surgeon of Era of Hernia Repair under Tension.[1, 10, 21, 23]

<table>
<thead>
<tr>
<th>Year</th>
<th>Surgeon</th>
<th>Technique of hernia repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>1870</td>
<td>Lister</td>
<td>Antiseptic surgery</td>
</tr>
<tr>
<td>1896</td>
<td>Halsted</td>
<td>Introduction of Gloves;</td>
</tr>
<tr>
<td>1904</td>
<td>Von Mickulicz</td>
<td>Aseptic surgery</td>
</tr>
<tr>
<td>1871</td>
<td>Marcy</td>
<td>Described first three principles of inguinal surgery; antisepsis/ asepsis, high ligation of the sac, and tightening of the internal ring.</td>
</tr>
<tr>
<td>Year</td>
<td>Surgeon</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>----------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1881</td>
<td>Lucas-Championniere</td>
<td>High ligation at deep ring, opened the external oblique aponeurosis to expose the entire inguinal canal</td>
</tr>
<tr>
<td>1887</td>
<td>Bassini</td>
<td>Reconstruction of posterior inguinal floor by approximation of &quot;triple layer&quot; (EO, IO TF) to the shelving border of the inguinal ligament with interrupted sutures with silk, leaving the cord under the external oblique aponeurosis.</td>
</tr>
<tr>
<td>1888</td>
<td>Williams Halsted</td>
<td>Similar to Bassini out change in cord placement-  Halsted I- Cord behind the skin  Halsted II- Cord behind the repair  Abandoned cord skeletonization.</td>
</tr>
<tr>
<td>1891</td>
<td>Robert Lawson Tait</td>
<td>Developed a repair of the femoral hernia from within the peritoneal cavity</td>
</tr>
<tr>
<td>1876</td>
<td>Thomas Annandale</td>
<td>Concept of preperitoneal hernia repair</td>
</tr>
<tr>
<td>1920</td>
<td>Cheatle G. L</td>
<td>Explored preperitoneal repair for bilateral hernia with single incision, periosteal flap to inguinal ligament.</td>
</tr>
<tr>
<td></td>
<td>Henry</td>
<td>Rediscover Cheatle procedure of preperitoneal repair; later on procedure known as Cheatle-Henry procedure</td>
</tr>
<tr>
<td></td>
<td>Nyhus</td>
<td>Popularize Cheatle Henry procedure in routine use, so the procedure known as NYHUS operation</td>
</tr>
<tr>
<td>1945</td>
<td>Shouldice E.</td>
<td>Three layered overlapping repair with continuous suturing.</td>
</tr>
<tr>
<td></td>
<td>McVay</td>
<td>Suturing of transverse abdominis arch to Cooper’s ligament. (Cooper ligament repair)</td>
</tr>
<tr>
<td>1948</td>
<td>Molony</td>
<td>Describe darn with the use of nylon for hernia repair</td>
</tr>
</tbody>
</table>

(5) Era of Tensionless Hernia Repair (Mid-twentieth Century to the Present)

Relaxing incisions and darn was introduced to overcome the tension led by the Bassini’s repair on the pubic end of the repair, resulting in pain and recurrence at that site.
• Wolfer designed the anterior relaxing incision in the rectus sheath to overcome this problem. Berger had made an incision in the anterior rectus sheath, sutured the lateral flap down to inguinal ligament.[10]

• An alternative method is to use foreign material to overcome the tension. Mc Arthur used strips of pedicled external oblique aponeurosis. Gallie and Le Mesurier used strips of fascia lata. Handley used silk for darn and staylace technique and Molony used nylon darn for hernia repair which gained wide acceptance.[10]

Billroth speculated: "If only the proper material could be created to artificially produce tissue of density and toughness of fascia and tendon, the secret of the radical cure of hernia would be discovered."[24]

Prosthetic mesh first used in 1944 by D.E. Acquaviva of Marseille (France). He presented the first use of a synthetic mesh – nylon (polypropylene was not available until 1957) in a manner that eliminated herma and tension while leaving a defect intact. His original report had 18 cases and had emphasized that the mesh should be "largely beyond the edges of the defect" and "pores not be too small nor the weave too tight", which could otherwise interfere with the incorporation of the prosthesis within its bed". The Acquaviva tension free technique, in its original concept of leaving a defect intact and covering it with a prosthesis must be credited with the primacy and the paternity of the tension free repair.[9, 25]

• Francis Usher (1908-80) was a pioneer who focused on development of mesh prosthesis. He tried different materials and finally arrived to use polypropylene, introduced as Marlex 50 by him, in a series of experimental and early clinical papers reported from 1959 to 1963. The results of this mesh on hernia repair were good.[26]
This mesh induces an inflammatory reaction and scarring. This characteristic led to an enormous impact on surgery and has become the most popular mesh available for surgical implantation. Numerous reports have attested to its usefulness.[10]

Presently, three biomaterials currently in widespread use throughout the world for hernia repair are (1) Polyester mesh (Dacron) (2) Polypropylene mesh; and (3) the Expanding (e)-PTFE patch [26]

• Pre peritoneal mesh placement was introduced by Henri Fruchaud in 1956 using a nylon mesh which was fixed to transverses abdominis/internal oblique and Cooper's ligament, which was then popularized by Rives, with slit to cover the cord.[9]

• In 1975, Stoppa and colleagues first described use of a large (patch that was six "to ten times larger than the area of the hernia defect) unsutured Dacron prosthesis
without slit in it, for repair of difficult groin hernias using a preperitoneal approach via a low midline incision.[26] He reported that properly placed mesh in the preperitoneal space acts as artificial non absorbable endoabdominal fascia, making the abdominal wall instantly and definitely pressure-tight and hernia-resistant.[10]

- **Mesh plugs** were introduced by Irving Lichtenstein in 1968 by using a rolled cylindrical or "cigarette" Marlex mesh plug for treatment of femoral and recurrent inguinal hernias.

In 1987, Bendavid devised a clever umbrella-shaped Marlex prosthesis for femoral hernia to be inserted from below into the preperitoneal space. He also described three-leafed "Fletching" mesh prosthesis for reconstruction of the groin floor. Around same time Arthur Gilbert also have introduce his plug.

In 1989, Rutkow and Robbins began using hand-fashioned "umbrella" plug which was later on commercially produced as ‘PerFix’ by C.R. Bard Company.[10]

In 1914 by Sir Francis Darwin, the son of Charles Darwin made statement that "In science, the credit goes to the man who convinces the world, not to the man to whom the idea first occurs”[9]

- **Lichtenstein** popularized **Meshplasty as a common concept for all the hernias** in 1989. He introduced the current concept of the “tension free” polypropylene mesh repair, as an office procedure under local anesthesia, into everyday common practice. **He also pioneered the idea that hernia surgery is special and it must be performed by an experienced surgeon and float the concept” Herniology”, which had lead a major shift towards use of prosthesis.**

  Thus, the fifth principle was established.

**Laparoscopic hernia repairs**

The first laparoscopic surgery for hernia was a closure of the neck of the sac done by P. Fletcher (1979, West Indies).

- **Ger** in 1982, first reported laparoscopic operation to close the neck of sac using a Michel clip, which did not have good result as there was no attempt to repair the posterior inguinal floor, but have gradually given way to attempts to repair the hernial defect.[10]

- **Arregui** in 1991, introduced TAPP (transabdominal preperitoneal repair).
• Phillips and colleagues in 1993, performed TEP (total extra peritoneal repair) by exposing the myopectineal orifice of Fruchaud and placing polypropylene mesh between the peritoneum and the abdominal wall.

• Fitzgibbons and colleagues in 1995, presented IPOM (intra peritoneal mesh repair) using polypropylene mesh.[23]
The true extent of the burden of hernia disease is unknown. However, one can estimate the burden of hernia with the help of some statistics presented in the literature.

Hernia repair is the second most frequently performed operation in France and in the United States, the prevalence being 36 for every 1000 males.[27]

In United States inguinal, femoral, umbilical, and epigastric hernias collectively represent the most common group of major operations performed by general surgeons.

Table 3: Abdominal wall hernia repairs in the United States[3]

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inguinal hernia</td>
<td>770,000</td>
<td>66.38%</td>
</tr>
<tr>
<td>Femoral hernia</td>
<td>30,000</td>
<td>2.59%</td>
</tr>
<tr>
<td>Umbilical hernia</td>
<td>175,000</td>
<td>15.08%</td>
</tr>
<tr>
<td>Epigastric, spigelian,etc.</td>
<td>80,000</td>
<td>6.90%</td>
</tr>
<tr>
<td>Incisional hernia</td>
<td>105,000</td>
<td>9.05%</td>
</tr>
<tr>
<td>Total</td>
<td>11,60,000</td>
<td>100%</td>
</tr>
</tbody>
</table>

Above statistics showed that total 770,000 inguinal hernia repairs were done in 2003 in United States of America, of which Lichtenstein 37% (295,000), Plug 34% (270,000), Laparoscopy 14% (115,000), Other mesh devices 8% (65,000) and Tissue-to-tissue 7% (55,000).[3]

- **In India**, in the year 2000, there were 2514 operative procedures performed in the General Surgical Department at one of the ESI hospitals in the Delhi area. 17% (435/2514) of the procedures were for hernias and 88% (382/435) were for inguinal hernias.

- **In United Kingdom**, in excess of 100,000 inguinal hernia repairs are performed each year, 30% of it are performed under local anesthesia as daycare surgery.[28]

- **In Australia**, a total of 39000 elective inguinal hernia repairs were performed in public and private hospitals each year.[29]

**Incidence in relation age and sex**

Indirect inguinal herniorrhaphy is one of the most frequently performed surgical procedures in children. The overall incidence of inguinal hernias in childhood ranges from 0.8% to 4%. The incidence of male to female is 10:1 in study of Mary et al, but 5:1 in study of Ein et al.
The incidence is much higher in premature infants, inguinal hernia develop in 13% of infants born before 32 weeks gestation and in 30% of infants weighing less than 1000 g.[30, 31]
In adults incidence is around 10% women and 90% men patients.[32]

Table 4: Incidence of hernia in relation to side of presentation in children. [31-33]

<table>
<thead>
<tr>
<th>Study</th>
<th>Right</th>
<th>Left</th>
<th>Bilateral</th>
<th>Recurrent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carvajal</td>
<td>55%</td>
<td>45%</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Diasamidze</td>
<td>46%</td>
<td>36%</td>
<td>8%</td>
<td>7%</td>
</tr>
<tr>
<td>Ein</td>
<td>59%</td>
<td>29%</td>
<td>12%</td>
<td>-</td>
</tr>
</tbody>
</table>

The incidence of developing a metachronous contralateral inguinal hernia (MCIH) following open repair of a unilateral inguinal hernia in children was 7.2% and was not sex or age specific. Children with a left sided inguinal hernia had a significantly higher risk of developing a MCIH than those with a right sided hernia (10.2 versus 6.3 per cent respectively). Most MCIHs occur in the first 5 years after unilateral inguinal hernia repair. The study concluded routine contralateral groin exploration is not indicated in any situation.[34]

The incidence of inguinal hernia surgery performed in emergency is 5.1% as compared to 36.5% in cases of femoral hernia.[35]

In our institute average 300 surgeries are performed per year.
Anatomy

**Inguinal region** is the lower part of the anterolateral wall of abdomen and is limited by the inguinal ligament inferiorly, lateral margin of rectus muscle medially and horizontal line from anterior superior iliac spine to lateral border of rectus muscle superiorly. The word “Groin” consists of the part 3cms above and 3cms below the inguinal ligament. Anatomy of inguinal canal is of interest in understanding inguinal hernia.[36]

*From superficial to deep the following layers are seen*- [37]

1) **Skin**

2) **Superficial fascia**- it consists of two layers
   a) **Camper’s fascia**- it is the fatty layer and it contains the cutaneous nerves and vessels
   b) **Scarpa’s fascia**- it is the membranous layer. Medially it is attached to the linea alba and continue as the Colles’ fascia in the perineum. It passes over the inguinal ligament and is continuous as the deep fascia of the thigh.

Figure 1: Inguinal region without subcutaneous fascia

(Curtsey: Netter Anatomy Images)
3) **External oblique muscle and aponeurosis** - It is a flat muscle which arises from the external surface of 5th - 12th ribs. Then it takes an oblique course downwards and medially. It inserts in linea alba, pubic tubercle and anterior half of iliac crest. It is muscular in the superior and lateral parts but becomes aponeurotic in its lower and medial parts.

   a) **Superficial inguinal ring** - It is a triangular aperture in the external oblique aponeurosis immediately superomedially to the pubic tubercle and lies obliquely with a medial crus and a lateral crus. The spermatic cord (or the round ligament of uterus) passes through it and carries the external spermatic fascia (or the external covering of the round ligament of the uterus) from the margins of the ring.

   b) **Inguinal Ligament** - It is a thick in rolled inferior border of the external oblique aponeurosis with a grooved abdominal surface and it stretches from the anterior superior iliac spine to the pubic tubercle and its convexity towards the thigh. From the medial part of the inguinal ligament arises the lacunar ligament and extends backwards and upwards to the pectenial line on the superior ramus of pubis. On reaching the pectenial line it becomes continuous with the thickening of the periosteum called the pectenial ligament (Cooper's ligament).

   c) **Reflected part of the inguinal ligament** - It is an expansion from the lateral crus of the superficial ring and ascends medially and behind the superficial ring behind the external oblique aponeurosis and in front of the conjoint tendon.

4) **Internal oblique muscle and aponeurosis** - It is the middle layer of the abdominal wall muscles. It arises from the thoracolumbar fascia, anterior two-thirds of the intermediate area of the iliac crest and lateral two-thirds of the inguinal ligament. It runs upwards and medially almost perpendicular to the external oblique. Insertion is to the 10th - 12th (lower three) ribs, the xiphoid process, the linea alba and the symphysis pubis. It is lower free border along with the transversus abdominis fibers arches over the spermatic cord and is called the conjoint tendon. As the spermatic cord (or the round ligament of uterus) passes under its free border some of its fibers cover it to form the spermatic muscle.
5) **Transversus abdominis muscle and aponeurosis** is the innermost muscle of the abdominal wall. It arises from the lateral one-third of the inguinal ligament, anterior two-thirds of the inner lip of the iliac crest, thoracolumbar fascia and lower six costal cartilages. It runs horizontally forwards and gets inserted into the xiphoid process, the linea alba and the symphysis pubis. Its lower fibers along with internal oblique fibers form the conjoint tendon.

6) **The transversalis fascia** is a thin layer that lies between the transversus abdominis muscle and preperitoneal fatty tissue. It represents the continuity of endoabdominal fascia represented by the diaphragmatic, iliac and the pelvic fascia besides the transversalis fascia.

Figure 2: Inguinal region – Anterior view
7) **Extra peritoneal space** is filled with loose connective tissue. It contains blood vessels (inferior epigastric, deep circumflex iliac artery, external spermatic artery), nerves (iliohypogastric, ilioinguinal nerves and genital branch of genitofemoral nerve) and lymphatics.

8) **Parietal Peritoneum**

**Inguinal canal**- it is an oblique passage through the lower part of the anterior abdominal wall and is present in both sexes. It is about 1.5 inches (4 cm) in length and extends from the deep inguinal ring in the transversalis fascia to the superficial ring in external oblique aponeurosis. It is almost parallel and just above the inguinal ligament. The deep inguinal ring is an opening in the fascia transversalis and it lies about 0.5 inch (1.3 cm) above the mid inguinal point. Medial to it are the inferior epigastric vessels. Its margins give rise to the internal spermatic fascia.

Figure 3: Inguinal canal and spermatic cord anatomy

![Inguinal Canal and Spermatic Cord](https://curtesy.netteranatomyimages.com/)

(Curtesy: Netter Anatomy Images)
Boundaries of inguinal canal

a) *Anterior wall* is formed by external oblique aponeurosis in its entire length and internal oblique fibers in its lateral one-third.

b) *Posterior wall* is formed by fascia transversalis and in its medial one-third by the conjoint tendon.

c) *Inferior wall or floor* is formed by the grooved upper border of the inguinal ligament and in its medial end by the lacunar ligament.

d) *Superior wall or roof* is formed by the arching lower fibers of the internal oblique and transversus abdominis muscle.

Figure 4: Inguinal region from posterior view
Contents of inguinal canal

a) Spermatic cord contains vital structures as follows:
   i. Vas deferens
   ii. Lymphatics
   iii. Testicular artery
   iv. Pampiniform venous plexus
   v. Artery to ductus deferens
   vi. Cremasteric artery

b) Ilioinguinal nerve

c) Genital branch of genitofemoral nerve

d) Round ligament of uterus (in females)

Nerve of the groin

Figure 5: Nerve anatomy of inguinal region

Iliohypogastric nerve (L1) and Ilioinguinal nerve (L1): Ilioinguinal and iliohypogastric nerves are terminal branches of the anterior ramus of first spinal nerve (L1), enters the abdomen anterior to psoas and quadratus
lumborum, which may divide within the psoas muscles and pierces the transversus abdominis muscles near the anterior superior iliac spine to run between internal and external oblique muscles. *Ilioinguinal nerve* running ventrally and parallel to the spermatic cord, behind the external oblique aponeurosis and passes through the external ring to run with spermatic cord while *iliohypogastric nerve* pierces the external oblique 2-5 cm above the external ring to innervate the skin above the pubis.\[37,38\]

b) *Genitofemoral nerve (L1,2)*: pierces the abdomen anterior to psoas, runs behind the psoas fascia, which divides lateral to common and external iliac vessels into genital femoral branches. Genital branch is laterocaudal at the level of the internal inguinal ring and runs with spermatic cord to innervate the cremasteric fibers are derived from internal oblique muscles \[37,38\]

c) *Lateral cutaneous nerve of thigh (L2,3)*

d) *Femoral nerve*

**APPLIED ANATOMY**

1) *Transversalis fascia* is a layer in the make-up of the posterior inguinal wall. It is the deepest, thinnest, and least important layer in terms of the prevention of herniation. It is a segment of the wider endoabdominal fascia. The true posterior wall of the inguinal canal is formed, in varying degrees, by the muscles or aponeurosis of the internal oblique and transversus abdominis.\[39\] Because of the human standing position, the inguinal region is a zone supporting the abdominal thrust, and weakened by the orifice of the inguinal and femoral passages. Peritoneal diverticulum may externalize into these orifices, leading to the formation of hernias.\[40\] It is the strengthening of this layer that is the main idea behind any hernia repair, be it tissue repair in form of herniorrhaphy of repair using prosthetic material like mesh called hernioplasty.

2) *Inguinal nerves*: The cutaneous nerves originating from these nerves studied by Akita and Niga, and found that the cutaneous nerve originates from the *ilioinguinal nerve* in 90.7%. In addition to that 35.2% also originates from the genital branches of the genitofemoral nerve. In 13.0% the genital branch and the ilioinguinal nerve united in the inguinal canal. In 11% cases the genital branch pierced the inguinal ligament to enter the inguinal canal, and
In 5% cases the genital branch pierced the border between the inguinal ligament and the external oblique aponeurosis to be distribute the inguinal region. Therefore, the courses of the genital branches vary considerably. [41]

These nerves are considered to be one of the culprit for post hernioplasty chronic pain, in particular ilioinguinal and/or genitofemoral nerve. [42]

Identification and preservation of these nerves during open inguinal hernia surgery reduce chronic pain [43], and it is easily feasible and not time consuming if there is knowledge of anatomy. [38]

Smeds et al suggested that the nerve injury is mainly due to inadequate dissection, failure to visualise and protect the nerves, and failure to recognise the aberrant location and anatomic variations of the nerves. Any partial or complete transaction of the nerve leads to neuroma formation and consequent pain along the distribution of that nerve. The nerves can also be damaged by nerve entrapment from post-operative fibrosis, mesh-related fibrosis or sutures used to fix the mesh. They further suggested that resection of nerve ‘at risk’ gives better outcome. [44]

In cases of post hernioplasty pain, cryoanalgesic ablation [45] and triple neurectomy can be considered for pain relief. [46]

3) Mesh can be put either over the fascia (ONLAY) or deep to it (INLAY).

4) In laparoscopic method the mesh is always put pre peritoneal either total extra peritoneal or transabdominal after incising the peritoneum. Intra peritoneal onlay mesh has been abandoned for inguinal hernioplasty.

5) When mesh put preperitoneal, one can obliterate the potential site of femoral hernia also.

6) Large mesh in preperitoneal space does not need fixation as it maintains its place by intra abdominal pressure and by tissue hydrostatic pressure as per Pascals’ Law. This is the basis of Stoppas’ prosthetic reinforcement of the visceral sac.
The etiopathology of the hernia formation and recurrence after hernia surgery had local as well as systemic factors. Cooper (1804) identified the transversalis fascia as the last barrier to groin hernia. Hernia development may be because of direct change in the groin tissue or may be because of rise in the intra-abdominal pressure working as precipitating factor. Strength of the abdominal wall was considered to be diminished by congenital deficiency, debility or aging.[23]

1. Anatomical Factor

Posture of the human have role in development of groin hernias as it develop from the myopectineal orifice of Fruchaud. In quadruped mammals thigh is flexed forward, groin structures are not stretched under tension and inguinal canal lies in an upward direction. The weight of the abdominal contents directed forward and downward, away from the inguinal canal. Where as in humans upright posture causes the gravitational stress to pass down to the lower abdominal wall which structurally not designed nor able to evolve its new role, this was further augment by absence of the posterior rectus sheath below the arcuate line. The downward direction of the inguinal canal and the weight of the intra-abdominal content pressing on its internal opening tend to dilate it and allow the loss of bowel to enter the canal. If these are the factors than it is surprising that less than 5% of the population develop hernia, it means that causes of groin hernia is probably multifactorial and one or more factors applying in any particular case.[47]

Patent processus vaginalis is considered to be the cause of indirect inguinal hernia in infants and are treated with simple high ligation, but in adults in whom it is patent and treated with high ligation it result in high rate of recurrence.[47] Epidemiologic evidence has shown that 20% of men pass into adulthood with a patent processus vaginalis, but less than 50% develop clinical hernia. In addition, indirect inguinal hernia may appear first in a man over 40 years of age, indicating that additional etiological factors may have role.[48]

Shutter mechanism is considered preventive mechanism of the abdomen against extremely high intra-abdominal pressure in response to coughing, straining, and lifting. The shutter is produced by descent of the transverses arch and "conjoint" tendon towards the inguinal ligament, in front of the internal abdominal ting. Contraction of the
transverses abdominis muscle also tenses the crura of the internal ring, derived from its transversalis fascia. At the same time, the anterior wall of the canal, made up of external oblique aponeurosis, presses on the internal inguinal ring and the floor of the inguinal canal, counter balancing intra abdominal forces pushing outward. The inguinal ligament is pulled upward by the same contraction, moving cranial to narrow the inguinal canal. As muscular power diminishes with age or disease, i.e., neuropathy, wasting, etc., these protective mechanisms fail, leaving the transversalis fascia at risk.[48]

**Increased intra abdominal pressure** as a cause of groin hernia has been promulgated since the time of Cooper. He stated that the cause of hernia was mechanical disparity between visceral pressure and resistances of abdominal musculature. If the first increased over the second, the abdominal wall ruptured, and a hernia emerged. There are factors that increase intra abdominal pressure includes cough, obesity, constipation, pregnancy, ascites, and unusual exertion (e.g., heavy lifting), prostatism etc. which leads a repeated mechanical stress and injury on the abdominal wall. If healing takes place, it will be less strong and less resilient than the original tissue. If there is actively raised intra abdominal pressure the counter mechanism activated and hernia does not appear, but when it raise passively the abdominal muscles are relaxed and counter mechanism do not activated leading to hernia. Excess body weight is no longer considered to be a factor in the development of groin hernias. In fact, adiposity may even have a protective influence against the development of a groin hernia.[47, 48]

2. **Metabolic Factors** play important role in integrity of fascia transversalis. Transversalis fascia is supported by muscle or aponeurosis fibres. These fibres are metabolically active and constantly balance state of production and absorption of collagen. So the factors affect these balance may have role in development of hernia. Increased proteolytic activity may cause weakness in structural tissue. Matrix metalloprotease (MMP)-2 over expression was measured in fibroblasts of patients with direct inguinal hernias, and MMP-13 over expression was detected in patients with recurrent inguinal hernias. Studies like these are observational, and it is not clear whether increased MMP expression leads to direct inguinal hernia formation. Alternatively, failing groin tissue may secondarily express increased MMP levels. Over expression of enzymes has been noted in aneurysms as well.[49]
Pans concluded that some "molecular alteration in collagen may be involved in the genesis of groin hernias." Why this defect appears preferentially in the inguinal region remains a mystery.[50]

3. **Cigarette smoking** leads to proteolysis by evoking a neutrophil and macrophage response, release of elastase and collagenase, destroys the lung parenchyma. Further, oxidants produced from combustion of tobacco damage antiprotease defences. Circulating enzymes may lead similar changes cause peripheral collagenolysis and causes hernia. Similar changes are also seen in patients of aneurysm.[47, 48]

4. **Genetic influence** in groin hernia is documented by familial tendency with autosomal dominant with incomplete penetrance of a preferential paternal factor.

A higher prevalence of inguinal hernia is well known among patients suffering from congenital connective tissue disorders like osteogenesis imperfecta, cutis laxa, and Marfan's syndromes. In children with congenital hip dislocation, inguinal hernia occurs five times more often in girls and three times more often in boys compared to children without this disease.[48]

5. **Spontaneous or iatrogenic trauma** of the abdominal wall cause inguinal hernia.

Previous appendectomy with cosmetic unilateral pfannenstiel approach may causes of damage to the iliohypogastric nerve and may be the cause of groin hernia.

6. **Physical exertion** historically believed to be the etiology of groin herniation and workmen compensation, but now more and more evidence accumulated that casts doubt on the legal foundation for such compensation. Weightlifters do not have an abnormal incidence of groin herniation and their intra abdominal pressure does not increase significantly in the erect posture. A single strenuous event preceded the appearance of inguinal herniation is noted in only 7% of men questioned after presentation.[48]
The natural history of an untreated inguinal hernia is poorly understood because until recently there were almost no contemporary data available. Published figures are based more on speculation than on scientific facts, leads difficulty in finding complication rate and life threatening risk rate for groups of populations in whom no one has a hernia repaired.

- The probability of hernia become painful rose to 90% by 10 years; however leisure activity affected in 29% patients and only 13% required time of because of hernia related symptoms.
- Probability of irreducibility increased from 6.5% at 12 months to 30% at 10 years, possibility of strangulation at 3 month was 2.3% at 3 months and 4.5% at 21 months. Operative mortality for obstructed hernia surgery is around 0.15%. [51, 52]. Operative mortality for obstructed hernia surgery is around 0.15%.
- Fitzgibbon and O'Dwyer had done two separate studies and concluded that indication of surgery in symptomatic patients is for comfort than prevention of complication. The watchful waiting is safe and acceptable option for the asymptomatic hernia or minimally symptomatic patients. Deferring an operation until the symptoms carries no increase in complications.[53, 54]
The concept of the indirect and direct areas dates back to Cooper in the 1840s, with Hesselbach using the inferior epigastric vessels as the defining boundary between these two areas.

- The majority of surgeons use *traditional* classification of groin hernias as indirect and direct inguinal or femoral.[55]
- In 1958, McVay and Chaff classified primary, recurrent and combined hernias. He also partitioned indirect hernias into small, medium, and large but did not use as classification system. [56]
- Other clinical types include:
  a) **Reducible hernia**—the contents return into the abdominal cavity by themselves or by manipulation but the sac remains in position
  b) **Irreducible hernia**—the contents can not be returned to the abdominal cavity but there is no evidence of any other complication
  c) **Obstructed or Incarcerated hernia**—(irreducibility + intestinal obstruction from within or without) the bowel in the sac is obstructed but the blood supply is not compromised.
  d) **Strangulated hernia**—(irreducibility + obstruction + arrest of the blood supply) along with obstruction the blood supply of the bowel also arrested.
- Rare hernias are also classified as
  a) **Sliding hernia (Hernia-en-glisssade)**—a portion of the wall is formed by another viscus eg. bladder or sigmoid colon.
  b) **Richters hernia**—only a part of the circumference of the bowel is present in the hernial sac.
  c) **Littres’ hernia**—the hernial sac contains the Meckles’ diverticulum
  d) **Maydl’s hernia (hernia-en-w)**—W shaped loop of intestine in the sac.

Various classifications had been suggested by Nyhus, Stoppa, Gilbert, Rutkow & Robbins, Aachen, Schumpelick and Zollinger but the utility of classification for the purpose of decision making was limited and no single classification was accepted for reproducibility.
Table 5: Comparison of hernia classifications.[55]

<table>
<thead>
<tr>
<th>Modified traditional</th>
<th>Nyhus-Stoppa [57]</th>
<th>Modified Gilbert</th>
<th>Schumpelick/Aachen [58]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A Indirect small</td>
<td>I</td>
<td>L1</td>
</tr>
<tr>
<td></td>
<td>B Indirect medium</td>
<td>II</td>
<td>L2</td>
</tr>
<tr>
<td></td>
<td>C Indirect large</td>
<td>IIIB</td>
<td>L3</td>
</tr>
<tr>
<td>II</td>
<td>A Direct small</td>
<td>IIIA</td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>B Direct medium</td>
<td>IIIA</td>
<td>M2</td>
</tr>
<tr>
<td></td>
<td>C Direct large</td>
<td>—</td>
<td>M3</td>
</tr>
<tr>
<td>III</td>
<td>Combined</td>
<td>IIIB</td>
<td>Mc</td>
</tr>
<tr>
<td>IV</td>
<td>Femoral</td>
<td>IIIc</td>
<td>F</td>
</tr>
<tr>
<td>O</td>
<td>Other</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R</td>
<td>Recurrent</td>
<td>IV A, B, C, D</td>
<td>—</td>
</tr>
</tbody>
</table>

(A- Direct, B- Indirect, C- Femoral, D- Combination of A-B-C)

- For all practical purposes, the anatomic sites, namely, indirect (lateral), direct (medial), and femoral appear to be universal, and recognition of the combined hernia (pantaloon) with defects in both the direct and indirect area.

- For quantifying the defect size for indirect or direct defects, small is (<1.5 cm, or approximately the tip of the fifth finger) or large (>3-4 cm, or two fingerbreadths in width) seen as common. Medium defects are clear to Schumpelick (1.5–3 cm), but judged empirically by Gilbert or by the loss of anatomic integrity of the direct floor space by Nyhus.

- Only Bendavid had considered the extent of hernia sac as important to be added in classification.

He proposed classification based on type, stage and dimension of defect (TSD) where he staged hernia as:

1. in the canal
2. beyond external ring – not in scrotum
3. Sac in scrotum


30
Most of the classifications suggested type and defect size as important, but preoperatively accurate defect size measurement is difficult. Some believe that extent of hernia will determine the tissue dissection while surgery.

Surgeons with a range of competencies perform inguinal herniorrhaphy. No currently exist clinical classification allow the competency level of surgeon to match the predicted difficulty of the hernia repair. A system of classification that stratifies hernia patients before operation to enable complex cases to be treated by the most skilled surgeons. Two clinical factors increase the difficulty of the operation: hernia size, which is readily quantifiable and patient obesity in the operative area (groin-fat thickness) which is not. Subscapular skin-fold thickness correlated well with groin-fat thickness (P=0.027) with a positive predictive value of 0.76. On these principles Kingsnorth had proposed new classification.

Kingsnorth’s new classification system proposed a score of 2–8, predicting grade of difficulty of repair can be generated as below.

Hernia size (H1–H4)
- Groin only, reduces spontaneously on lying down (H1)
- Groin only, reduces completely with gentle manual pressure (H2)
- Inguinoscrotal, reducible with manual manipulation (H3)
- Irreducible (H4)

Groin fat thickness (F1–F4) (Subscapular skin-fold thickness, an indirect measurement)
- <15 mm (F1)
- 15–25 mm (F2)
- 25–35 mm (F3)
- >35 mm (F4)

- A thin patient with hernias that reduce spontaneously (H1F1=score of 2) can be designated to operating lists of trainees.
- A fatty patient with irreducible hernias (H4F4=score of 8) can be designated to more experienced surgeons.[59]
In our study, we follow the classification based on Schumelick – Arif modification of Achen classification with addition of stage of hernia suggested by Bendavid. This completely explains the hernia status. (TDS Classification)[55]

**Type:**
- Lateral / indirect  L
- Medial / direct  M
- Combined (L+M)  C
- Femoral  F

**Dimension of defect:**
- I  < 1.5 cm
- II  1.5 – 3 cm
- III  > 3 cm

**Stage of sac extension:**
- 1  Sac in the canal
- 2  Sac beyond External ring – Not in scrotum
- 3  Sac in scrotum

In present study, this adaptation of classification used to record the data of patients.
Diagnosis of inguinal hernia

The symptoms and signs vary with the type, size, duration, and presence or absence of complications. Indirect hernias generally present in infancy or during the first year of life.

Clinical features:
1. Symptoms-
   a) Swelling in inguinoscrotal region – In adult life the hernia discovered accidentally by the patient or discovered by the physician during routine examination. In certain cases the swelling appears after sudden severe strain.
   b) Pain- It generally is a dragging pain when hernia is developing or expanding in size, which is relieved with rest but increases after activity. Some time it may be of dullache. The pain may be severe and continuous if hernia is associated with complications.
2. Signs- the inguinal hernia usually diagnosed on physical examination.
   • A globular or pyriform swelling, with an expansile cough impulse, which generally reducible is almost diagnostic of hernia.
   • Direct (medial) hernia arises from the posterior wall of the inguinal canal while indirect hernia arises from the deep ring.

Table 6: Clinical differences between direct and indirect hernia

<table>
<thead>
<tr>
<th>FINDING</th>
<th>INDIRECT</th>
<th>DIRECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Occurs earlier in life</td>
<td>Older age group</td>
</tr>
<tr>
<td>Sex</td>
<td>Not uncommon in female</td>
<td>Very rare in female</td>
</tr>
<tr>
<td>Occupation</td>
<td>No relation</td>
<td>Common with strenuous work</td>
</tr>
<tr>
<td>Bilaterality</td>
<td>Less common</td>
<td>More common</td>
</tr>
<tr>
<td>Shape</td>
<td>Usually pyriform</td>
<td>Usually globular</td>
</tr>
<tr>
<td>Extent</td>
<td>May be complete or incomplete</td>
<td>Usually incomplete</td>
</tr>
<tr>
<td>Entrance</td>
<td>Through deep ring</td>
<td>Through Hasselbach's triangle</td>
</tr>
<tr>
<td>Reducibility</td>
<td>Reduction more difficulty</td>
<td>Mostly reduces spontaneously</td>
</tr>
<tr>
<td>Direction of reduction</td>
<td>Upwards, laterally and backwards</td>
<td>Upwards and backwards</td>
</tr>
<tr>
<td>Finger invagination</td>
<td>Cough impulse at tip of finger</td>
<td>Cough impulse on pulp</td>
</tr>
<tr>
<td>Deep ring occlusion</td>
<td>No bulge</td>
<td>Bulge present</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td>Irreducibility</td>
<td>Common</td>
<td>Less common</td>
</tr>
</tbody>
</table>

**Role of Ultrasonography in diagnosis of hernia:**

Diagnosis of hernia is a clinical skill, but when swelling is not apparent and patient had pain in inguinal region than ultrasound is a non-invasive, non-ionising radiation modality, which is highly successful at soft tissue imaging. Grom pain from an occult hernia can be a difficult clinical diagnosis made easier by good imaging.[60]

**Other modalities:** These are described to help in diagnosing occult hernia with unexplained inguinal region pain. Herniography suggested to be safe and reliable method by some.[61] Occult hernia had been diagnosed at the time of laparoscopy for other diseases or on the contra lateral side of the hernia surgery.[62]

**Differential diagnosis of inguinal hernia** includes femoral hernia, congenital hydrocele, encysted hydrocele of cord, lipoma of cord, undescended testis, psoas abscess, inguinal lymphadenopathy, saphena varix and varicocele.
Major techniques of hernia repair

Among the most notable contemporary classic hernia tissue repairs are the Bassini, Halsted, Shouldice and, McVay (Cooper Ligament) repairs. The most common prosthetic open repairs done today are the Kugel patch repair, the Lichtenstein onlay patch repair, the PerFix plug and patch repair, and the PROLENE Hernia System bilayer patch repair. Laparoscopic hernia surgeries include TEP and TAPP.

Type of Anesthesia:

Surgery for inguinal hernia repair can be performed under all types of regional anesthesia, general anesthesia and local anesthesia preferred. The anesthesia employed for hernia should be a consensus choice between patient and surgeon.[63]

- Local anesthesia become widely popular because of its safety and open hernia surgery required minimal handling of the hernial sac and its contents and it is effectively body surface surgery. Many surgeons use surgery under local anesthesia where as others use exclusive spinal or epidural anesthesia.

- At Lichtenstein hernia institute, initially field block was the mean of achieving local anesthesia but later shifted to simple infiltration technique, because the field block was blind procedure, time consuming, required larger volume of the local anesthetic solution and did not always result in satisfactory anesthesia. Some time accidental needle puncture of the ilioinguinal nerve resulted in prolonged postoperative pain, burning, or electric shock sensation within the field of the ilioinguinal nerve innervations.[64] Some study suggest intraoperative pain may be a problem,[65] so combined ilioinguinal blockade and local infiltration anaesthesia is recommended for groin hernia repair to reduce intra-operative pain.[66] Uncomplicated bilateral inguinal hernioplasty in adults are feasible under local anesthesia with equally comparable postoperative pain and recovery periods.[67]

Marre et al. in his study found that the open inguinal hernia repair performed under local in 73% (n = 316), epidural in 21% (n = 94), or general in 6% (n = 25) anesthesia.[68] In another study general anesthesia (GA) was used in 51%, spinal anesthesia (SA) in 10%, and local anesthesia (LA) in 37%.[53]
Despite sufficient scientific data to support the local anesthesia, large epidemiologic and nationwide information from databases show high use of spinal anesthesia and low use of local infiltration anesthesia.[69]

**Classical tissue repairs**

**Bassini’s repair:** In 1887 Bassini, the Italian (father of modern herniorrhaphy), revolutionized the concept of surgical treatment of hernias. He advocated ligation and resection of the hernial sac followed by opening of the fascia transversalis and then reconstruction of posterior wall of the inguinal canal by approximating the internal oblique, transverse abdominis and fascia transversalis "triple layer" to the shelving border of the inguinal ligament with interrupted sutures with silk, leaving the cord under the external oblique aponeurosis. His recurrence rate of 3% over a period of 3 years was one tenth of the failure rates observed during that period. Following Bassini’s original report, numerous techniques (82 inguinal and 79 femoral repairs) have been described. Most common modification accepted is not to open fascia transversalis and to suture are placed between transverse abdominis arch and inguinal ligament, which is now recognized as modified Bassini’s repair.[23]

![Figure 6: Original Bassini repair](image)

The canal's posterior wall is opened and the deep epigastric vessels are exposed. The "triple layer" (Transversalis fascia, transversus abdominis muscle and internal oblique muscle) is sutured to inguinal ligament (Courtesy Nyhus & Condon's HERNIA, 5e, LWW)

**Halsted repair:** At the same time of Bassini’s repair, Williams Halsted (1852-1922) developed two types of herniorrhaphy that differed from Bassini’s repair, in the positioning of the spermatic cord. In Halsted I the cord is under the skin, and in Halsted II it is under the repair. Both Bassini and Halsted established the fourth principle of inguinal herniorrhaphy: reconstruction of the posterior inguinal floor.[10]
**Shouldice repair:** E. Shouldice (1891-1965), Toronto reported his technique of repairing inguinal hernia by overlapping layers with a continuous suture. He used transversalis fascia, along with both anterior and posterior lamina, arranged in three distinct layers and then repaired the opening, in each layer in turn, by overlapping its margins rather than by stitching them together edge-to-edge. The end result is to reinforce the muscular wall of the abdomen with six rows of suture. This technique has performed masterfully at the Shouldice clinic, with recurrence rates of less than 1%.[9, 23]

Figure 7a: Shouldice repair – First layer.
Dissection showing ligated cremasteric stump, lower flap edge sutured with inner aspect of upper flap. (Courtesy: Nyhus & Condon's HERNIA, 5e, LWW)

Figure 7b: Shouldice repair – Second layer.
Upper flap edge sutured with outer edge of the sutured lower flap. (Courtesy: Nyhus & Condon’s HERNIA, 5e, LWW)

**McVay repair (Cooper ligament repair):**

- Cooper was the first to describe the superior pubic ligament, although he never used it to repair surgically a groin hernia.
- The first Cooper ligament repair done in 1897 by the Austrian surgeon, Georg Lotheissen, who used the superior pubic ligament in 2 patients who had lost their inguinal ligaments in the course of prior unsuccessful hernia repairs.
- McVay and Anson revived Lothiesson's operation in 1942. They considered the superior pubic ligament to be the ideal structure for reconstructing the posterior wall of an inguinal hernia, since it shares the same tissue plane and derived from the same tissue origin as the transversus aponeurosis and the transversalis fascia. They advised suturing the transverse abdominis arch to Cooper's ligament for repair of inguinal
hernias through complete exposure of preperitoneal area.[23] Doing so frequently resulted in considerable suture-line tension, enough to require relaxing incisions. Patients complained of considerable and prolonged postoperative pain and failure rates became unacceptable. This procedure however, had value to surgeons by demonstrating the strength of the superior pubic ligament and showing its utility in large and difficult hernia repairs. It is the reliable structure to which prosthetic material can be fixed, when a large defect must be spanned. Now for the laparoscopic meshplasty, cooper’s ligament is the landmark to fix the mesh.

Figure 9: McVay (Cooper ligament) repair

Showing intermittent suturing of Cooper’s ligament with transversus abdominis arch.

(Courtesy Nyhus & Condon’s HERNIA, 5e, LWW)

**Tension-Free Hernia Repairs:**

- The most important advance in hernia surgery has been the development of tension-free repairs. In 1944, D.E. Acquaviva of France presented the first use of a nylon synthetic mesh to eliminate hernia and tension while leaving a defect intact (Tension free concept).[9] In 1958 Francis Usher had introduced polypropylene (Marlex 50) for hernia repair. Usher opened the posterior wall and sutured a swatch of Marlex mesh to the undersurface of the medial margin of the defect (which he described as the transversalis fascia and the conjoined tendon) and to the shelving edge of the inguinal ligament. He created tails from the mesh that encircled the spermatic cord and secured them to the inguinal ligament. The use of mesh was restricted for difficult or recurrent hernia. [9, 25]

The most common prosthetic open repairs done today are the Kugel patch repair, the Lichtenstein onlay patch repair, the PerFix plug and patch repair, and the PROLENE Hernia System bilayer patch repair.
**Lichtenstein onlay patch repair:**[70]

- Lichtenstein introduced the current concept of the “tension free” polypropylene mesh repair as an office procedure under local anesthesia, into everyday, common practice and because of that onlay hernia surgery with mesh is known as “Lichtenstein’s tension free hernioplasty”.[70]
- Lichtenstein’s group had produced excellent results and had recurrence rate of 0.2%, even non expert surgeons obtain the excellent result and had recurrence rate less than 0.5%. Lichtenstein technique of onlay tension-free mesh did not need a long learning curve to obtain highly acceptable results in the hands of general surgeons make it the choice of method for hernia surgery by them.

In this technique, a sheet of prosthetic mesh measuring about 5 by 10 cm is used. The lower edge is attached by a continuous suture of 2/0 prolene which secures the mesh medially to the lacunar ligament and then proceeds laterally along inguinal ligament beyond the internal ring. A slit in the mesh at the internal ring allows emergence of the spermatic cord. The superior edge of the mesh secured with a similar continuous suture to the rectus sheath and conjoined muscle and tendon above.

**PerFix plug and patch repair:**

- Irving Lichtenstein first to introduce tightly rolled cylindrical or cigarette plug as treatment of femoral and recurrent inguinal hernia. This design improved by Arthur Gilbert into a cone or umbrella shape.
• The PerFix Plug repair of direct and indirect hernias is an adaptation of Gilbert's free-formed umbrella-shaped plug, which initially used as a plug in the internal ring for treatment of indirect inguinal hernias.[71]

Figure 10: Gilbert's Free PerFix Plug repair (free-formed umbrella-shaped plug)

A PerFix plug situated in the internal ring. Within the insert is illustrated the toggle bolt like action of a PerFix plug as the mesh spreads out beneath the crura of the internal ring or the transversalis fascia of a direct defect.

(Courtesy: I.M. Rutkow / Surg Clin N Am 83 (2003))

• The PerFix Plug currently manufactured to place in the internal ring and fixed with sutures to the surrounding tissues. When a direct hernia is present, the PerFix Plug used in a similar fashion. When pantaloon or unusually large direct hernias are present, multiple plugs are sewn together to repair the defect. In addition to the plugs, an onlay patch also provided, which can be used with or without sutures over the posterior wall and around the spermatic cord lateral to the internal ring. Increasing numbers of surgeons use a PerFix plug and “reinforce” the repair by securing an onlay patch in a manner similar to that of Lichtenstein (Figure. 11). This hybridization of two well-known, tension-free techniques is termed a “Plugstein” repair. [71]

Figure 11: Plugstein repair

Perfix Plug Flower-shaped polypropylene mesh plug with multiple petals, and onlay graft with slit to accommodate the spermatic cord.

(Courtesy: I.M. Rutkow / Surg Clin N Am 83 (2003))
The recurrence rate for direct or pantaloon defects is 2% and for indirect defect it is less than 1% on the follow up of 4 years.[71]

**Prolene Hernia System**

PROLENE Hernia System (PHS) is bi-layer polypropylene mesh introduced by Gilbert in 1998. Three-in-one device having round disc for preperitoneal repair, plug effect of connector, and oblong shaped onlay component. The Prolene Hernia System (PHS) was developed as an option inguinal hernia repair that combined the benefits of anterior and posterior mesh components. For using this system the inguinal canal is approached anteriorly as described for the Lichtenstein repair. The indirect sac is dissected and ligated or inverted, and a preperitoneal pocket is created through the internal ring or posterior wall using sponge. The posterior portion of the PHS is then deployed in the preperitoneal space. The anterior portion positioned and sutured much like the onlay patch in the Lichtenstein repair. A lateral slit made in the PHS mesh to accommodate the cord and relocate the internal ring. The lateral anterior portion of the PHS is then deployed under the external oblique aponeurosis laterally.[72]
Kingsnorth found a reduction in immediate postoperative pain with PHS and was associated with a shortened operative time by 4 to 5 minutes.[73]

Randomized trial comparing the Prolene Hernia System, mesh plug repair and Lichtenstein method for open inguinal hernia repair for short- and long-term results did not show any clinically significant difference in postoperative pain and quality of life between the three types of mesh hernia repair. Severe early postoperative pain reliably predicted the likelihood of persisting chronic groin pain.[74, 75]

**Kugel repair**

The Kugel repair is considered a simple and minimally invasive repair, but non laparoscopic preperitoneal repair, its success is dependent on the experience and training of the surgeon. The Kugel repair combines the ease of an anterior approach with mesh placed in the preperitoneal position. The mesh is designed to expand into its full dimensions after being rolled or folded and placed in the preperitoneal space through a relatively small opening. A 2-to 3-cm incision is located halfway between the superior iliac spine and the pubic tubercle passing through the external oblique, internal oblique, and transversalis fascia. Any indirect sac is ligated or inverted. The inferior epigastric vessels are identified and should remain attached to the transversalis fascia while the peritoneum is freed from the posterior aspect of the transversalis fascia, creating a preperitoneal pocket in which to place the Kugel patch. The Kugel patch, typically a standard size of 8 - 12 cm, inserted into the preperitoneal space and allowed to expand. The patch secured with a single stitch and allowed to cover the defect. The suture holds it in place and then held in place by the natural intra-abdominal forces (Pascal's principle) from the peritoneum as the patient stands and proceeds with normal activities.[76]

Figure 14: Kugel Patch.

"Race-track" oval shaped polypropylene mesh graft with pocket for insertion and larger gauge polypropylene ring to hold graft's flat shape. (a) inner and outer welds; (b) transverse slit; (c) outer apron, (d) tissue apposition hole and v-shaped cut.[76]
Stoppa-Rives giant prosthetic repair

The technique is an important tension-free technique done through an open posterior approach, recommended for large, complex, or bilateral hernias. It is performed using one of two standard incisions - a infra umbilical vertical midline or a low horizontal skin incision.

The midline fascial layers are divided, providing access to the preperitoneal space. A large piece of mesh (Stoppa recommended Dacron) is then prepared in a chevron shape with a dimension of 24*18 cm. The mesh is then placed into the preperitoneal space using clamps. No attempt is made to secure the mesh with clips or sutures. The defects in the abdominal wall are left unsutured. This repair is similar in many ways to the laparoscopic repair, and familiarity with the anatomy from the “inside” is helpful when approaching hernias laparoscopically.[76]

The Cochrane Database Systematic Review is the highest level of evidence. In 2002 Cochrane retrospective study five randomized controlled trials, 1,51,3008 patients, not depend on the operative technique and concluded that the implantation of meshes significantly decreases the overall recurrence rate, the occurrence of chronic pain and the time of return to normal activity, as compared to non-mesh techniques.[77]
Prosthetic materials

From the beginning of modern anatomic hernia surgery in 1887 by Bassini recurrences have frustrated surgeons. The need for a satisfactory prosthetic material to bridge or reinforce defect of hernia required for more than a century. Various materials, including auto grafts (the patient's own tissue) have been tried.

**Autografts:** The most successful of the auto grafts is fascia lata, which has been used as suture material, a pedicle graft, and as a free transplanted graft. However, in addition to requiring a second operation to harvest it, fascia lata weakens and fails over time and dissolves in the presence of infection.

**Metal Prosthetic Graft Materials:**

Table 7: Metal Prosthetic Graft materials and its outcomes

<table>
<thead>
<tr>
<th>Material</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver filigree mesh (1900)</td>
<td>Became brittle and fractured and eventually extruded causing multiple sinuses and fistulas.</td>
</tr>
<tr>
<td>Meyer &amp; Bartlet</td>
<td></td>
</tr>
<tr>
<td>Tantalum Gauze (1948) Koontz, Douglas</td>
<td>Produces dense fibrosis infiltrating to surrounding structures - Irregularities in the abdominal wall contour, Seroma formation, Fatigue fractures of the gauze mesh result in patient discomfort,</td>
</tr>
<tr>
<td>Stainless steel mesh (1928) Goepel</td>
<td>Set up electrolyte reactions between ingredients if composition varied. Rigidity and foreign body sensation, MRI contraindicated</td>
</tr>
</tbody>
</table>

**Nonmetallic synthetic prostheses:**

Most surgeons now use a nonmetallic synthetic prosthetic material in inguinal hernias because techniques are comparatively easy to master and are associated with superior outcomes. The goals of treatment in the case of hernia are to relieve pain, cure the hernia to prevent acute incarceration and successful long term outcome.

**Polyester (Dacron)** is polymer from ethylene glycol and terephthalic acid, developed in 1939. Mesh wash prepared in 1950 and started its use in hernia surgery. The mesh has advantages of adaptability, pliability and tolerance in tissues. It was the first nonmetallic mesh to stand test time for four decades and still in use, but its use has decreased after polypropylene mesh become popular.[26]
**Polypropylene** discovered and manufactured by Karl Ziegler (1898–1973) of Germany and Giulio Natta (1903–1972) of Italy, for which they shared the Nobel Prize in chemistry in 1963 for their work, which began in 1938.[9]

- Francis Usher (1908-80) was a pioneer, who focused on development of mesh prosthesis. From freeze dried homographs and lyophilized dura mater, he tried different materials and finally arrived at a new polymer, known as 'polypropylene', first introduced as Marlex 50 in 1959, and the results of hernia repair were good. In 1963, it was improved as Marlex mesh and marketed by C.R. Bard (Bellerica, MA, USA).

- All products described as Polypropylene mesh, Marlex mesh, Prolene mesh (Ethicon), and Surgipro (US Surgical Corporation, USA) are similar products.[26]

- This mesh induces an inflammatory reaction and scarring. This characteristic led to an enormous impact on surgery and has become the most popular mesh available for surgical implantation. Numerous reports have attested to its usefulness.[10]

**Polytetrafluoroethylene (PTFE)** was first discovered accidentally in 1938 by Plunkett of E.I. Du Pont Company.

- In 1963, Shinsaburo Oshige of Sumitoma Electric Industries (Osaka, Japan) discovered a process for expanding PTFE to produce a structure with improved mechanical strength.[10]

- W.L. Gore has refined the technique for expanding PTFE (e-P'TFE) to provide a sheet material for surgical repair of hernias as Gore-Tex Soft Tissue Patch (STP). Gore-Tex STP has been shown to be stronger than Marlex or Mersilene mesh and is equivalent to these materials in terms of suture retention strength.[26]

**Absorbable Mesh:**

- Polyglycolic acid (Dexon) and polyglactin 910 (Vicryl) meshes have been developed from suture material.

- **Dexon** is braided fibers, produces mesh which is soft, pliable and stretchable prosthetic netting.

- **Vicryl** mesh is tightly woven broad cloth that is flexible but not elastic. Both of these biomaterials are biodegradable and gradually absorbed over a period of approximately 90 days and should not be used as the sole prosthesis for repair of abdominal hernias. Dexon mesh could be used to wrap the injured spleen for successful tamponade for parenchymal hemorrhage. Vicryl mesh used to repair abdominal wall defects, but had
inadequate fibrous tissue incorporation into the mesh before hydrolysis of the prosthesis, so it is not suitable for permanent repair of abdominal wall defects [78]

Coated nonabsorbable prosthesis:
These are primarily designed for ventral hernia repair to avoid direct exposure with viscera, so they may be used for TAPP to eliminate direct contact. The basic premise of these prosthetics is that the coating decrease adherence of the protein coagulum, thus partially inhibiting the inflammatory response of mesh, hence help in reducing chronic pain and recurrence due to prosthetic shrinkage.

C-Qur mesh (Atrium Medical) is a midweight polypropylene mesh (50 or 85 g/m2) coated with an absorbable omega-3 fatty acid preparation derived from fish oil. The coating is about 70% absorbed in 120 days and has had all protein removed to avoid an immune response.

Glucamesh (Brennen Medical) available only in Europe. It is a midweight polypropylene mesh (50 g/m2) coated with the absorbable complex carbohydrate, oat beta glucan.

TiMESH (GFE, Germany) is a polypropylene mesh coated with titanium.[79]

There are some conflicting data, there are no obvious differences in connective tissue and inflammatory markers with these meshes compared with bare polypropylene. Clinically, there are minor symptom improvements compared with heavyweight and partially absorbable prosthetics placed laparoscopically (TAPP).[79, 80]

Partially absorbable prosthetics:
To reduce the density of polymer and subsequent inflammatory response, yet maintain the intra operative handling characteristics and long-term wound strength, prosthetics have been developed that mix non absorbable polymers (e.g. polypropylene) with absorbable polymers (e.g. polyglactin) Vypro II and Ultrapro. Schumpelick and colleagues showed statistically significant less inflammation from polypropylene–polyglactin.[79]

Bellon and colleagues found that partially absorbable meshes for hernia repair offer advantages over nonabsorbable meshes.[81]

Biologic prosthetics:
The emerging biologic prosthetics primarily been designed for use in contaminated fields, limiting their role in inguinal hernia repair because the vast majority of these operations are clean. There is no difference in outcome with this prosthesis (Surgisis) compared to polypropylene prosthesis. With a theoretic increased risk of long-term
recurrence, relatively high cost, and no clear benefit, the use of these products for
elective inguinal hernia repair should be considered investigational.[79]

**Biologic response to prosthesis:** [79]

After any prosthetic implanted, an extraordinarily complex series of events takes
place.

- Immediately after implantation, the prosthetic adsorbs proteins that create a
  coagulum around it.
- This coagulum consists of albumin, fibrinogen, plasminogen, complement
  factors, and immunoglobulins.
- Platelets adhere to this protein coagulum and release a host of chemo
  attractants that invite other platelets, polymorphonucleocytes (PMNs),
  fibroblasts, smooth muscle cells, and macrophages to the area in a variety of
  sequences.
- Activated PMNs release proteases to attempt to destroy the foreign body in
  addition to organisms and surrounding tissue. PMN’s also further attract
  fibroblasts, smooth muscle cells and macrophages.
- The presence of a prosthetic within a wound allows the sequestration of
  necrotic debris and a generalized prolongation of the inflammatory response
  of platelets and PMNs.
- Macrophages then increasingly populate the area to consume foreign bodies as
  well as dead organisms and tissue. These cells ultimately coalesce into foreign
  body giant cells that stay in the area for an indefinite period of time, their role
  being unclear.
- The fibroblasts and smooth muscle cells subsequently secrete monomeric
  fibers that polymerize into the helical structure of collagen deposited in the
  extracellular space.
- There is a general net production of collagen for about 21 days, after which
  there is a net loss and a changing proportion of type III (immature) to type I
  (mature) collagen. The collagen helices also undergo cross linking to increase
  strength.
- The overall strength of this new collagen gradually increases for about 6
  months, resulting in a relatively less elastic tissue that has only 70% to 80% of
  the strength of the native connective tissue
**Factors affecting the biological response of prosthesis:**

The factors those affect the biological response assist the surgeon in choosing prosthesis. Following variables may be useful in determining the choice prosthesis.

(1) *The raw material used to make the prosthesis*

1. Synthetic nonabsorbable
2. Coated nonabsorbable
3. Partially nonabsorbable
4. Biological

(2) *The prosthesis’s design*

i. *Density (weight) - g/m²*

The weight of the mesh depends on both the weight of the polymer and the amount of material used (pore size).[82]

Thickness and weight were used to classify mesh as follows:[81]

1. Heavy weight  > 80 g/m²
2. Medium weight: 50-90 g/m²
3. Light weight: 35-50 g/m²
4. Ultralight weight: < 35 g/m²

Heavy weight meshes have thick polymer, small pore size and high tensile strength, which activate a profound tissue reaction and dense scarring. Whereas light weight have thinner filaments, larger pores > 1 mm, activate less pronounced foreign body reaction and are more elastic, able to withstand pressure maximum intra abdominal pressure.[82]

At present polypropylene prostheses are being modified into prostheses made with less material, with large pores and a tighter spatial organization of filaments.

ii. *Porosity*· Porosity is the main determinant of tissue reaction.

1. Very large pore: > 2000 µm
2. Large pore: 1000-2000 µm
3. Medium pore: 600-1000 µm
4. Small pore: 100-600 µm
5. Microporous (solid): < 100 µm

Pores must be more than 75 µm in order to allow infiltration by macrophages, fibroblasts, blood vessels and collagen.[82]
Granulomas normally form around individual mesh fibers as part of the foreign body reaction. Bridging describes the process whereby individual granulomas become confluent with each other and encapsulate the entire mesh (Figure 15).[82] This leads to a stiff scar plate and reduced flexibility. It occurs in meshes with small pores of less than 800 μm.

- Lightweight larger pore size mesh results in better tissue in-growth and lower foreign body reaction, provides optimal flexibility for improved physical properties, allowing a better activity profile post-surgery, but may lead to a higher risk of adhesions.[83]

- It seems 2.5 mm pore size is ideal for monofilament mesh, although some authors recommended pore sizes as large as 3 and 6 mm.[84]

---

**Figure 15: Granulomas, bridging and encapsulation of entire mesh.[82]**

iii. **Strength:** The tension placed on the abdominal wall can be calculated by the law of Laplace which states that 'in an elastic spherical vessel (abdomen), the tension, pressure, wall thickness and diameter.'

\[
\text{Laplace Law} \\
\text{Tension} = \frac{(\text{Diameter} \times \text{Pressure})}{(4 \times \text{Wall thickness})}
\]
• The maximum intra-abdominal pressures generated in healthy adults occur whilst coughing and jumping and are estimated to be about 170 mmHg. Meshes used to repair large hernias, therefore need to withstand at least 180 mmHg before bursting (tensile strength up to 32 N/cm).[82]
• This is easily achieved as even the lightest meshes will withstand twice this pressure without bursting (for example, burst pressure of Vypro = 360mmHg[85]). This illustrates that the tensile strengths of 100 N/cm of the original meshes were vastly overestimated.

![Figure 16: Comparison of mesh strength with abdominal wall pressures.](image)

iv. **Elasticity:** The natural elasticity of abdominal wall at 32 N/cm is about 38%. Heavy-weight meshes have only half this elasticity (4–16% at 16 N/cm) and can restrict abdominal distension.[82] Light-weight meshes have an elasticity of about 20–35% elasticity at 16 N/cm.[85]

v. **Constitution:** Mesh fibers can be monofilament, multifilament (braided) or patches (for example, ePTFE). Multifilament fibers have a higher risk of infection.[82]

vi. **Shrinkage:** Shrinkage occurs due to contraction of the scar tissue formed around the mesh. Scar tissue shrinks to about 60% of the former surface area of the wound.[85] The smaller pores of heavy-weight meshes lead to more shrinkage due to the formation of a scar plate.[82]
(3) The technique of implantation
   
   i. Anterior approach and prosthetic placement
   
   ii. Anterior approach with combined anterior-posterior prosthetic placement

   iii. Anterior approach with posterior prosthetic placement

   iv. Posterior approach: Open or Laparoscopic

   In each approach, layer of abdominal wall, folding of mesh and fixation of prosthesis play a big role in tissue response and recurrence.[79]

(4) The clinical scenario

   i. Symptoms: duration, pain, severity

   ii. Associated diseases: immunological, infection, obesity

   iii. Emergency surgery

   iv. Anatomy: defect size and location, extent, recurrence

   v. Future risk: need for prostatectomy

The surgeon must weigh the relative risks and benefits of each prosthetic for each given clinical scenario.

The surgeon should know the ideal requirement of prosthesis.

The characteristic of ideal prosthesis should be:[79]

1. Bio-chemically inert
2. Invoke a favorable host response.
3. Stimulate fibroblastic activity to allow incorporation into tissue than encapsulation
4. Possess good handling characteristics while operating.
5. Pliable so that no stiffness been felt by patients.
6. Strong enough to withstand pressure to prevent recurrence.
7. Place no restrictions on post implantation function.
8. Perform well in the presence of infection.
9. Resist shrinkage or degradation over time.
10. Make no restrictions on future access.
11. Block transmission of infectious disease.
12. Be inexpensive and sterilizable
13. Be easy to manufacture in the required forms [79]

No currently available prosthesis is perfect or free of problems, and the choice of material thus requires compromise and been selected by individual surgeon’s preferences.
Form the inception of the hernia surgery the complications well reported. The drive to reduce the complication had made the innovations in the hernia surgery. The complications have multi factorial etiology and some had reduced its incidence but still exist. Use of prosthesis in hernia surgery had reduce the recurrence to a minimal level but have open the new frontier to research on better outcome of pain. The complications of hernia surgery are technique and technology related.

Below table will show the morbidity related to hernia surgeries in general, specific complications attributed in details later.

**Table 8: General complications of inguinal hernioplasty**

<table>
<thead>
<tr>
<th></th>
<th>Operative</th>
<th>Early</th>
<th>Later</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incision</strong></td>
<td>Bruising, Hematoma</td>
<td>Infection</td>
<td>Chronic sepsis &amp; Sinus formation</td>
</tr>
<tr>
<td><strong>Scrotum</strong></td>
<td></td>
<td>Genital edema</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orchitis / Atrophy</td>
<td></td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Open</strong></td>
<td>Vas injury</td>
<td>Hydrocele</td>
<td>Recurrence &amp; Pain</td>
</tr>
<tr>
<td></td>
<td>Nerve Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Laparoscopic</strong></td>
<td>As above and</td>
<td>Hydrocele</td>
<td>Port site hernias</td>
</tr>
<tr>
<td></td>
<td>Vascular injuries,</td>
<td>Seroma</td>
<td>Recurrence pain</td>
</tr>
<tr>
<td></td>
<td>Visceral Injuries</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Systemic</strong></td>
<td>General &amp; Local</td>
<td>Chest Infection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anesthesia</td>
<td>Urinary infection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Venous thrombosis</td>
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</tbody>
</table>

**Wound related Complications:**

Infection is major complication in all surgery so as the hernia surgery.

- Eduardo Bassini’s original triple-layer repair (1889) had shown wound infection 4% [63].
- The commonest organisms for wound infection are *Staphylococcus aureus* and *Staphylococcus epidermidis*.
- Minor bruise or erythema occurs in 3%, wound infection 3% and wound hematoma 1% in hospital record but on community surveillances it was found to be 4 time higher rate.[86]
Forte et al had reported superficial hematoma (1.3%), superficial infection (1%), wound suppuration (0.5%), serous effusion (0.7%).[87]

- The published Cochrane Database (2007) found older patients with more than 70 years of age had 3 times more wound infection rate. Duration of surgery lasts <30 minutes had 2.7% and > 90 minutes had 9.9% infection rate. Prophylactic antibiotics and control group in elective inguinal hernia surgery found overall infection rates of 2.9% and 3.9%, in hemorrhaphy 3.5% and 4.9% while in hernioplasty it was 1.4% and 2.9%. Based on these results antibiotic prophylaxis for elective inguinal hernia repair cannot be universally recommended, neither its administration can be consider against when high rates of wound infection are observed.[88]

- Late mesh infection rate between 2-5 years is 0.35%. The facts suggest that mesh infection had not related with type of mesh insertion, nor the fixation materials.[89]

**Scrotum related complications:**

- **Seroma:** The problem of scrotal edema in open hernia (Lichtenstein repair) found to around 1.3% and local hypoesthesia reported in 4.3% of the patients.[87] Seroma can develop with any mesh type but with larger pores may be less likely to occur.[90]

- The testicles are concerned for ischemic orchitis and testicular atrophy. Ischemic Orchitis is acute condition and defined as – “post operative inflammation and painful enlargement of testis (2-3 times) within 24-72 hours with low grade fever and woody hard consistency”. In cases of primary inguinal hernia it is found in <0.1% and in recurrent hernia surgery it <0.5%. [87] Over all rate of testicular pain, swelling, epididymitis and atrophy incidence 0.3% to 5.0%.[6] The patients having severe or very severe pain 3 months after surgery than 18% had testicular pain at 30 months follow up and related well with post hernioplasty testicular atrophy.[91] Patients treated using PHS 1.4% diagnosed with testicular atrophy, while 4.4% experienced hypoesthesia.[92]

- **Vas deference trauma** occurs as obstruction or transaction, which are more common in recurrent hernia surgery and the incidence is about 0.04%.[6]

- **Hydrocele** had reported to be 0.7% of open hernia surgery It may be associated with overzealous skeletonization, and tissue dissection from the sac and at the internal ring, with common mechanism of lymphatic obstruction.[6]

**Vascular problems:** Bleeding from either arteries or veins can occur at all anatomic levels during an inguinal hernia repair.[6]
• *Superficially,* subcutaneous hematoma or severe ecchymosis can result from vessels i.e., external pudendal, circumflex iliac, and superficial epigastric.

• *On a deeper plane,* during resection of the cremaster the external spermatic artery can result in a tense hematoma and ecchymosis that extend to the scrotum.

• At the time of division of the transversalis fascia, deep inferior epigastric vessels (one artery, two veins) can be divided particularly during recurrent hernia surgery.

• Within the *space of Bogros,* a venous circulation is present which may be the source of brisk bleeding i.e., iliopubic vein, rectusial vein, and less commonly an iliopubic artery is present.

• The presence of an *aberrant obturator artery* originating from the deep inferior epigastric artery can be the source of bleeding when blind sutures are inserted in the ligament of Cooper without splitting the transversalis fascia or when the lacunal ligament is incised from below the inguinal ligament while an attempt is made to free an incarcerated femoral hernia. This dangerous step must be fraught upon and has earned the artery the unenviable designation of "artery of death."

• Injuries to the *femoral vein* may be caused by suture of the anterior wall of the vein during inclusion of the shelving edge of Poupart's ligament in the repair or by compression of the femoral vein by a suture that is placed too laterally on the ligament of Cooper.

• A minor but not uncommon complication is thrombophlebitis of the dorsal vein of the penis, with an incidence of 0.65%

**Associated factors**

Associated conditions has no direct relation with hernia but were present as cofactor or etiological factors. Associated factors also play role in selection of anesthesia.

• At Shouldice Hospital, the study of 7159 patients revealed that 52.1% of all patients were more than 50 years of age. Associated cardiovascular factors recorded on these patients were anticoagulation therapy (aspirin, ticlopidine, warfarin 12%), history of myocardial infarction (15%), history of angina (15%), therapy for congestive heart failure (17%), hypertension (20%), and cardiac arrhythmias (50%).[6]

• In one study, the factors were hypertension (55%), IHD (2%), COPD (9.1%), DM (9.2%), Prostatism (21.4%), Cigarette smoking (37%) and alcohol (24.1%) of the patients.[53]
Urinary retention in post herniorrhaphy related to type of anesthesia. Meta analysis had shown the incidence of urinary retention was lower with local anesthesia (LA) 0.37%, with regional anesthesia (RA) 2.42%, and general anesthesia (GA) 3.00%. The low incidence of retention with LA is in accordance with the inhibitory effects of RA and GA on bladder function.[93]

Emergency hernia surgery incidence was 5.1% for inguinal hernia where as 36.5% for femoral hernia, as studied from Swedish Hernia Register (n=1,07,838).[35] Bowel resection performed in 22.7% of emergent femoral repairs and 5.4% of emergent inguinal repairs. Femoral hernia operations comprised 1.1% of groin hernia operations on men and 22.4% of operations on women.[94]

Mortality after hernia surgery defined as standardized mortality ratio (SMR) within 30 days. Mortality risk was not raised above that of the background population for elective groin hernia repair, but it was increased 7-fold after emergency operations and 20-fold if bowel resection was undertaken.[35]

Complications related to the use of prosthetics.
Most of the complications already described. The complications specific to mesh are depend upon choosing a mesh. The surgeon must decide which properties are the most important for the specific situation.

- Polypropylene meshes are durable and have a low infection risk but they have little flexibility and a high adhesion risk. The use of heavyweight meshes is associated with increased complications and adverse events, such as fistula and adhesion formation and pain.[85] Although these complications are mainly observed during intra-peritoneal application, they have also been observed as a result of Extra-peritoneal placement.[95]
- Heavyweight meshes have an increased surface area and, therefore, produce a more intense foreign body reaction. They also tend to shrink more than lightweight meshes and are stiffer, which can make normal abdominal movements difficult or unnatural.[84]
- Lightweight typically refers more to meshes with a larger pore size, resulting in a smaller surface area. The lower amount of material present in lightweight meshes should lead to decreased foreign body reaction and fibrosis.[96]

The main factors to consider in relation to complications outlined below.
**Mesh infection:** Mesh infection is feared because it is difficult to eradicate without removing the mesh and can become clinically apparent many years after implantation.[97] Mesh infection remains about 0.1–3%. [98]

The risk of infection mainly determined by the type of filament used and pore size. Micro porous meshes (for example, ePTFE) are at higher risk of infection because macrophages and neutrophils are unable to enter small pores (< 10 micron). This allows bacteria (< 1 micron) to survive unchallenged within the pores. A similar problem applies to multifilament meshes. The meshes at lowest risk of infection are, therefore, those made with monofilament and containing pores greater than 75 micron.[82]

**Adhesion risk:**

Adhesions result from the fibrin exudates that follow any kind of trauma. These exudates form temporary adhesions until the fibrinolytic system absorbs the fibrin. Absorption delayed in the presence of ischemia, inflammation and meshes (foreign body). In these situations, they mature into tissue adhesions.

- All meshes produce adhesions when placed adjacent to bowel, but their extent determined by pore size, filament structure and surface area. Heavy-weight meshes induce an intense fibrotic reaction which ensures strong adherence to the abdominal wall but also causes dense adhesions. In contrast, micro porous ePTFE does not allow tissue in-growth. It has a very low risk of adhesion formation, but is unable to adhere strongly to the abdominal wall.[82]

These two extremes illustrate the difficulty of producing a mesh which will adhere well to the abdominal wall but not to the bowel. Composite meshes aim to do this by providing an additional surface which can be safely placed in contact with bowel whilst peritoneal mesothelial cells grow over the mesh. It takes up to 7 days to regenerate peritoneum; however, once formed, it should prevent adhesion formation to the mesh.

**Recurrence:**

The use of meshes thought to reduce dramatically the incidence of hernia recurrence. In nearly all cases, recurrent herniation occurs at the edges of meshes. This is commonly due to inadequate fixation, or underestimation of shrinkage of the mesh, at the original operation.
There is little evidence that recurrence is related to the type of mesh used, although it has been proposed that light-weight meshes have a higher risk due to their increased flexibility and movement.[85]

- Two-thirds of recurrences occur after 3 years (median, 26 months).[82]
- This suggests that a technical error is unlikely to be the only cause of recurrence and defective collagen synthesis may be equally important.
- All meshes cause a foreign body reaction which has an effect on the ratio of Type I and III collagen synthesized.[85]
- Altered ratios of collagen affect both tensile strength and mechanical stability and may increase the risk of recurrence. It is not clear if the type of mesh used has any effect on this.[85]

**Pain**

Meshes are associated with a reduced risk of chronic pain compared to suture repair. It is thought to be related to the ability to use tension-free technique rather than the mesh itself. However, pain remains a serious complication of mesh repair and can occur up to 40% of hernia surgeries [99]. With regards to acute postoperative pain, there is little difference in the type of mesh used. Chronic pain following hernia repair has gained increased recognition and may be because of foreign body reaction of mesh or nerve(s) injury.[16, 91]. Explants removed for chronic pain are found to have nerve fibres and fascicles around the foreign body granuloma within the mesh. Neuroma were found at the interface of mesh and host tissue suggesting mechanical destruction of nerves by mesh. It follows that meshes with small pores and greater foreign body reaction, will cause higher rates of chronic pain.[80, 100] Pain described in separate chapter.

**Mesh degradation**

Degradation of meshes is rare and mainly seen in polyester meshes and may be due to hydrolysis, resulting in brittleness and loss of mechanical strength.[82] Calcification can also occur but has only been documented in meshes with small pores.[101]
The surgical injury can lead to chronic pain is well reviewed using a systematic collection of data, the estimated incidences of chronic pain after leg amputation about 60%, thoracotomy about 50%, breast surgery about 30%, cholecystectomy 10–20%, and inguinal herniorrhaphy about 10%. Predictive risk factors for chronic postoperative pain include preoperative pain, repeat surgery, psychological vulnerability, workers compensation, surgical approach with risk of nerve damage, moderate or severe intensity of acute postoperative pain, radiation therapy, neurotoxic chemotherapy, depression and anxiety.[102, 103]

Post hernioplasty mild pain lasting for a few days is common following mesh inguinal hernia repair. However, moderate to severe pain persisting more than 3 months after inguinal surgery should be considered pathological.

**Chronic pain definitions:**

- The International Association for the Study of Pain (IASP) defines pain as an "unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage". This definition declares that the pain having a physiological basis as well as a very real psychological or subjective component.[12]

- National Library Medicine MeSH term has defined pain as “An unpleasant sensation induced by noxious stimuli which are detected by nerve endings of nociceptive neurons”. [11]

- International Consensus Conference on hernia in Rome had consensually defined chronic groin pain according to the IASP definition which was based on non surgical chronic pain. The following definition for chronic post herniorrhaphy neuropathic pain: “a pain arising as a direct consequence of a nerve lesion or a disease affecting the somatosensory system, in patients who did not have groin pain before their original hernia operation, or, if they did, the post-operative pain differs from the pre-operative pain”. A present, clinical diagnosis of neuropathic pain is not well defined.[104]

Transition between acute and chronic pain is defined by most authors in terms of time.

- The IASP provides one of the most referenced definitions of chronic pain. Chronic pain is that which persists beyond the normal time frame for healing, usually taken to
be 3 months. The IASP allow considerations of further characteristics in relation to the "appropriateness" of the disorder.

- The two most commonly used chronological markers to denote chronic pain have been three and six months since the initiation of pain, however these distinctions are arbitrary.[12]

- In acute pain there is an advantage to the individual, as it allows rest and the inflammatory process of healing to occur. In chronic pain there is no biological value, as there is no advantage to the individual in experiencing persistent pain.

- The Practice Guidelines of the American Society of Anaesthesiologists for Chronic Pain Management considered chronic pain as a "persistent or episodic pain of a duration or intensity that adversely affects the function or well being of the patient, attributable to any non-malignant etiology"[105].

**Characterization of Chronic pain:**

Portenoy categorized both acute and chronic pain as nociceptive, neuropathic or psychogenic in origin.[106]

**Nociceptive pain** is due to chronic activation of nociceptive afferent neurons and it may be somatic or visceral. In nociceptive pain due to tissue inflammation, the sensory experience reflects the normal adaptive functioning of the pain system.[107]

**Neuropathic pain** is caused by a primary lesion or dysfunction in the nervous system. It is due to central reorganization of sensory processing after injury to an afferent pathway. It may be sustained by-

1. mechanisms that involve disturbances in the peripheral nerve or nerve root- *peripheral neuropathic pain*, or

2. the reorganization of nociceptive information processing by the central nervous system- *deafferentation syndrome*.[12]

- The pathway for pain and temperature is known as the spinothalamic pathway and their 'Gate Control theory of pain' emphasized the central nervous system as an active system that filters, selects and modulates the inputs of the peripheral nervous system. It also emphasized the dorsal horns as dynamic activity stations where inhibition, excitation and modulation can occur.[108]
Because of these major understanding, the chronic groin pain after hernia surgery have been classified as *neuropathic* cause due to inguinal nerve(s) damage or *non-neuropathic* cause due to mesh or other related factors.

The groin hernia repair with a mesh implant can lead to chronic nociceptive pain due to the continuous inflammation around the mesh. However, so far no study has clearly differentiated neuropathic pathogenesis from inflammatory pathogenesis. Since the mesh inflammation itself can lead to nerve damage, it is difficult to clearly differentiate chronic neuropathic from nociceptive pain following groin hernia repair, although nerve damage seems to be prerequisite for development of chronic pain.[104]

Chevrel has described four types of neuralgias for post hernia repair:[6]

*Neuroma pain*: The most common type, it was caused by proliferation of nerve fibers outside the neurilemma following complete or partial nerve section. *Hyperesthesia* is seen along the corresponding dermatome. Pain is exquisite at the site of neuroma and simulates an *electric shock*.

*Deafferentation pain*: A burning pain following partial or complete nerve section or entrapment in a ligature with chronic paroxysmal exacerbations. Initially, an area of *anesthesia* followed by adjacent areas of *hypoesthesia*, then *hyperesthesia* and contact *dysesthesia* in the corresponding dermatome.

*Projected pain*: The intact nerve is encased in a callus or *entrapped* in a ligature. Pain is *elicited by light touch* along the course of the nerve.

*Referred pain*: The lesion is at a distance such as an inflammatory granuloma around a suture or the stump of a peritoneal sac.

Therefore, studies are in progress based on well-defined neuro-physiological assessments to identify sub-groups with different types of neuroplasticity (wind-up phenomena, allodynia, reduced pressure pain thresholds, hypoesthesia, etc.), which hopefully will be able to identify patients who can be re-operated versus those requiring pharmacological treatment.[104]

**Tools (methods) of pain assessment:**

The symptom complex of chronic groin pain varies from a dull ache to sharp shooting pain along the distribution of inguinal nerves. There is no single test to confirm the etiology behind the pain or to point out the exact nerve involved.
Postoperative pain assessed by various researchers using various tools. Commonly used tools are Verbal rating scale (VRS), Visual analogue scale (VAS), Numerical Rating Scale (NRS), McGill Pain Questionnaire and SF-36 Questionnaire.

McGill Pain Questionnaire (McPQ), SF-36 Questionnaire, Duration-Intensity-Behavior Scale (DIBS), Carolinas Comfort Scale (CCS) Pain Disability Index (PDI) and Wisconsin Brief Pain Questionnaire (WBPQ) are used to assess the quality of life with different dimensions of physical functioning, pain, general health, vitality, social functioning, emotional and mental health. These are multidimensional questionnaires assessing sensory, affective and psychosocial aspects of pain.[109,110]

In contrast, the Visual Analogue Scale (VAS), Verbal Rating Scale (VRS), and Numerical Rating Scale (NRS) are simple unidimensional tests that only rate sensory components of pain and omit affective and psychosocial pain aspects. All three pain-rating scales are valid, reliable and appropriate for use in clinical practice, although the Visual Analogue Scale has more practical difficulties than the Verbal Rating Scale.

For general purposes the Visual Analogue Scale has good sensitivity and generates data that can be statistically analyzed for audit purposes. Patients who seek a sensitive pain-rating scale would probably choose this one. For simplicity patients prefer the Verbal Rating Scale, but it lacks sensitivity and the data it produces can be misunderstood.[111]

The ideal pain assessment tool should be determined by type of pain and the setting in which it is measured. Researchers commonly rely on unidimensional systems, as multidimensional questionnaires are generally considered too long and too complicated.[110].

`Unidimensional scales have routinely been employed in the evaluation of post herniorrhaphy groin pain syndromes [110]`

1. **Verbal rating scale (VRS):** it is graded with a 4-point verbal rating as – no pain, mild, moderate and severe. They defined as below -
   - *Mild pain* - occasional pain and did not require analgesics.
   - *Moderate pain* - affecting patients’ daily activities, required analgesics occasionally
   - *Severe pain* - restrained patients from daily activities and required routine analgesics.

2. **Visual analogue scale (VAS):** it is a 10-cm horizontal line labeled ‘no pain’ at one end (with 0 points) and ‘worst pain imaginable’ (with 100 points) at the other end. The patients are asked to mark on this line where the severity of pain is shown.[110, 112]
Gold standard pain rating scale serves best for post hernioplasty pain is lacking.

- Loos et al had suggested to rounded to near centimeters converting VAS scale 0-10 score and consider moderate to severe pain when VAS score ≥3 [113]. They further studied two frequently used pain rating scales (VAS and four-point VRS) for scale failure and to determine which test performs better in patients with groin hernia repair. They concluded that four point VRS scale perform better than VAS, but to convert VAS into VRS scores, cut off points are mandatory. They suggest four categories of VRS corresponded to VAS categories were as follows:
  - 0–8 = no pain,
  - 9–32 = mild,
  - 33–71 = moderate,
  - >71 = severe pain. [110]

In our study Visual Analog Score describe by patients from range 0 to 10, considering rounding and above cut of points, we have redefined Verbal rating scale in our study, which are as follows:

\[
\begin{align*}
P_0 &: VAS Score 0 - No pain \\
P_1 &: VAS Score 1-3 - Mild \\
P_2 &: VAS Score 4-6 - Moderate \\
P_3 &: VAS Score 7-10 - Severe
\end{align*}
\]

Many other studies had used self defined criteria.

- Verstraete et al had used pain and discomfort as tool where they defined, ‘‘Pain’’ was defined as a subjective, invalidating sensation in the groin or upper thigh, with or without need for analgesics; ‘‘discomfort’’ as a non continuous, not invalidating sensation in the groin or upper thigh, without need for analgesics and expressed as ‘‘I sometimes feel it when . . . ’’. They found pain in 8% patients at 3 months and 4% after 3 years.[114]

Factors associated with chronic pain:
Various studies performed to look at the difference in chronic groin pain rates with and different associated factors e.g. nerve identification, isolation, preservation; nerve excision; heavyweight or lightweight mesh; and mesh fixation.[115] Others have studied associated factors like age, preoperative pain, socioeconomic status, open and laparoscopic hernia, non mesh sutures, early post operative pain, genital complication etc.[14]
**Chronic pain to Age and employment status:**

- There were very few studies, which relate the chronic pain with age. For that the studies have divided the patient’s age in three groups young age (0-39 yrs.), middle age (40-60 yrs.) and old age (>61 yrs.)

- Bay-Nielsen et al. found 28.7% had chronic pain and the relation to young, middle and old age groups were 39.7%, 33.2% and 17.6% respectively with functional impairment rate of 11.2% and 6.1% in young and old age groups. [13] they further conclude that pain was more common in patients younger than 40 years of age.[116]

- Poobalan study also found 30% chronic pain incidence and the relation of chronic pain to age <40 and > 60 yrs was 58% and 15%. [117] Finding suggest that chronic pain and its severity is more in young patients than old age, and pain also decreased with increasing age. Patients with full time employment were more likely to have chronic pain than retired (P=0.001).[117]

**Pain association to Sex:**

- Though the inguinal hernias are not common in the females, Bay-Nielsen had included female gender for nationwide study, found 38% incidence of chronic pain in female compared to 28% in male (P<0.05)[13]. Danish hernia database study on women found 4.3% reoperation rate in compare to 3.1% in men and the reason for reoperation was femoral hernia (41.5%)[118].

**Hernia presentation and pain:**

- Alfieri et al. had studied 955 patients with 1050 total repairs, 55% on right side and 45% on left side. Alfieri et al. had reported moderate to severe pain at 6 months in 2.0% (16/797) unilateral and 2.8% (5/176) bilateral hernia repairs (P=0.16) Alfieri et al. had reported moderate to severe pain at 6 months in 1.25% (4/321) direct, 2.3% (15/653) indirect and 3.5% (1/32) pantaloons hernia repairs (P=0.67) [15].

- As per Nyhus classification the study of Fitzgibbon had indirect inguinal hernias comprised 53% of hernias (type 1=12%, type 2=29%, type 3b=12%) and direct inguinal hernias (type 3a) 41%.[53]

**Pre operative pain and chronic pain:**

Only few studies had reported relation between preoperative pain and postoperative chronic pain.
• Poobalan et al. had found chronic pain in 35% patients having pre operative pain, compare to only 7% patients having no preoperative pain, stated significant predictive value (P<0.005) between preoperative and chronic pain.[117]

• In contrast, Liem et al. had found no significant relation between them (P=0.2).[119]

• Page et al. had studied pain from primary inguinal hernia and the effect of repair on pain, showed that hernia surgery reduced the preoperative pain but some of the patients develop pain at the operative site which was not preoperatively present. In contrast, other study had found that 30% of the patients reported no change in pain from before surgery and 5% had worse pain than before surgery.[14, 120]

Type of Anesthesia:

• Despite sufficient scientific data to support the local anesthesia, large epidemiologic and nationwide information from databases show high use of spinal anesthesia and low use of local infiltration anesthesia.[69]

• Alfieri et al. had reported moderate to severe pain at 6 months around 2.0% in each form of local, general and spinal/ epidural anesthesia (P=0.89).[15]

Influence of nerves on chronic pain:

• Most of the researchers agreed that the nerves of inguinal canal plays major role in chronic pain, so it required recognition of anatomy of the ilioinguinal, iliohypogastric, and genitofemoral nerves along with their variations.

• The practice of identification of all 3 nerves is quite poor. Ravindran et al conducted a survey in the United Kingdom regarding the handling of inguinal nerves during open hernia repair and showed that ilioinguinal nerve (IIN) was routinely identified by 88% of surgeons, iliohypogastric nerve (IHN) by 58% and genitofemoral nerve (GFN) by 54%. The individual nerves were routinely divided by 7%, 5% and 6% of surgeons, respectively.[121]

There was no definite consensus available on routine identification of inguinal nerves and preservation or division. The survey also pointed out that those surgeons who performed more than 50 hernias per year were more likely to preserve the nerve and others were more likely to ignore it.[122]

There are various studies for nerve identification, isolation, preservation and division but many contrary views have emerged. There are studies favor identification, isolation and preservation of nerves,[43] others found no added advantage of nerve preservation or division
on chronic pain, but they found sensory disturbances in division group [123, 124]. Other study recommend prophylactic neurectomy at the time of surgery associated with less chronic pain. [125] Although it seems intuitive that a suture tied down on a nerve would cause pain, this has not been studied in any scientific manner.[72]

- Alfieri et al reported moderate to severe pain at 6 months after hernia surgery in
  1.3% when all nerve identified,
  1.1% when 1 nerve not identified,
  2.8% when 2 nerves not identified,
  4.7% when all nerves not identified
  1.7% when all nerve identified, but 1 or 2 nerves divided or injured
  40% when all nerve identified and divided.

The analysis found statistical difference (P=0.02) between that lack of identification of nerves with the presence of chronic pain. The risk of developing inguinal pain increasing with the number of nerves concomitantly not detected and the division of nerves was strongly correlated with the presence of chronic pain, thus they strongly stress the importance of always identifying and preserving all 3 nerves of the inguinal during hernia.[43]

- Picchio et al in their double-blind, randomized controlled trial of preservation or elective division of ilioinguinal nerve on 813 open inguinal meshplasty, found chronic pain in 23.5% and 27% respectively at 1 year. They conclude that pain not affected by elective division of the ilioinguinal nerve, but sensory disturbances in the area of distribution of the transected nerve are significantly more.[123] The neurologic deficit is minimal and consists of a loss of cremasteric reflex and an area of anesthesia of the inguinoscrotal fold no larger than 3 cm to 5 cm in diameter.

- Tons observe red common nerve likely to get injured is genitofemoral nerve, the incidence of chronic pain reduced by preserving it, and if necessary elective division to reduces chance of entrapment syndromes. [126]

- Bartelett study, ilioinguinal, iliohypogastric and genital nerves identified and either of them divided and compared with preservation of nerve. They found no difference on pain score of nerve division group and suggested practical approach of nerve division when they are at risk of damage.[20]

- In contrast, Mui et. al in similar study design found 28.6% and 8% (P=0.008) and concluded that prophylactic ilioinguinal neurectomy significantly decreases the
incidence of chronic groin pain after Lichtenstein hernia repair without added morbidities. It should be considered as a routine surgical step during the operation.[122]

- Caliskan et al had found that iliohypogastric neurectomy with subcutaneous transposition of spermatic cord decreases post operative chronic pain (PCP) without increase risk of sensory changes.[127]

There are now consensus international guidelines to preserve all three inguinal nerves during open inguinal hernia surgery, elective resection of suspected injured nerve was recommended, but there is no recommendation for a procedure on resected nerve endings.[104]

**Effect of mesh on nerve:**

- Demirer et al in his experimental study found that ultra structural changes seen in peripheral nerves in experimental group operated with mesh suggested that mechanical compression of peripheral nerves is associated with myelin degeneration, endoneurial and perineurial edema, fibrosis, axonal loss, and edema that may cause peripheral neuropathy. Chronic groin pain after hernia repair can be possibly caused by the entrapment of peripheral nerves in the scar tissue formed by the mesh.[128]

- Karakayali et al studied, synthetic mesh on ilioinguinal nerve motor conduction and chronic groin pain found no significant differences on ilioinguinal nerve motor conduction studies between the mesh and shouldice groups. They found a significant correlation between EMG results and inguinal pain, suggest that chronic pain may be caused by nerve injury resulting in dissection or compression of the nerves.[129]

**Post operative pain in relation to time:**

Pain after 1 and 4 weeks considered as early postoperative pain, and as a predictor for chronic pain studied by very few studies.

- Callesen et al found that the risk of chronic pain was significantly higher (P<0.05) in patients with a high early postoperative pain score compared with those with a lower postoperative pain score after 1 and 4 weeks.[130]

- One study found that patients having coughing at 1 wk had significant higher risk (P<0.05) of developing chronic pain.[131]

- Pain persisted limited to 1 week in 23%, 2 weeks in 13%, 1 month 11%, 3 months in 8%, 1 year 3% and more than 1 years in 4%. [114]
• Picchio studied post hernia surgery pain and found 28% complained mild pain, 17% moderate pain, and 6% severe pain at the 1-month follow up. After 6 months, the numbers were 25, 9, and 3%, and after 1 yr 18, 4, and 2%, respectively.[123]

• Jaiswal et al (India) found 0.78% had mild chronic pain and well controlled with oral analgesics with minimal follow up of six months and concluded incidence of chronic pain was less and less disabling than what is generally reported.[19]

• Bhattacharjee et al had studied the discomfort & pain after 5-7 years found that significant groin discomfort was described by 6% patients with 3% had restricted daily activity after plug and patch repair, concluded that significant restricting groin symptoms were uncommon.[17]

• There was no correlation between the incidences of pain in relation to follow up, but with time the severity of pain decrease, suggesting “burn out” effect of the pain complaints.[14]

• Courtney et al studied severe chronic pain following hernia repair and concluded that chronic pain persists in most of patients who report severe or very severe pain at 3 months after hernia repair.[91]

• There was an overall decrease in pain with time, from 29.7% at 6-12 months to 18.1% at 37-48 months after surgery. Pain was more common in patients younger than 40 years of age.[116]

*Chronic pain in relation to experience of surgeon:*

• Alfieri et al reported moderate to severe pain at 6 months in 1.9% (17/856) surgery done by senior surgeons and 3.4% (4/117) by residents (P=0.14).[15]

• Other study suggested that there was significant impact of training of resident on recurrence in open repair but not on other complications. Recurrence rate was more than 5% in first year of training but achieved nearer to 1% after 4 years of training.[132]

*Chronic pain in relation to recurrent hernia:*

Most of the study had combination of patients having primary and recurrent hernia, and data did not specify chronic pain incidence separately. Only few studies have compared the chronic pain risk in both groups.
• Callesen et al had found that incidence of moderate to severe pain after 12 months of surgery was higher after recurrent hernia (14%) than primary hernias (3%) (P<0.001) [130]

• Poobalan et al. had found that recurrent hernia surgery associated with more chronic pain than primary surgery (P=0.04), probably related to technically more difficult operation with a higher risk of nerve damage. [117]

**Chronic pain in relation to type of study:**

There were various type of studies had been done for pain includes review article, cross sectional cohort, meta analysis, randomized controlled trail, multicentre randomized controlled study etc.

• Aasvang et al had reviewed article with more than/equal 100 patients and pain more than 6 months as tool for study inclusion, studied 35 articles and published results on age, gender, time course, preoperative pain, employment status, type of surgery, etc.

  They found more pain when pain is primary outcome objective than secondary outcome.

  Less pain was reported in single centre study than multicentre study.[14]

• Bay-Nielsen et al. had studied the *cross sectional cohort study* using questionnaire and found 28.7% chronic pain incidence at 1 year and is associated with functional impairment in more than half of those with pain.[13]

**Chronic pain in relation to open/Laparoscopic surgery:**

• Aasvang and Kehlet in his review found that the overall incidence of chronic pain after hernioplasty was 12% but it was significantly higher (P<0.01) in which open 18% (range 0–75.5%) than laparoscopic surgery 6% (range 1–16%).[14]

• Lau et al found that the prevalence of chronic pain after TEP was 9.2%, mostly mild and transient in nature and had negligible impact on daily activity.[131]

• The EU Hernia Collaboration had done *meta-analysis* of laparoscopic or open-mesh repair showed that laparoscopic hernia repair develop significantly less (P<0.05) chronic pain than open.[133]

• Over all meta review have shown that laparoscopic repairs (TEP and TAPP) are better in recovery and pain, but it should made easier, safer and less expensive.[134]
Neumayer in very well-conducted, large multicentre randomized controlled study found a chronic pain incidence of 10% after laparoscopy and 14% after open surgery (P>0.05), and recurrence rate of 10% and 4.9% respectively at 2 years.[135]

**Chronic pain in relation to mesh / non-mesh repairs:**
- A comparative analysis between non-mesh (Bassini's) and mesh (Lichtenstein) repair of primary inguinal hernia postoperative pain were significantly low (p < 0.001) in Lichtenstein meshplasty.[136]
- EU Hernia Trialists in his review found less pain after mesh repair compared to non-mesh repair [133] Similar observations were reported by Poobalan et al [16].
- In contrast Bay-Nielsen found no difference in young males operated with mesh or non-mesh repair.[116]
- The Cochrane Database Systematic Review is the highest level of evidence. In 2002 Cochrane retrospective study five randomized controlled trials, 1,51,3008 patients, not depend on the operative technique and concluded that the implantation of meshes significantly decreases the overall recurrence rate, the occurrence of chronic pain and the time of return to normal activity, as compared to non-mesh techniques. [77]

**Chronic pain in relation to Types of Mesh:**
There are many meshes available for hernioplasty includes heavy prolene mesh, soft prolene mesh, Vypro mesh, Ultrapro mesh etc. These had showed different pain incidences.
- Bringman observed that chronic pain, stiff abdomen, and foreign body sensation are least often observed with the use of a lightweight mesh [84].
- Koning found that the patients with titanium coated lightweight mesh had a shorter convalescence than those with the standard heavyweight mesh but there was no difference in postoperative pain or recurrence at the 1-year follow-up.[99]
- Leardi concluded that even suture less plug mesh had 13.0% rate of early post operative pain which was 25% after 2-4 years follow up, but pain is mild in nature and not seriously affect the patients quality of life.[137] In contrast, Millikan et al had 0.4% chronic pain with longer follow up in series of more than 2000 patients.[138]
- Smietanski in prospective cohort study on lightweight poliglecaprone/polypropylene mesh (UltaPro) concluded that use of partially absorbable light mesh reduces postoperative pain at long-term follow-up.[139]
**Chronic pain in relation to types of mesh fixation:**

- Paajanen et al. had studied fixation of mesh with absorbable sutures than polypropylene Lichtenstein operation and found no significant difference in pain and other outcome of measures.[140]

**Various methods of open hernia surgery:**

- The most commonly performed tissue repairs are those of Bassini, Shouldice and McVay had cumulative pain rate is; some inguinal pain in 62.9% and moderate to severe pain in 11.9% at 1 year, and at 2 years the result was 53.6% and 10.6% respectively.[5]

- Li et al. had done meta-analysis of randomized controlled trials for preperitoneal and Lichtenstein repair, found no difference in chronic pain and other complications.[141]

- Zhao et al. in his meta-analysis of RCTs on Lichtenstein repair, Plug mesh and Prolene Hernia System found no difference in recurrence and chronic pain.[142]

- Nienhuijs study at single centre preperitoneal Kugel procedure had reported less chronic pain at three months than Lichtenstein procedure.[143] In contrast other study had shown higher chronic pain and recurrence rate with Kugel in compare to Lichtenstein repair.[144]

**Management of severe chronic pain:**

- Delikoukos et al. have reported 14/1633 patients with moderate to severe pain after 1.5 to 4 years. 6 patients treated with surgery showed ilioinguinal nerve entrapment and/or pubic tubercle are the cause of chronic severe pain, staple removal and neurectomy with mesh removal was consider as treatment of choice.[144]

- Aroori et al. reported 12.3% (18/146) chronic pain incidence. Of which 4 had mild pain and treated with analgesic. Other patients having severe pain treated with various methods. The patients having predominant neuropathic symptoms were treated with Amitriptyline (n=2). The patients with mixed nature of pain having maximum tenderness at GF distribution (n=5), over the pubic tubercle (n=4) and in the inguinal nerve distribution (n=1). They are treated with nerve block using 0.5% Chirocaine alone or with 20 mg of methyl prednisolone acetate (Depo-Medrone), followed up every 3 monthly, at median follow up of 45 months 77%(n=10) were completely pain free, 15.4% had mild pain (n=2) and one patient had still significant persistent pain.
They suggested that majority of the patients are treated successfully with therapeutic injection in to the point of maximal tenderness.[145]

- Amid suggests that many cases the pain may be debilitating and ends in re-exploration of the wound and division of the three nerves is desirable.[46]

- Aasvang et al in 2005 reviewed papers the surgical options of mesh removal, stitch removal and neurectomy for management of chronic pain and found that neurectomy have reported favourable outcome, and insufficient information was available for effect of mesh or stitch/staple removal. They also found that all study were poorly designed in respect of preoperative diagnostic criteria, intraoperative success in identifying a pathological lesion or nerve and quality of follow up.[146] They design preoperative criteria of > 1 year pain related impairment of daily activities and well localization of maximum pain point, intraoperative removal of mesh and selective neurectomy in cases of macroscopic nerve injury and validated outcome with pre and post operative quantitative sensory testing. They concluded that said procedure improves pain related impairment.[147]

Treatment for persistent chronic neuralgia after inguinal hernioplasty should follow a step-by-step therapeutic protocol. In the initial phase, patients treated with oral analgesic and afterwards with repeated infiltrations of anesthetic and cortisone. The noninvasive methods are to be preferred, whereas neurectomy interventions reserved for selected cases.[148]

**Recurrence of hernia**

- Malik in his comparative analysis between non-mesh (Bassini's) and mesh (Lichtenstein) repair of primary inguinal hernia recurrence occurred in 2.0% out of 392 patients those with Lichtenstein mesh repair, on the other hand 7.1% patients with Bassini's repair reported recurrence within 3 years time.[136]

- Haapaniem found recurrent hernia reoperation in 4.6% after recurrent hernia repair and 1.7% after primary hernia repair at 24 months.[149]

- Neumayer et al in multicentre trails of 2164 patients with 85% follow up for 2 years had higher recurrence in laparoscopic patients 10.1% than open repair 4.9%.[135]

- Liem found recurrences rate 3.8% at 2 years and 4.9% at 4 years in the laparoscopic group, and 6.3% and 10 0% in the open surgery group ($P=0.006$).[119]

- Martin has reported that Lichtenstein hernioplasty had recurrence rate of 0.5%.[150]