Review Article

The Abdominal Wall Closure - What Do We Know So Far?

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Gone are the days when the abdominal wall was just a barrier beyond which the surgeon worked; the intimate understanding of the abdominal wall is a pre-requisite for every surgeon, both in closure of laparotomy wounds and in minimal access surgery of the abdominal wall unit itself. This article reviews the basic concepts of the abdominal wall and the various methods of closure available to the current surgeon; a ready-reckoner of what we know so far.

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The abdominal wall was once considered to be just a structure that lies in between a surgeon and his/her livelihood. Initially considered to be a static myo-aponeurotic structure, has now been found to be a dynamic unit with multiple components, each of which contribute to the functioning of this unit. In this chapter, we will try to understand the anatomy and dynamics of the abdominal wall, the different scenarios presented to the surgeon and finally the various techniques of closure available at the surgeon's disposal in every circumstance.

Anatomy of the abdominal wall[1] :

The abdominal wall proper can be divided into medial and the postero-lateral components - the medial component is made up of the rectus sheath containing the rectus abdominis and the pyramidalis fused at the midline, postero-laterally by three sheet like muscles and their aponeuroses – the external oblique, internal oblique, and the transversus abdominis. The aponeuroses of the sheet muscles participate in the rectus sheath formation.

The rectus sheath is formed by the aponeuroses of all lateral muscles – external oblique (EO), internal oblique (IO) and transversus abdominis (TA). The posterior sheath, formed by the posterior slip of the IO and the TA aponeuroses is deficient below the **semi-circular line of Douglas**, below which the rectus muscle rests on the fascia transversalis, pre-peritoneal tissues and the peritoneum itself.

All the muscles and aponeuroses attach to a fibrous structure in the midline – the ***linea alba.***

Editor's Comment :

- The abdominal wall anatomy and the closure techniques are rapidly evolving.
- A review of where we are now will help us advance the field ahead and thus improve our understanding and ultimately, patient outcomes.

The potential sites of weaknesses of the anterior abdominal wall are reinforced by the transversalis fascia which forms the deepest part, just above the visceral peritoneum itself (Fig 1).

Wound Healing under the Microscope:

A discontinuity/ disruption in a tissue is termed a "***wound***". The surgeon is intimately involved in the controlled creation and attempt at treating wounds. A wound is usually a result of trauma to the local tissue and the healing process (in an uncomplicated wound) occurs in three stages –

i. Inflammation
ii. Proliferation
iii. Maturation

The inflammation phase lasts for a few days, mediated mainly by neutrophils, is responsible for clearing the wound of non-viable and necrotic tissue – *microscopic debridement*.

The proliferation phase is seen over the next few days to weeks, where an influx of macrophages lead to fibroblast proliferation and collagen deposition.

The maturation phase lasts from months to years, during which remodelling of the wound occurs leading to deposition of regular collagen fibres which add to the strength of the wound[2].

Even the well healed wound does not reach the pre-injury strength [50% strength at 150 days post-injury[3]].

Though such distinct stages are known, it must be borne in mind that there is some degree of overlap between the stages and **wound failure** can occur at

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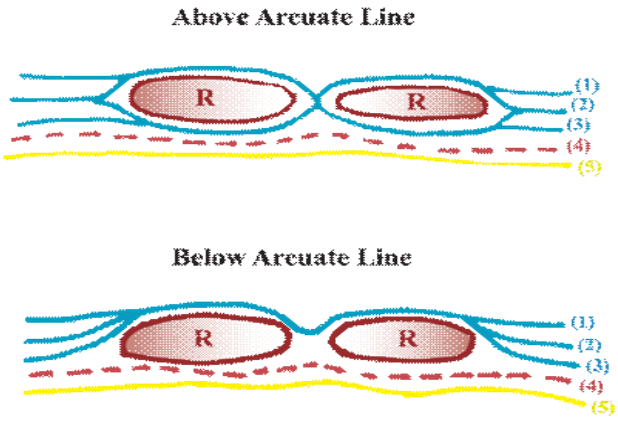

Fig 1 — Cross section of the abdominal wall unit. (1) External Oblique Aponeurosis, (2) Internal oblique aponeurosis (3) Abdominis aponeurosis (4) Transversalis fascia (5) Peritoneum

any time following injury / surgery due to inadequacy in any of the phases of healing, either due to host factors or due to improper supportive therapy.

The Biochemical Parameters of Wound Healing :

Collagen :

Collagen is a triple-helix molecule (300nm in length) which is synthesised by the tissue fibroblasts and deposited in a matrix of proteoglycans and this molecule is crucial to the strength of any wound. The synthesis of collagen needs adequate levels of Vitamin C which acts as a co-factor in the maturation of these collagen fibrils.

Total collagen content of the wound reaches normal levels within a few weeks – but these are unorganised and do not add any strength to the wound[4].

A high level of collagen deposition and lysis (*collagenolysis*) occurs over the period of weeks to months, which ensures that there is a replacement of type III collagen by type I collagen with remodelling making sure that there is adequate wound strength with collagen cross-linking and wound contraction.

Any aberration in the steps of healing can lead to immediate or remote wound complications.

Wound Types :

Wounds can be classified based on the type of surgery done – clean, clean-contaminated, contaminated, dirty *(www.cdc.gov)*, whereas wound healing is classified based on amount of tissue lost – primary, secondary, delayed primary/ tertiary intention.

At one end of the spectrum Clean wounds are where there is no expectation of wound contamination, whereas there is almost a sure chance of surgical site incident / infection (Fig 2).

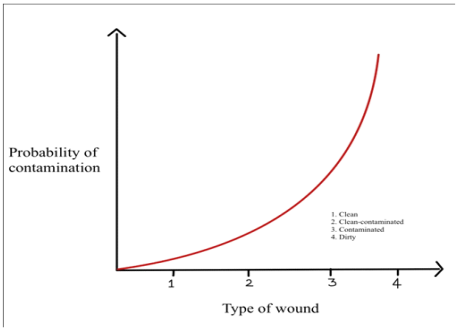

Fig 2 — Relationship between probability of wound contamination and the type of wound

The classical example of a wound that heals by ***Primary intention*** is the surgical wound, which is closed by sutures – heals with no tissue loss. ***Secondary intention*** is when there is devitalised tissue in the area which means that the wound cannot be closed and it has to be allowed to heal by granulation and subsequent scarring and fibrosis, whereas ***Tertiary intention*** is when a dirty wound which has been sufficiently surgically treated which now has healthy tissue which can be closed surgically.

There is always loss of strength with any wound, surgical or non surgical. Providing support to wounds is paramount to wound healing as the tissues never reach the pre-injury tensile strength.

Wound Support :

The health of the wound essentially depends two things – the patient and the surgeon.

Patient factors that adversely impact wound healing are advancing age, poor nutrition, reduced oxygen tension, irradiation, malignant diseases all of which have been discussed time and again.

The surgeon factors, pertinent to the abdominal closure, can be discussed in 2 broad categories – ***type of suture material*** and ***techniques of closure*** used.

The Suture Material :

Suture materials have come a long way since the Ancient Egyptians and a surgeon now has many an option to choose from. The ideal suture, as described by Lord Moynihan, should have high tensile strength that is reproducible, evoke minimum tissue reaction, be a traumatic and avoid chance of infection, while ensuring that they do not break down until sufficient tissue strength has been achieved. Suture materials used in current practice have most, if not all, of the above characteristics.

Broadly speaking, suture materials can be divided into:

i. Absorbable materials
ii. Non – absorbable materials

Catgut, polyglactin (vicryl), polyglecaprone (monocryl) and polydioxanone (PDS) are ***absorbable materials***; braided silk, polypropelene (prolene), nylon and surgical stainless steel are commonly used ***non-absorbable materials***.

Since the midline abdominal

incision is a relatively common and versatile incision used for abdominal exploration, the closure of the midline wound and its problems will be discussed in the following sections.

The Surgeon :

The surgeon is by far the more important factor involved in any procedure – patient factors are different for each patient, but improper technique and non-scientific decisions should evoke the expectation of a problem.

Minimal tissue handling **(dissection, resection or repair)**, identifying intra-operative problems **(in anatomy and pathology)**, and avoiding unintentional movements **(tissue/ instrument handling)** are fundamental in avoiding intra-operative and eventually postoperative complications.

When faced with closing the abdominal wall itself, identification of the components of the abdominal wall unit, prevention of damage to the unit and underlying structures by improper handling or forceps application and minimal handling and least possible trauma are integral to ensuring a *dependable and reproducible closure* in every situation.

Midline Closure – Elective Laparotomies :

The cornerstone of an elective surgery is that the procedure is undertaken with a well prepared, surgically fit (barring the disease process itself) patient in whom closure of the abdominal wall is a given – unless some drastic intra-abdominal catastrophe occurs, and certain norms are established when it comes to the actual closure itself.

Closure of the peritoneum is not recommended; mass closure of the rectus sheath is acceptable in the abdominal wound. Considering the collagenase activity that occurs at tissue 5-7mm on either side of the midline[5], closure of the tissues taking a minimum of 10mm width and 10mm away from each other has been found to be adequate closure. Such a technique should ensure that subcutaneous tissue, muscle, omentum or underlying viscera are not included in the bite (Fig 3).

Challenging this concept of "wide" bites, a group of surgeons and scientists from the Netherlands undertook the landmark "**STITCH trial**". They hypothesised that smaller and closer placed bites would result in a lower incidence of postoperative incisional hernias. (Bite thickness and distance between two bites were **5mm** each)

They randomised patients into two groups – one group receiving the small bites and the other group receiving the conventional closure; cases were matched in all variables and all types of cases (including aortic and gynaecological surgical cases) were included in the study.

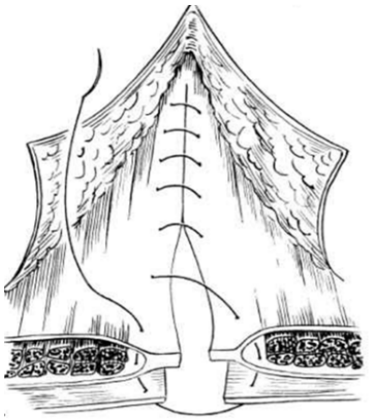

Fig 3 — Conventional abdominal closure (Courtesy Fischer's Mastery of Surgery, 7th Ed.)

At 1 year of follow-up, they found that the group that received the smaller bites had a much **lower incidence of incisional hernia** as compared to the conventional group (13% *versus* 21%), while requiring more stitches, more time of closure (14min vs 10min) and higher suture : wound ratio (5.0 *versus* 4.3).

The inference they postulated was that use of more stitches resulted in a more even distribution of forces which avoided necrosis and led to deposition of the ideal ratio of collagen type 1: collagen type 3[6].

Emergency Laparotomy :

Emergency laparotomies pose specific but different challenges to abdominal closure – the index operation might be a damage control surgery undertaken to stabilise the patient's physiology, such as massive bleeding due to trauma, intra-abdominal sepsis, peritonitis or bowel ischemia and abdominal closure of such cases might not be feasible.

The major challenge in emergency cases is the possibility of development of postoperative abdominal compartment syndrome. Such cases might benefit from **temporary abdomen closure (TAC) techniques**[7].

In cases where closure can be safely performed, a continuous suture using a delayed absorbable material is usually used. But in cases where rise in intra-abdominal pressure is encountered/ anticipated, this continuous suturing produces a "**Hack-Saw**" effect, which cuts through the abdominal wall unit.

The sutures are fixed at two places and a running stitch is given throughout the wound, which distributes the forces equally across the wound. During any activity that increases the intra-abdominal pressure, the suture bite gets distracted. This leads to a sawing motion at that site and eventually cuts-through, leading to **abdominal wound dehiscence (or burst abdomen).**

Meta-analytic studies have now recommend that in cases where the chance of burst abdomen is high, interrupted closure of the abdominal wall unit should

be preferred over continuous closure, but the incidence of incisional hernia is similar in either case.

Interrupted Closure of Emergency Laparotomies :

Various techniques have been described which can be adopted in cases where there is a significant risk of postoperative abdominal wound dehiscence.

1. The Smead-Jones technique
2. Modified Hughes' Stitch
3. Figure of "8" or the "X" stitch.
4. The retention suture.

The ***Smead-Jones technique*** involves taking an outside-in bite 2cm away from the wound, crossing to the opposite side, taking an inside-out bite close to the wound edge, emerging from the skin, crossing to the opposite side, taking a near bite superior to the previous bite (outside-in) and taking a far bite (2cm away inside-out) on the opposite side and tying a knot (Fig 4).

The ***Modified Hughes' Stitch***, which is a modification of the Smead-Jones' technique involves a double far-near near-far bites, done in a horizontal and vertical mattress fashion[8] (Fig 5).

The ***Figure of 8*** or the ***"X" stitch*** involves an outside-in bite 2cm from the wound edge, crossing the wound and emerging inside-out 2cm away from the wound edge 4cm away from the initial bite; crossing of sutures, and similar bites at right angles to the precious bites and knotting (4 throws). The free end of the suture is passed deep to the sutures using a right-angle forceps, 4 more knots given and the knots are cut and then buried[9].

The ***Retention suture*** is a type of suturing that uses full thickness bites of all abdominal layers (external retention sutures) or all layers except the skin (Internal retention sutures). The external type is then threaded through a rubber/ PVC/ latex tube (red rubber catheter / infant feeding tube / per-urethral catheter) and tied. This technique has been largely abandoned due to lack of evidence in reduction of burst abdomen[10] (Fig 6).

Temporary Abdominal Closure (TAC) Techniques :

The Temporary Abdominal Closure (TAC) or Open Abdomen (OA) techniques, originated as a method of Damage Control Surgery for trauma but now has been expanded to non-traumatic cases that require a laparostoma creation almost always as a life-saving measure. This is particularly useful when cases where there was inadequate source control in intra-abdominal sepsis, bleeding or in cases of doubtful gut viability when a re-look laparotomy is required.

In cases where closure is not prudent, temporary abdomen closure provides protection to the intra-abdominal viscera, while ensuring decompression and avoiding the potential complications of abdominal compartment syndrome.

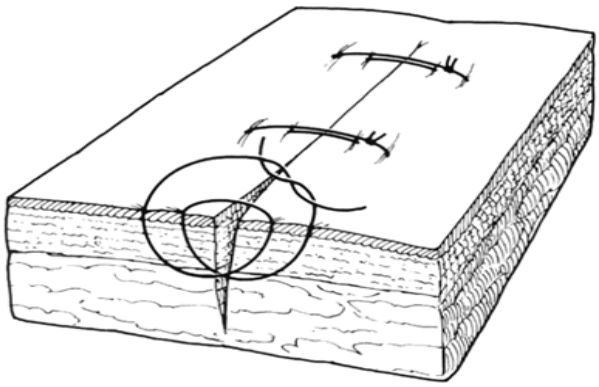

Fig 4 — Smead-Jones' Far-near-near-far technique

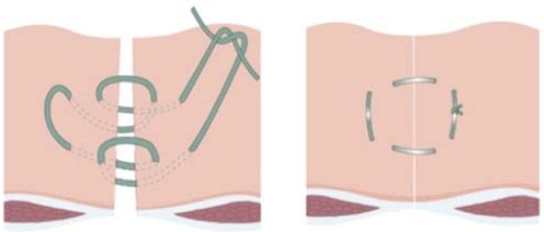

Fig 5 — the Modified Hughes' Stitch

The aim of any TAC should be closure of the abdominal wall unit as early as possible without incurring the risk of intra-abdominal hypertension / Abdominal Compartment Syndrome (ACS), latest by post-operative day 8-10. Delay of closure will lead to subsequent loss of abdominal wall domain due to retraction and fibrosis, which will cause difficulty in fascial closure[11].

1. Simple Packing – Covering of the exposed viscera with non-absorbent moist dressings and covering; repeated change of dressings with peritoneal lavage every 24 hours is required[12].

2. Skin-only closure – Closure of skin using towel clips or stapling devices with plan to re-explore frequently. This method avoids the fluid and heat loss associated with the open abdomen (Fig 7).

3. Bogota Bag – Originally used at Bogota, Columbia, it involves

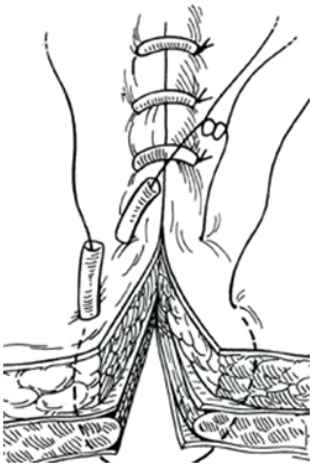

Fig 6 — Retention suturing

suturing a clear, sterile IV bag / urobag to the skin. Enables daily inspection and lavage, while preventing the fluid and heat loss[13] (Fig 8).

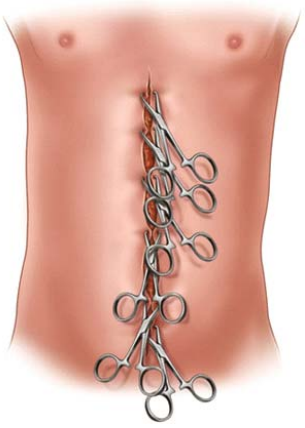

Fig 7 — Skin only Closure (using towel clips)

4. Mesh closure – Use of mesh to bridge the fascial gap (absorbable polyglactin mesh or non-absorbable polypropylene mesh). This method avoids exposure of the viscera to the atmosphere, while promoting granulation, over which a skin graft can be done. The eventual incisional hernia can be then repaired in an elective setting after 6-12 months. (**Fabian protocol**) (Fig 9).

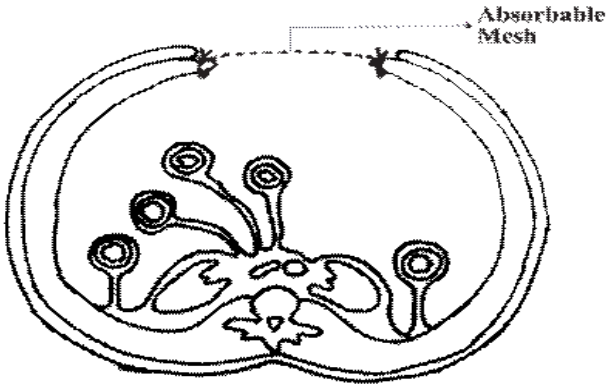

Fig 9 — Approximation of the sheath using bio-absorbable mesh - Fabian Protocol

5. Vacuum packs / Vacuum Assisted Closure (VAC) dressings – Vacuum pack is the use of moist dressings and attaching the wound to a wall-suction to ensure that the wound effluents are removed from the wound. VAC dressing uses negative pressure applied to a polyurethane sponge which along with removal of wound effluent, helps in wound contraction and eventual wound closure.

6. The Witmann Patch closure – If closure is not feasible by the first week of the laparostoma creation, serial closure using the Witmann patch can be used; this avoids the loss of abdominal wall domain which may complicate future incisional hernia repair.[14]

7. Combination methods – Use of vacuum assistance and fascial bridging using meshes, allowed for more rates of abdominal wall closures. Studies done by Acosta et al., and Rasilainen et al., have used vacuum assisted closure of the open abdomen, with non-absorbable mesh sutured to the fascia which resulted in a 78-89% delayed fascial closure rates, with 7-12% of cases developing entero-atmospheric fistulae[15].

a. The technique involves thorough abdominal toileting, covering of the viscera with a sterile perforated plastic sheet, moist laparotomy pads, dry gauzes followed by suturing of an oval-shaped polypropelene mesh to the fascia using a monofilament running suture material. Between the moist dressings and the mesh, two silicone drain tubes were placed and brought out through the skin, connected to a suction apparatus (100-150mmHg negative pressure). This entire setup was covered with and transparent occlusive dressing.

b. This wound is to be explored every 2-3 days; the mesh being cut open in the midline, peritoneal lavage done, packs changed and the mesh re-sutured tighter than previously, thus bridging the fascial defect.

c. The abdominal closure is attempted when the defect is 3-5cm with weak tension between the edges. The mesh is removed, the abdominal fascia closed and the skin closed (Fig 10).

8. Fascial bridge techniques – At the index operation or during subsequent re-look surgeries, fascial closure can be attempted using the component separation technique, as tight abdominal closure can pre-dispose to development of Abdominal Compartment Syndrome[16]. Separation of the abdominal wall unit to

Fig 8 — Bogota Bag closure

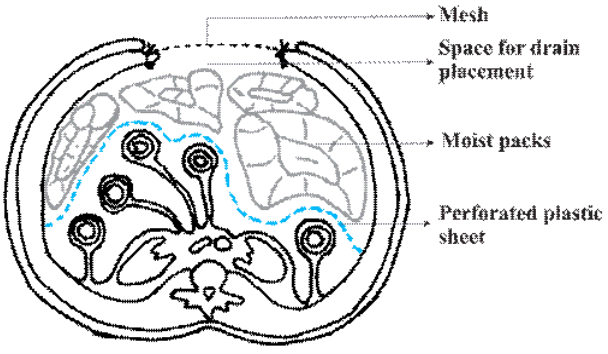

Fig 10 — Combination methods

its specific components, along with Transversus Abdominis release bilaterally yields up to 10cm above umbilicus, 20cm at the umbilicus, and 8cm in the supra-pubic region. This can be combined with mesh closure as well[17] (Fig 11).

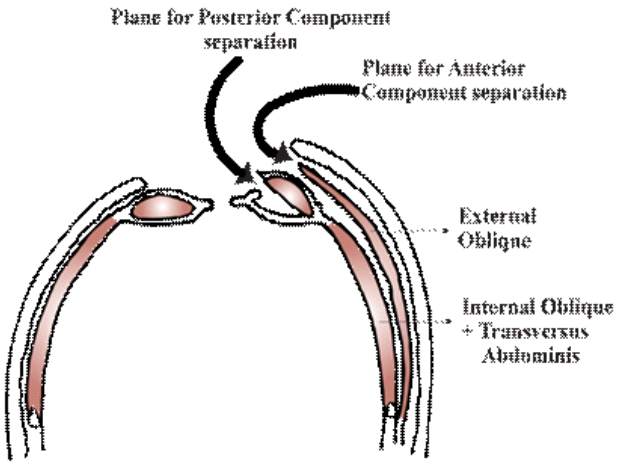

Fig 11 — Component Separation Techniques (Courtesy Fischer's Mastery of Surgery, 7th Ed)

The primary aim of any surgery in emergency is source control. If closure at the index surgery is feasible, it should be done – continuous / intermittent suturing, the choice being case specific.

The option of an Open Abdomen with Temporary Abdomen closure techniques with re-look laparotomies must be remembered, though local complications of intestinal fistula formation, fascial retraction, intestinal ischemia and systemic complications of fluid and heat loss with subsequent hemodynamic collapse must always be borne in mind.

The eventual outcome of these patients is to achieve abdominal closure at the same admission, while planning for an elective incisional hernia repair at a later date with abdominal wall reconstruction techniques.

Conclusion

The abdominal wall is a complex, dynamic structure to which surgery acts to disrupt the mechanics of its functioning. The aim of closure is to ensure the return of function of this abdominal wall unit. Understanding the mechanics of this structure and knowledge of the various closure methods are essential in the arsenal of any surgeon.

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