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**Review Article**

# A review of literature and new comprehensive classification of "Mesh Repair Methods" (MRM classification) for abdominal wall hernias

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## ABSTRACT

The use of prosthetic mesh has brought a revolution in the history of the repair of abdominal wall hernia. Evidences suggest that using mesh for hernia repair significantly reduces recurrence. Every plane of abdominal musculature has been explored for mesh implantation. Various names have been used to describe each plane and different methods of implantation. But the terminologies used for various practices of mesh implantation are ambiguous and confusing. Inconsistent and confusing terminologies leads to difficulty in comparing and analyzing the literature. The aim of this review is to group various practices by identifying the basic method of utilizing various planes of abdominal wall musculature and bring them under some self-explanatory terminologies. Hernia-mesh implantation methods related articles were searched using Medline, PubMed and the Cochrane library during October 2024 to March 2025. 90 articles were shortlisted for this study. In our review of various available articles, we focused on identifying: abdominal plane utilized, number of planes utilized, number of sheets of mesh implanted, details of mode of implantation (open, endoscopic or hybrid), terminologies used for the planes, and overall name given for that concept. We tried to group various methods of mesh implantation according to above findings. This new comprehensive classification of "mesh repair methods" (MRM classification) is intended to be self-explanatory and its adoption would avoid ambiguity and improve comparison and communications for research studies of various practices of hernia mesh implantation.

**Keywords:** Hernia mesh implantation, Abdominal muscle planes, Double mesh and sandwich repair

## INTRODUCTION

The use of prosthetic mesh has brought a revolution in the history of the repair of abdominal wall hernia. Evidences suggest that using mesh for hernia repair significantly reduces recurrence. Thus prosthetic mesh has become the integral part of the hernia surgery. It is observed that the location of the mesh also determines the incidence of recurrence.[1] Most common anatomical location for the placement of mesh include onlay, inlay, sublay or underlay. Commonly a single mesh is placed in one of the preferred planes. However, literature reveals two discrepancies in the descriptions of the mesh implantation regarding: terminologies of muscle planes used for mesh implantation, and terminologies used for various methods of mesh implantation.

Terminologies used for various muscular planes of abdominal wall is not consistent and this variability causes confusions due to uncertainty regarding the exact plane utilized, leading to difficulty in comparisons of surgical techniques and even leads to the invalidation of various meta-analysis comparing surgical outcome. Parker et al resolved this issue by introducing a consensus-based nomenclatures and introduced "international classification of abdominal wall planes (ICAP)" to describe mesh insertion for ventral hernia repair.[2]

Similarly, literature revealed the ambiguity in terminologies used for various methods of mesh implantation. Most commonly used classification for meshplasty is based on anatomical location of mesh i.e. onlay, inlay and sublay; where sublay is further divided in three locations. Routinely used terminologies are multi-meaning and don't give clear idea. For example, when more than one mesh is used for hernia repair, these methods are referred by various names like 'double mesh repair', 'double prosthesis repair', 'dual mesh repair', 'two layered prostheses', 'bi-layer mesh repair', triple mesh repair' and 'sandwich repair'. But none of these terms clarify whether two separate meshes are being placed in same plane or more than one plane. Moreover, these terms create confusion and difficulties in comparisons. There is no comprehensive classification for the methods of mesh implantation. The aim of this review is to provide a comprehensive classification of various mesh implantation methods for proper understanding and comparisons for research purpose.

## METHODS

Hernia-mesh implantation methods related articles using keywords were searched using Medline, PubMed and the Cochrane library during October 2024 to March 2025. 90 articles were shortlisted for this study. Following particulars were noted down: abdominal plane utilized, number of planes utilized, number of sheets of mesh used, details of mode of implantation (open, endoscopic or hybrid), terminologies used for the planes, and overall name given for that concept.

## RESULTS

In our review of various selected articles, we observed that the hernia mesh related methods practiced so far can be grouped according to the following.

### *Number of sheets of mesh implanted in a hernia repair*

It includes a single mesh implanted in a selected plane, two separate sheets of mesh implanted in a single plane, two separate sheets of mesh implanted in two different adjacent planes, two separate sheets of mesh implanted in two different distant planes, and three sheets of mesh or three-in-one prosthesis implanted in three different planes.

### *Modes of implantation of mesh or prosthesis*

Various modes of achieving mesh implantation include open, endoscopic and hybrid techniques.

Literature also revealed various discrepancies in the terminologies used.

### *Multiple and confusing names for abdominal wall planes*

The routinely used nomenclature for abdominal planes for mesh implantation are onlay, inlay, sublay or underlay. Instead these terms are used variably and are confusing and sometimes incorrect.

Such variability misleads the reader.[2]

**Table 1: "Mesh Repair Methods" classification.**

| **A) Classification as per the number of planes utilized for the mesh implantation** | | |
|---|---|---|
| **a) Mono-planar or uni-planar mesh implantation** | | **Abbreviations** |
| Onlay | Onlay- prefascial | O-PF |
| | Onlay- subfascial | O-SF |
| Inlay | | I |
| Sublay | Sublay- retrorectus/retromuscular | S-RR/RM |
| | Sublay- preperitoneal | S-PP |
| | Sublay- intraperitoneal | S-IP |
| **b) Bi-planar mesh implantation** | | |
| Adjascent biplanar | Inlay + sublay | I+S-R/RM |
| | Inlay + onlay | I+O-PF/SF |
| Distant biplanar - muscle sandwich repair | Onlay+sublay-retrorectus /retromuscular | O+S-RR/RM |
| | Onlay + preperitoneal | O+S-PP |
| | Onlay + intraperitoneal | O+S-IP |
| **c)Tri-planar mesh implantation** | | |
| | Onlay+inlay+sublay-retrorectus/retromuscular | O+I+S-RS/RM |
| | Onlay+inlay+S-preperitoneal | O+I+S-PP |
| | Onlay+inlay+S-intraperitoneal | O+I+S-IP |
| **B) Classification as per the number of mesh utilized for the mesh implantation in same plane** | | |
| Single mesh | | |
| Multiple meshes | | |

Type of onlay needs to be additionally specified as O-PF or O-SF; O- onlay, I- Inlay, S- sublay, PF-prefascial, SF- subfascial, AR-anterectus, RR- retrorectus, RM- retromuscular, PP- preperitoneal, IP-intraperitoneal.

***Multiple names for two sheets of mesh implanted in one plane***

When two separate sheets of mesh are implanted in the same plane one above another, this method is variably labeled as double-buttress repair, double mesh repair, and sandwich technique.[3-5]

***Multiple names for two separate sheets of mesh implanted in two adjacent planes***

When two separate sheets of mesh are implanted in the two adjacent planes, the method is also called as double mesh adjusted to the defect and double mesh repair.[6,7]

***Multiple names for two separate sheets of mesh implanted in two distant planes***

When two separate sheets of mesh are implanted in two different distant planes, this method is also labeled as double mesh repair/double prosthesis repair, bilayer repair, double onlay mesh repair, sandwich techniques.[8-10]

***Multiple names for three different sheets of mesh or three in one prosthesis implantation in three different planes***

When three separate sheets of mesh or a prosthesis made up of three parts is implanted in such a way that the mesh occupies all three planes, this method is variably labeled as triple mesh technique, bilayer mesh prosthesis repair, and all-in-one prosthesis repair.[11-13]

***Positional deviation in onlay mesh implantation***

The term onlay mesh placement classically denotes mesh implantation is done on the surface of anterior fascia of abdominal musculature. But onlay term is also accepted when mesh is implanted under the external aponeurosis showing deviation from the definition.[14] Similarly, same term "onlay" is also used for "intraperitoneal onlay" mesh placement.[15]

Observing various ambiguities in the overall name given to various currently practiced patterns, a new classification by title "Mesh Repair Methods" (MRM) classification is introduced which would be self-explanatory and comprehensive.

## DISCUSSION

Even after almost four decades of regular and increasing utilization of mesh, ambiguity still exists related to nomenclatures of abdominal muscle planes and nomenclature of the method of implantation. However, an initiative has been taken by Parker et al who by reaching to the consensus-based nomenclatures introduced the "international classification of abdominal wall planes (ICAP)" to describe mesh insertion for ventral hernia repair.[2] Common mesh placement sites of muscle planes are onlay, inlay or interposition, retro-rectus, pre-peritoneal, intra-peitoneal and relatively rare mesh placement muscle planes are retro-muscular, inter-oblique, retro-oblique, and ante-rectus.

Similarly review of literature revealed that terminologies used for various methods of mesh implantation are also ambiguous and confusing which causes difficulty in comparisons of methods. For this a new comprehensive classification named as "mesh repair methods" (MRM classification) is being introduced as follows.

As per the number of planes utilized for the mesh implantation - mono-planar or uni-planar: mesh implanted in only one plane, bi-planar: two separate sheets of mesh implanted in two different planes, and tri-planar: three separate sheets of mesh implanted in three different planes.

As per the number of sheets of mesh implanted in the same plane: single sheet of mesh implanted in one plane, and multiple sheets of mesh implanted in same plane.

This is a self-explanatory, primary classification which gives clear idea regarding the basic nature of mesh repair methods by denoting the number of planes utilized and avoids various confusions in different nomenclatures used in the literature. Almost each and every method so far published can be accommodated in this classification. Moreover, each group needs to be further divided into subgroups: plane wise, method wise, and concept wise.

***Mono-planar or uni-planar***

This denotes that a single sheet of mesh is implanted in a selected muscle plane and is labeled as onlay, inlay or interposition, sublay-retrorectus, sublay-retromuscular, sublay-preperitoneal and sublay-intraperitoneal.

***Onlay mesh placement***

Classically onlay mesh placement refers to insertion of mesh over the anterior fascia of abdominal musculature. Onlay mesh placement can be performed by open as well as by endoscopic methods.

Open onlay mesh placement in subcutaneous plane was popularized by Chevrel et al.[16] But literature also revealed some examples of deviation from the definition of onlay repair. Best example of this deviation is Lichtenstein's tension-free mesh repair where repair is done by placing mesh subfascially beneath the external aponeurosis, and is still considered as onlay mesh repair.[14] Similar style is also adopted by Miyake et al who placed the mesh in a space called as ante-rectus plane which lies in between anterior rectus sheath and the rectus abdominis muscle (MUAR) and Butterfield et al also explored this space for mesh placement while doing ostomy closure.[17,18] So this entity also needs to be considered as onlay repair.

So instead of using term "onlay" barely, it needs to be rechristened as - onlay-pre-fascial (O-PF), and onlay- sub-fascial/ante-rectus (O-SF/O-AR). Onlay term is also used for intraperitonal mesh e.g. intra-peritoneal onlay mesh (IPOM), but it would be meaningful to be considered in sublay-intraperitoneal group.[15]

***Endoscopic onlay mesh placement***

Various subcutaneous endoscopic/laparoscopic techniques (SET/SLT) found in literature are enumerated here according to the entry approach - by peri-umbilical approach "endoscopic-assisted linea-alba reconstruction" (ELAR); by supra-pubic approach "subcutaneous onlay laparoscopic approach" (SCOLA), "preaponeurotic endoscopic repair" (REPA), "full endoscopic suprapubic subcutaneous approach" (FESSA) and "endoscopic pre-aponeurotic repair" (EPAR); and by lumbar approach "subcutaneous onlay mesh" (SCOM).[19-24]

***Inlay mesh placement***

'Inlay' mesh placement refers to mesh implantation in the defect where edges of mesh are sutured with the edges of the hernia defect. So also termed as - interpositional or bridging mesh. However, it is rarely done alone as it may not tolerate the forces on the border sutures created by wall tension and intraabdominal pressure and yields an unacceptably high recurrence rate to 44%.[25]

Literature revealed that mostly Inlay implantation is used as an adjuvant to some other implantation when other sublay or onlay plane is also utilized. This type of double mesh repair will be considered under the head "adjacent bi-planar repair".

***Sublay mesh placement***

Here the intention is to keep the mesh beneath the muscle, with three further possible location of the mesh. The term "sublay" doesn't give clear idea as where exactly mesh is placed beneath the rectus muscle as there are retrorectus, preperitoneal and intraperitoneal spaces. Therefore, sublay mesh placement is further classified into three groups - sublay- retrorectus or retromuscular, sublay-preperitoneal, and sublay-intraperitoneal.

***S-retrorectus or retromuscular mesh placement***

The retrorectus placement describes mesh placed posterior to the rectus abdominis muscle and anterior to the posterior rectus sheath. But when the same compartment is extended by transversalis abdominis muscle release (TAR) for wider mesh implantation, then proper term should be "retromuscular".

*Open approach*

Rives et al translated the Stoppa's concept for the ventral hernias above the arcuate line, and placed the mesh between the posterior rectus sheath and rectus abdominis muscle.[26]

*Endoscopic approach*

Retromuscular placement of mesh laparoscopically is possible by following approaches: endoscopic subcutanous approach, endoscopic inter-muscular approach, and endoscopic trans-abdominal approach.

Retro-rectus mesh placement by endoscopic subcutaneous approach which further includes three entry points as: trans-hernial entry, peri-umbilical entry, and suprapubic entry.

***Trans-hernial entry***

With the successful technical feasibility of SCOLA, it was further extended to the retrorectus compartment by entering trans-hernially by open technique and further separating peritoneum around the defect and then by cutting open the posterior rectus sheath with the help of narrow retractors, laparoscopic instruments and endotorch, retrorectus space is created for the mesh implantation. This method is termed as MILOS.[27] Similarly, Schwartz et al attempted sublay-retrorectus mesh placement by approaching this space by totally minimally invasive technique trans-hernially and called it as the endoscopic mini/less open sublay (EMILOS).[28]

***Peri-umbilical entry***

Tretino hernia team (THT) technique describes periumbilical approach to enter retromuscular plane and reconstructing linea alba by using linear staplers and placing retromuscular mesh.[29]

***Subcutanous suprapubic entry***

Totally endoscopic sublay anterior repair (TESAR) which starts as a suprapubic subcutaneous endoscopic approach and then enters the retrorectus plane by making para-hernial incision in the anterior rectus sheath.[30]

***Retrorectus mesh placement by endoscopic inter-muscular approach***

It includes three entry points as: epigastric entry, lateral entry, and suprapubic entry.

*Through epigastric port*

Belyansky et al introduced a novel method of sublay-retrorectus mesh placement by the extended-view totally extraperitoneal repair (eTEP) by using totally inter-muscular laparoscopic technique including extraperitoneal suture closure of the defect and wide mesh coverage in the retromuscular compartment (eTEP RS) with use of minimal fixation and resulting into decreased pain after repair.[31] With this access one can also expand the space in

the Transversalis abdominis plane by releasing the transversalis abdominis muscle from posterior rectus sheath and spread the mesh widely and also suture the wider defects easily without tension (eTEP-TAR).[32]

*Through lateral ports*

Shenoy et al approached the rectrorectus space through three lateral ports.[33]

*Through suprapubic port*

Li et al described a similar method through the suprapubic port in the preperitoneal space and then approaching the retrorectus space at the level of arcuate line. They call this method as totally endoscopic sublay repair (TES).[34]

***Retrorectus mesh placement by endoscopic transabdominal approach***

This is carried out laparoscopically by making posterior sheath flaps for mesh placement and is described as transabdominal retromuscular umbilical prosthetic hernia repair (TARUP), and transabdomina retromuscular mesh repair (TARM).[35,36]

*Preperitoneal mesh placement*

The preperitoneal mesh placement describes mesh placement in the plane between posterior rectus sheath or transversalis fascia below arcuate line and in front of the peritoneum. This space can be approached by open as well as endoscopically. For discussion purpose the matter is divided into two: for inguinal hernia and for ventral hernias.

*Preperitoneal mesh placement for inguinal hernia*

Open methods for preperitoneal mesh placement can be divided into two approaches-by extra-inguinal preperitoneal approach (EIPP), and by inguinal approach i.e. trans-inguinal preperitoneal (TIPP) approach.

*Extra-inguinal pre-peritoneal approach (EIPP)*

Various methods published are: Stoppa's GPRVS "giant prosthetic reinforcement of the visceral sac", Nyhus open posterior repair, Ugahary's MOPP- minimal open preperitoneal prosthesis, Kugel's preshaped mesh patch, Lange's transrectus sheath extraperitoneal procedure (TREPP).[37,41]

*Trans-inguinal preperitoneal (TIPP) approach*

Approaching preperitoneal space transinguinally proved to be much easier and reproducible either through the deep inguinal ring or by splitting transversalis fascia. Here various published methods are Gilbert's prolene hernia system, Pelissier's polysoft mesh, Lourenco's onstep open new simplified totally extraperitoneal technique.[12,42,43]

***Endoscopic technique- by two approaches***

*Intermuscular endoscopic approach*

McKernan and Law introduced a new revolutionary endoscopic technique called as totally extraperitoneal (TEP) repair for inguinal hernias.[44] This was followed by Daes et al who came up with enhanced view TEP (eTEP).[45]

*Transabdominal endoscopic approach*

Arregui et al used conventional laparoscopy for creating preperitoneal pocket by incising the peritoneum. This technique is called as TAPP.[46]

***Preperitoneal mesh placement for ventral hernia***

*Open type*

Kohler et al introduced an open preperitoneal umbilical hernia meshplasty (PUMP) for umbilical hernia repair.[47]

***Endoscopic preperitoneal mesh repair- approaches***

*Intermuscular endoscopic approach*

Li and Bittner introduced an endoscopic totally extraperitoneal approach (TEA) technique for primary ventral hernia repair through a suprapubic port.[48] Li et al introduced subxiphoid top-down endoscopic totally preperitoneal approach (eTPA) for midline ventral hernia repair.[49] Alpuche introduced eTEP-PP for preperitoneal mesh placement in various ventral hernias superior to the arcuate line.[50]

*Transabdominal endoscopic approach*

TAPP using conventional laparoscopy and by incising the peritoneum in the nearby area of hernial defect, a preperitoneal pocket is created for mesh implantation. As a natural extension of TAPP for inguinal hernia, it is extended to various ventral hernias like umbilical/ epigastric hernia, suprapubic hernias, spigelian hernia, and lumbar hernias. TAPE technique was used for lumbar hernias, and suprapubic hernia.[51-56]

*Retroperitoneal endoscopic lumbar approach*

Li et al attempted retroperitoneal totally endoscopic extraperitoneal (R-TEP) technique.[57]

***Intraperitoneal mesh placement***

*Open approach*

Ventral patch mesh (Ventralex TM ST hernia patch (Bard Davil Inc, Warwick, RI, USA) and Parietex TM composite ventral patch) is being used for medium size for umbilical, periumbilical, epigastric, spigelian and incisional

hernias.[58] Intraperitoneal non-adherant composite mesh implantation is still in practice for larger defects.[59]

*Transabdominal endoscopic approach*

By conventional laparoscopic approach, after tackling the ventral hernias, mesh is implanted over the parietal peritoneum and secured by trans-fascial sutures or by tackers, and is labeled as intra-peritoneal onlay mesh (IPOM).[15] Similarly IPOM is also attempted for inguinal hernia, parastomal hernia repair 5 and perineal hernia.[60,61]

***Use of more than one sheet of mesh in the same plane***

Mostly a single mesh (non-coated/coated) is implanted in a selected plane. But literature reveals that sometimes more than one mesh is also needed to be implanted in the same plane. Following literature impress that two prostheses are placed in the same plane in overlapping manner so, it would be prudent to term it as "monoplanar superimposing mesh" technique. Literature revealed that superimposing meshes are used preperitoneally as well as intraperitoneally.[61,62]

***Use of two sheets of mesh in two different planes***

*Bi-planar mesh placement*

A new ideology of placing two different meshes in two different abdominal planes, particularly for the larger defects with the loss of domain was introduced by Usher long back in 1961, and recently been summarized by Kockerling et al in 2018.[10]

Our literature search showed that placing two different meshes in two different abdominal planes is practiced as various possible combinations like: onlay + retrorectus, onlay + preperitoneal, onlay + intraperitoneal, onlay + inlay, and inlay + retrorectus mesh placements.

Our endeavour is to suggest term as "bi-planar mesh placement" which would be self-explanatory as compared to terms "double mesh", "double prosthetic repair", "dual mesh repair". This would avoid confusions in cases where two separate meshes are used in two different planes. But it is also necessary to clarify whether they are placed in adjacent planes or in distant planes.

So, bi-planar mesh repair can be further clarified by following terms – viz. adjacent biplanar mesh placement i.e. inlay and onlay or inlay and retro-rectus, and distant biplanar mesh placement ie onlay and sublay.

***Adjacent biplanar mesh placement***

When two meshes are placed in two adjacent planes like inlay along with retromuscular/RR or inlay along with onlay to support each other. Following literature has found it useful to prevent recurrence.

Mesh-plug is sutured to the edges of hernia defect and patch of mesh is placed as onlay sub-aponeurotically for inguinal hernia repair and other small hernias.[63]

Inlay and retrorectus or preperitoneal mesh implanted for subxyphoid hernia, for the situation when despite all surgical efforts fascial defect could not be approximated in repair of midline big incisional ventral hernias and in a defect after resection of a big abdominal wall endometriosis on the left rectus muscle.[6,64,65]

***Distant biplanar mesh placement***

The rationale for using two meshes in different planes is typically desired to achieve better stabilization of a bridging situation or defect closure, and thus prevent the recurrence. The technique is mostly used for large hernias with loss of domain. Kockerling et al have thoroughly described various aspects of these techniques under the heads "sandwich repair". But this terminology has been used even for various different repairs like 'Marlex-peritoneal sandwich' repair where single sheet of mesh is sandwiched between two flaps of sac peritoneum.[10] So, to avoid confusion "muscle sandwich repair" would be the meaningful term for denoting some muscle has been sandwiched in between two meshes placed in two distant planes.

***Muscle sandwich repair method***

Following are the natural combinations of distant biplanar muscle sandwich repair, onlay + intraperitoneal (O+IP), onlay + preperitoneal (O+PP), and onlay + retrorectus/retromuscular (O+RR/RM).[66-68]

These biplanar methods are mostly done by open surgery but some researchers have used hybrid technique combining laparoscopic technique with open repair.[88]

***Tri-planar mesh placement***

Implanting mesh in all three abdominal planes i.e. onlay, inlay and sublay has also been explored either in the form of three separate sheets of mesh in three different planes or by using a three-in-one prosthesis.

*Triple mesh technique*

Triple mesh technique is used by Parikh et al in repair of big recurrent lumbar incisional hernia by placing extraperitoneal mesh as underlay, inlay mesh to bridge the defect and one more additional onlay mesh, aiming to reduce the recurrence.[11]

*Three-in-one prosthesis*

Gilbert popularized the "three-in-one" prosthesis for inguinal hernia repair where two pieces of flat mesh are connected by a cylindrical connector. Underlay portion of this prosthesis is deployed in the pre-peritoneal space,

connector remains in the defect as inlay and onlay part is deployed in sub-apponeurotic plane.[12] On similar pattern Guttadauro et al came out with "all-in-one mesh hernioplasty" for primary inguinal open repair.[13]

## CONCLUSION

The terminologies used for various practices of mesh implantation are ambiguous and confusing. The varied terms and similes are used in the literature to convey the methods of mesh implantation. Inconsistent and confusing terminologies leads to difficulty in comparing and analyzing the literature. In this review author identified exact nature of the mesh placement according to abdominal muscle planes, number of planes utilized for mesh placement and the nomenclature used for those methods. Furthermore, author grouped various methods of mesh implantation under the new classification to accommodate various ways of mesh implantation (Table 1). New classification of "Mesh Repair Methods" is self-explanatory, inclusive and its adoption would improve comparison and communications for research studies of various practices of hernia mesh implantation and will help in avoiding ambiguity.

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