Implementation of Modern Incisional Hernia Repair Techniques

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Abstract

Incisional hernia is one of the most common complications (5–20%) after abdominal surgery. Surgery is the only option to cure a hernia. Symptoms of an incisional hernia depend on the size of the abdominal wall defect and the protruding tissue. About 30% of the patients with an incisional hernia will have an operation performed. Traditional surgical sutured techniques have very high recurrence rate, whereas recurrence rates can be substantially reduced using modern mesh techniques. Mesh placement in a retromuscular position have excellent results in curing the hernia, but often involves large incisions and demands dissection of the retromuscular space of the rectus abdominis muscles. The mesh reinforces the repair of the abdominal wall. Alternatively, a mesh can be placed in the abdominal cavity on the posterior surface of the abdominal wall, fixed with sutures or tackers. To prepare the abdominal wall all adhesions must be dissected with a risk of bowel injury.

A Swedish multicenter randomized controlled trial (RCT) PROLOVE has been performed on midline incisional hernia repair, comparing open (OHR) retromuscular mesh to laparoscopic (LHR) intraabdominal mesh techniques, focusing on pain and quality of life and a retrospective long term follow up for recurrence and QoL after the implementation of the retromuscular hernia repair at two specialist centers.

Paper I covers the RCT with 133 included patients in a short term perspective. Elsewhere laparoscopic techniques had proved to cause less postoperative pain, have fewer complications and shorten recovery. LHR had fewer surgical site infections (SSI) ($p<001$). The operative techniques did not differ in pain and time to recovery. The preoperative quality of life (QoL) was low but restored to norm level at 3 weeks, with physical function being better after LHR.

Paper II covers 124 patients remaining at 1 year follow up for complications, QoL, and predictors for an uneventful recovery. The reoperation rates were similar; wound complications were more common in OHR, contrary to recurrence in LHR. Recurrence rate did not differ. QoL was restored after 8 weeks and maintained at 1 year at norm level. The LHR technique was a predictor for an uneventful recovery.

Paper III investigates the contraction behavior of a cohort of 36 meshes included in the PROLOVE trial. Patients with metal clip-marked meshes had x-ray exams within 2 days and 1 year after surgery. Mesh area change was in LHR – 6% and in OHR +10%, probably within the limits of the technique used for measuring, and not regarded as clinically significant. No correlation was found between mesh area change and recorded pain levels.

Paper IV covers a long-term follow up of 11 years on 301 patients with midline incisional retromuscular hernia repair performed 1998–2006. Over all recurrence rate was 8%, with no difference between primary or secondary hernia repairs. Long term QoL was lower than the norm, similar to patients with 2 chronic conditions. Satisfaction with surgery high was high.

Conclusions

Incisional hernia patients have low QoL which is restored by both LHR and OHR, but OHR has more SSIs. OHR has excellent long-term outcome. Mesh contraction at LHR and OHR is not a clinical problem.

Key words: Surgery, Incisional Hernia Repair, Retromuscular mesh, Laparoscopy, IPOM, recurrence, contraction

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To my boys; Martin, Hugo and Carl

Målet är ingenting, vägen är allt
— Robert Broberg

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List of Original Publications

This thesis is based on the following original work, which in this thesis will be referenced to by the Roman numeral.

I. Short-term outcomes for open and laparoscopic midline incisional hernia repair: a randomized multicenter controlled trial: the PROLOVE (prospective randomized trial on open versus laparoscopic operation of ventral eventrations) trial.
    Rogmark P, Petersson U, Bringman S, Eklund A, Ezra E, Sevonius D, Österberg J, Montgomery A. Ann Surg 2013;258(1):37-45.
    doi: 10.1097/SLA.0b013e31828fe1b2.

II. Quality-of-Life and Surgical Outcome 1 Year after Open and Laparoscopic Incisional Hernia Repair: PROLOVE: A Randomized Controlled Trial.
    Rogmark P, Petersson U, Bringman S, Ezra E, Österberg J, Montgomery A. Ann Surg 2016; 263(2):244-50.
    doi: 10.1097/SLA.0000000000001305.

III. Long term retromuscular and intraperitoneal mesh size changes within an RTC on incisional hernia repair and a review of the literature.
    Rogmark P, Ekberg O, Montgomery A, Submitted

IV. Long-term follow up of retromuscular incisional hernia repairs; recurrence and quality of life.
    Rogmark P, Smedberg S, Montgomery A, Submitted

Abbreviations

ASA	American Society of Anesthesiologists
BMI	Body Mass Index
CST	Component Separation Technique
DC	Double-Crown (technique)
ePTFE	Expanded polytetrafluorethylene
HRQoL	Health-Related Quality of Life
IH	Incisional Hernia
IHR	Incisional Hernia Repair
LHR	Laparoscopic Hernia Repair
PP	Polypropylene
PE	Polyester
PTFE	Polytetrafluorethylene
PVDF	Polyvinylidene difluoride
OHR	Open Hernia Repair
QoL	Quality of Life
SF-36	Short Form-36
PF	Physical Function
RP	Role Physical
BP	Bodily Pain
GH	General Health
VT	Vitality
RE	Role Emotional
MH	Mental Health
PCS	Physical Composite Score
MCS	Mental Composite Score
AUC	Area under the Curve
CI95%	Confidence interval with 95% width
IQR	Inter-Quartile Range
Md	Median
Mn	Mean
OR	Odds Ratio
SD	Standard Deviation

Thesis Overview

	Question	Method	Results	Conclusion
I	Is laparoscopic repair of midline incisional hernias less painful than open repair, and therefore have a shorter recovery period and better quality of life?	A multicenter RCT with SF-36 pain assessment after 3 weeks as primary endpoint. Question-naires and clinical examination at 8 weeks assessed secondary endpoints.	64 LHR and 69 OHR. No difference in pain was detected. SF-36 physical sub-scales favored the LHR, $p<0.009$. More wound infections occurred in the OHR group, $p<0.001$.	No difference in pain and equally restored QoL after 8 weeks. Fewer complications favor LHR in the short term perspective (8 weeks).
II	Does LHR lead to faster recovery of QoL and is it maintained at 1 year? To assess predictors for bad surgical outcome.	1 year follow up of RCT from paper I with clinical examination and questionnaires including QoL assessed by SF-36. Uni- and multi-variable logistic regression for risk factor analysis of QoL.	No difference in QoL. Event-free recovery occurred in 85% after LHR and 65% after OHR. Abdominal wall symptoms decreased from 82% to 13%. 92% satisfied patients. Obesity pre-dicted better QoL.	Patients with midline IHR restore their QoL, with no difference between surgical techniques. SF-36 seems suited for assessing QoL in patients with abdo-minal incisional hernia.
III	Is mesh contraction a clinical problem in retromuscular and intraabdominal IH mesh repair?	A cohort from paper I received radio-opaque markers at the mesh borders. X-ray examinations after 1 day and 1 year were compared.	Mesh area change was −4.4% in the intraabdominal space, and +0.5% in the retromuscular space.	Mesh contraction is not a clinical issue. A recurrence is probably more dependent on fascial closure, mesh fixation and mesh placement.
IV	What is the long-term recurrence rate and QoL after midline hernia repair using a standardized retromuscular OHR technique?	All living patients operated for midline IH 1998–2006 in 2 hospitals had clinical examination and questionnaires, including QoL.	301 patients with a follow up of 137 months. Recurrence rate 8%, with no difference between primary and recurrent repair.	Retromuscular OHR is well tolerated over time with low recurrence rate also after a recurrent hernia repair.

Introduction

I believe that 15 per cent of all patients upon whom laparotomy has been performed, if examined five years or more thereafter, will be found to be suffering from post-operative hernia. I am convinced that this percentage is too low; yet it is sufficiently high to make the subject one of vital importance to every physician and surgeon. Some modern surgeons do not care to make this admission, which partially accounts for the lack of figures from which to prove this assertion.

...that ventral hernia is a frequent complication which renders the lives of the patients miserable and often entirely useless, so that they merely exist in contemplation of second operations, the ultimate results of which are more or less disappointing, since relapses take place in more than one-half of the cases.

B. Brinkley Eads, 1901

Incisional hernia formation has been a serious complication since the introduction of abdominal surgery. It has troubled both patients and surgeons (Eads, 1901). It was recognized as very difficult condition to repair with poor long term results. Many patients have suffered the sequelae of surgery, even if the original disease or cause for an operation has been cured.

The definition of hernia, *rupture* in Latin, *bud* in Greek, is the abnormal eventration of an organ through an opening in a wall of a cavity. The protrusion can form a clinical problem causing pain, disfigurement and in worst cases impaired blood circulation to the protruding organ with ischemia and necrosis as a consequence.

Brief history of Surgery

Modern surgery evolved in the middle of the 19th century with the development of anesthesia. In 1842 ether was used by Crawford W. Long when excision an atheroma in the neck, and in 1844 a tooth extraction was performed by the American dentist Horace Wells under analgesia of nitrous oxide (NO_2). Wells first tries were unsatisfactory (the patient was resistant to NO_2) and his partner Thomas Green Morton sought another solution and found ether as a replacement. Dentistry then lead the way into general anesthesia. Friday October 16, 1846 is regarded as

the birth of anesthesia, when the first surgical procedure under ether anesthesia was performed in Massachusetts General Hospital, an excision of a cyst in the neck of a young man. Morton was acting anesthesiologist; already with experience of several tooth extractions with his former partner Wells (Hæger et al., 1988).

The development of aseptic techniques was also a significant step forward. Joseph Lister demonstrated that infection was caused by bacteria, and by an aseptic technique infection could be prevented. Amputation was often the solution to survive a contaminated wound, certainly for war time surgery. Mortality rates of amputated patients with complex infected wounds were of as high as 50% in civilian practice, and 90% under military conditions, prior to aseptic techniques (Howard, 1999). With the fear of entering the abdominal cavity diminished surgeons could allow themselves to increase the operating time for more thorough safer dissection with less blood loss, increasing the chances for the patient to survive with fewer complications.

The "Listerian method" emphasized treating the wound before, under and after surgery using an aseptic technique. The Hungarian physician Ignaz Semmelweiss had shown already in 1847 that childbed fever could be reduced if hands were cleaned before treating the women. However, several decades passed before handwashing became mandatory before surgery. Sterilization of instruments and the use of operating room cap, gown and mask were introduced in the 1880s. William S. Halstead at Johns Hopkins Hospital introduced surgical gloves initially to his scrub nurse (and future wife) who had developed a skin reaction to the mercuric chloride used for sterilization. Soon the routine use of gloves for the entire operating team was adopted.

Alexander Fleming reported his first findings on penicillin in 1928 and a decade later it was developed for clinical use. With penicillin the antibiotic era started, creating hope for the end of surgical infectious complications and also the cure of infectious conditions so that surgery sometimes could be avoided. Antibiotics have facilitated more complex surgery to be performed on fragile patients with severe diseases and comorbidities.

Abdominal wall anatomy

No disease of the human body, belonging to the province of the surgeon, requires in its treatment a greater combination of accurate anatomical knowledge with surgical skill, than Hernia in all its varieties.

— Sir Astley Cooper 1804

Detailed knowledge of the anatomy of the abdominal wall is of utmost importance for the surgeon when entering the abdominal cavity. The object should always be to minimize the trauma and avoid incisions that could cause irreversible damage by cutting nerves, muscles and vessels. These are prophylactic actions that should

be well known by all surgeons and not only by the "repairing" team coming after to restore the damage done when trying to cure the original disease.

The abdominal wall encloses the abdominal cavity. It is bounded cranially by the lower ribs and cartilage laterally and the xiphoid process in the midline. Caudal boundaries are the iliac crest, the inguinal ligament and the tuberculum pubicum of the pelvic bone, which in turn is fused to the contralateral side by the symphysis.
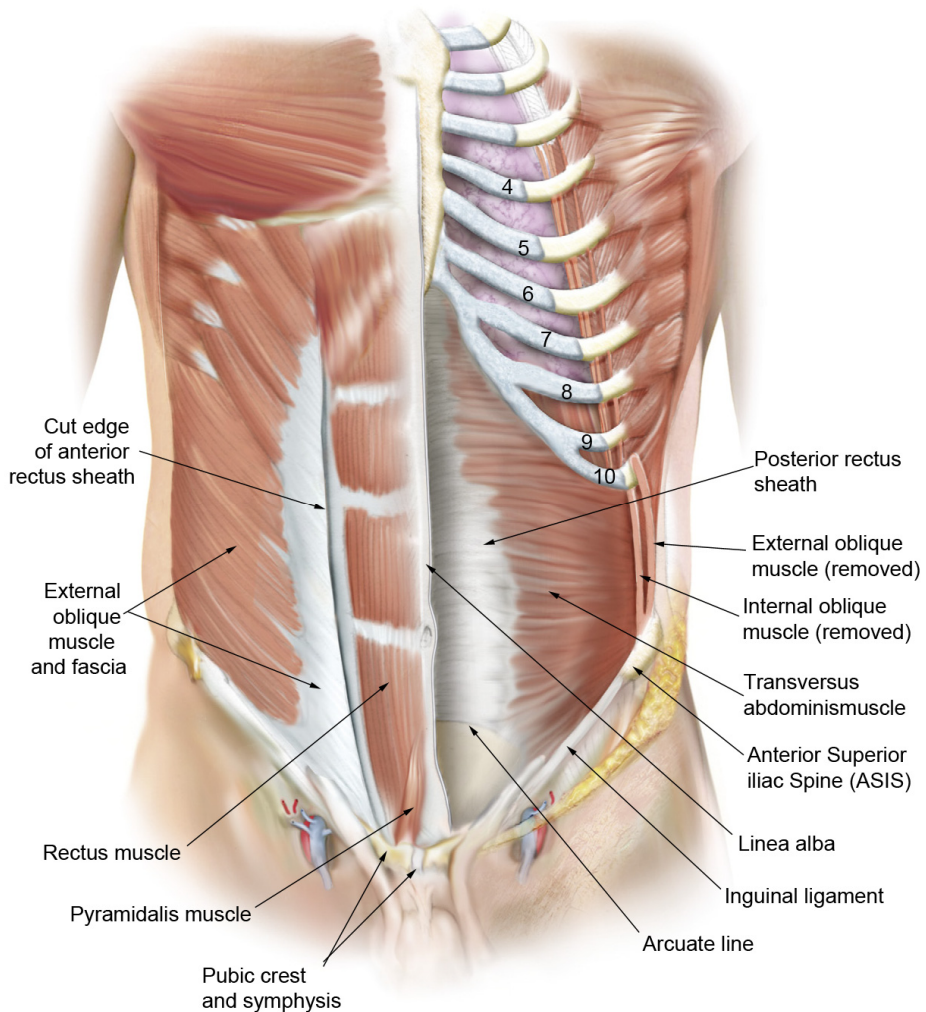
Figure 1 Abdominal Wall Anatomy (Rosen, 2012)
Used by permission from Elsevier for thesis; non-profit University use

The muscular structure consists of 8 muscles working in groups to achieve stability and flexibility to the torso. Ventrally the two rectus abdominis muscles attach to the pubic bone on each side between the tuberculum pubis and the symphysis, and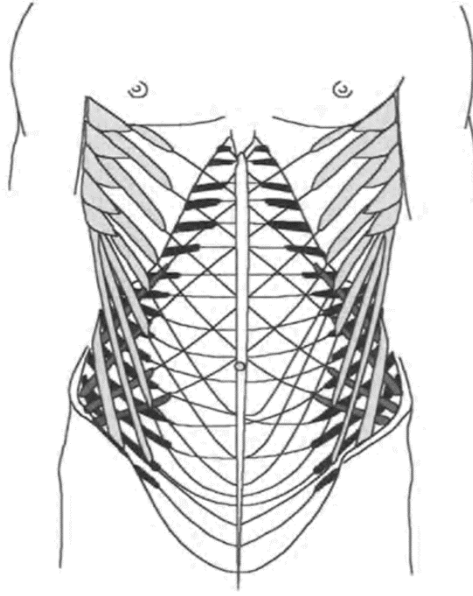 reaches to cartilage of the 5th, 6th, and 7th ribs and to the xiphoid. The rectus muscles are covered anteriorly by a firm fibrous sheath, an aponeurosis. Three or four fibrous transverse tendon-like bands of the rectus muscles attach to the anterior aponeuroses. Posteriorly, the muscles are also covered by an aponeurosis, which ends about 5 cm below the umbilicus, in the arcuate line. There are virtually no adhesions, vessels or nerves between the muscle and the posterior aponeurosis making this and ideal plane for dissection and mesh placement.

The peritoneum of the abdominal cavity covers the dorsal aponeurosis and the lower part of the rectus muscles, with just a thin fatty layer interspaced between the structures. A small triangular *m. pyramidalis* may be present, originating medially from the pubic bone and inserting in the midline ventral of the rectus muscles below the umbilicus.

The anterior and posterior aponeuroses fuse between the xiphoid process and the symphysis to form a dense fibrous plate in the midline, the *linea alba*. Above the umbilicus it is 1-2 cm wide and below only a few millimeters wide. The *linea alba* can stretch during pregnancy or in overweight forming a gap between the rectal muscles (*diastasis m. recti)* appearing like a hernia, even though no actual wall defect exists.

Blood supply to the rectus muscles comes mainly from the upper and lower deep epigastric arteries and veins which originate in the external thoracic and external iliac vessels, respectively. Minor arteries and veins follow the intercostal nerves which enter the rectus muscles laterally and supply motor innervation to the muscles. Cutaneous braches innervating the skin of the abdominal wall, penetrate through the subcutaneous tissue in the midaxillary line, and medially of the rectus muscles.

Lateral to the rectus muscles is a tendinous line, *linea semilunaris*, where lateral wall attaches to the rectus sheath. The lateral wall consists of three separate muscles: the inner transverse abdominal muscle, the internal oblique abdominal muscle and the external oblique abdominal muscle. The oblique abdominal muscles run at right angles to each other; the external runs from lateral-cranial to medial-caudal. This arrangement makes the external oblique muscle form a functional unit with the contralateral internal oblique muscle. It is in the lateral wall where the grid incision is performed at open appendectomy. There is a potential risk of damage to both nerves and muscles by stretching or cutting when access is limited at operation.

Wound Healing

Every surgical incision is a tissue trauma that heals with a scar. The wound healing is a dynamic process which traditionally can be divided into four phases which seamless overlap: coagulation, inflammation, fibroplasia and remodeling. Under normal circumstances the time span of these phases are somewhat predictable.

The first phase (coagulation) begins immediately after the injury and causes hemorrhage and exposure of subendothelian tissue. Catecholamines and other signal substances (cytokines) are released from tissue mast cells initiating the healing process. At the end of this phase platelets produce clotting factors to form fibrin and further release of cytokines (formerly "growth factors"). This phase lasts minutes to hours.

In second phase (inflammatory), migration of leukocytes into the wound occurs. This phase lasts for several hours. In the first 24 hours polymorphonuclear leukocytes dominate followed by invasion of macrophages. The immune system is activated. The recruiting and formation of connective tissue cells is initiated.

The third phase (fibroplasia) is when the collagen fibers are synthesized. Collagen is the most important component of the extracellular matrix, supplying stability and tensile strength. Mineralization can decrease its compliance and form

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bone or cartilage. Several types of collagen exist (in fact, 28 are known) of which collagen I and III are of importance in wound healing.

Collagen I is the most abundant form (over 90%) in the body. It is formed by aggregation and crosslinking of multiple collagen fibrils into fibers. The crosslinking is dependent on proteinases and vitamin C as a cofactor. A long term deprivation of vitamin C results in deficient collagen synthesis manifested as scurvy. Defects of genes coding for collagen or proteinases have been linked to connective tissue diseases, e.g. the Ehler-Danlos syndrome.

Collagen III is synthesized in the wound by fibroblasts, a fibril form. In the extracellular space the fibrils are modified by matrix metalloproteinases (MMP) (Klinge et al., 2001). The modification of collagen III into collagen I is a dynamic process with constant synthesis and degradation. In this phase the regulation favors the synthesis.

In the optimal case this phase is not disturbed by any extrinsic factors like a complication. A prolonged fibroplasia phase is needed if a contamination occurs; or if diminished blood flow decreases the levels of oxygen, nutrients and immune system support; or if the wound closure fails (because of high tension) to keep the wound edges approximated to make it favorable for the granulation tissue to adhere.

Eventually the healing passes into the fourth phase (remodeling), which can start within 24 hours after injury and lasts for weeks to months to years. The regulation of degrading and synthesizing collagen becomes more balanced and the collagen III is transformed to collagen I. The scar contracts and eventually decreases in size and softens.

Abdominal wall pathophysiology and incisions

Surgical techniques incrementally developed from technical novelties in each time period. Many procedures were (are still) based on the "fast and easy" access to the targeted organ in the abdominal cavity. Incisions are placed traditionally, most commonly in the midline, but sub-arcuate, transverse abdominal, and lateral oblique incisions are still in frequent use.
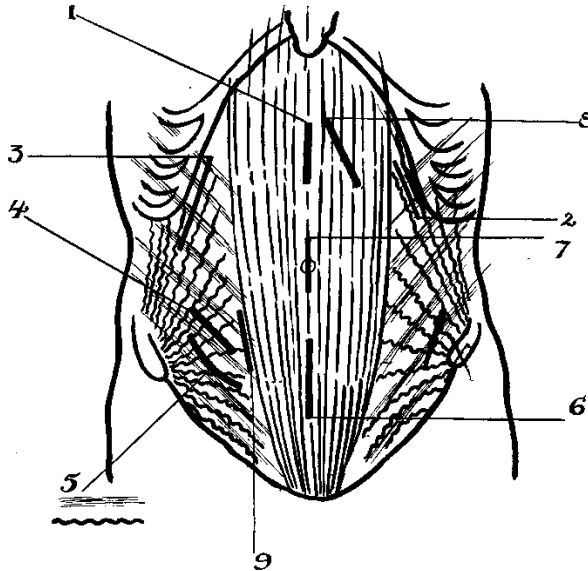
Figure 3. Common surgical incisions
1,6 7 -- Upper, lower and umbilical midline; 2,3 --oblique subarcuate (hypochondric), 4 -- McBurney (grid-iron) appendectomy; 5 -- Nyhus (inguinal repair) (Eads, 1901)

The position of the incision is of major importance. The optimal goal is to have good and safe access of the target organ of interest within the abdominal cavity, with minimal trauma caused to the abdominal wall. This will sometimes result in a compromise. The midline is optimal for access of the abdominal cavity in terms of minimal trauma. Irreversible damage to muscles and nerves are avoided. If a hernia develops as a result of a defect wound healing, it can be repaired with potential minimal trauma both to nerves and muscles. The development of minimal invasive techniques, mainly the laparoscopic, has minimized the trauma to the abdominal wall even further.

When the wound closing sutures in the aponeuroses of the incision borders fail an incisional hernia develops. This is can be caused either by a suture thread fracture or, more common, a failure of the tissue to withstand the tension in the abdominal wall. Without any counterforces the contraction of the lateral oblique muscles and the intraabdominal pressure act together in separating the wound edges and promoting the development of a hernia defect.

Placing new sutures in the "ragged" tissue edges is not a valid option. Approximating the borders of the fascia demands an increased tension of the abdominal wall structures which already has adapted to a new "functional" location. If a failure is noted in the immediate postoperative phase it is named a wound rupture, burst abdomen or wound dehiscence. If the patient is not burdened by other complications, an immediate operative repair is often the treatment of choice. If surgery is not advisable due to other conditions or contraindications, a planned hernia will develop which may later be repaired.

Mesh/Prosthesis

If we could artificially produce tissues of the density and toughness of the fascia and tendon, the secret of radical cure of hernia can be discovered.

Theodore Billroth,1878
(Rutledge, 1995)

Early techniques

A suture repair of an incisional hernias was reported already in early days to be as high as 25% in contaminated cases (Bull, 1905). Techniques using anatomical flaps and different devices developed as sutures alone were not sufficient. Trusses were commonly used to keep the hernias (partly) reduced, and were sufficient for an acceptable quality of life in many patients. Every truss needs though to be tailor-fit to fulfill its purpose with a minimum of discomfort.

In the late 1800s two optional operative strategies emerged; one was reinforcing the hernia defect borders with stronger tissue, e.g. *fascia lata* from the leg, the other a transposed aponeurosis of the abdominal wall being sutured to close the gap. Repair with *fascia lata* was often restricted by the inability to generate tissue to cover larger defects.

Foreign materials to cover the gap or defect were introduced in the 1900s. Incisional hernias accumulated as a result of the World War I. Koontz experimented with 'harvested fascia'. These fascia transplants were treated with alcohol or formalin that were demonstrated to work and effectively integrated with host tissue (Koontz, 1926). Other techniques utilized adjacent aponeurosis as flaps to cover the defect (Rothschild, 1935), or used lateral longitudinal incisions to release tension on the aponeurosis to allow closure (Gibson, 1920). However, recurrence rate over time using different variation of techniques were still deemed too high (Read, 1999).
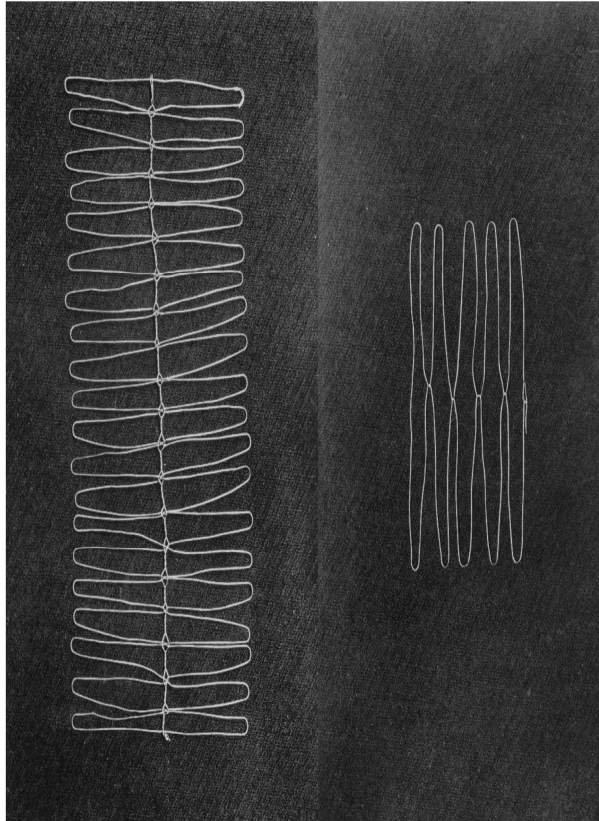
Figure 4.
Silver filigree (Bartlett, 1903)

Bartlett summarized the early development of hernia repair (Bartlett, 1903). Witzel created silver wire filigree by running wire as a network of crosswires. The next logical step was prefabricated silver filigrees for implantation, first used by Göpel. Bartlett also mentions Meyer who reported three patients successfully repaired with "a netting made up in just the same way that ordinary mosquito bar is constructed". Silver was the material of choice because of its known antibacterial properties. Later stainless steel (Babcock, 1952) and tantalum were the next materials in line. These materials were biologically inert, but difficult to handle. Material fatigue fracture was common and the risk of sinus and fistula formation was impending. Other alternatives were sought (Gallie and Lemesurier, 1923).

Mesh properties

The era after the introduction of plastics for different purposes brought a great number of compounds into both ordinary life and medicine. It became evident that "plastics" displayed a variation of biological reactions based on the chemical composition and the production process. Remnants of chemicals (e.g. stabilizers, pigments, catalysts) could alter the tissue response and prove unreliable in both short and long time perspective. In 1953 ideal characteristics of biomaterials was presented (Scales, 1953).

Necessary qualities of synthetic materials to be used as implants (Scales, 1953)
The implant must:

1. Not be physically modified by tissue fluids.
2. Be chemically inert.
3. Not excite an inflammatory or foreign body cell response in the tissues.
4. Be non-carcinogenic.
5. Not produce a state of allergy or hypersensitivity.
6. Be capable of standing up to mechanical strains imposed upon it, as for example, friction when placed in a joint.
7. Be capable of being fabricated in the form required with reasonable ease at a relatively low cost.
8. Be capable of being sterilized.

This list, compiled from Cumberland (from 1903) and Scales, has been extended 50 years later with desirable physical handling properties for surgical use (LeBlanc, 2003).

Ideal surgical clinical characteristics of synthetic products
1. Permanent Repair of the Abdominal Wall (i.e., no recurrences)
2. Ingrowth characteristics that result in a normal pattern of tissue repair and healing
3. Does not alter the compliance of the abdominal wall musculature
4. Lack of adhesion predisposition
5. Cuts easily and without fraying
6. Inexpensive
7. Lack of long-term complications such as pain or fistulization

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In view of modern laparoscopic techniques additional desirable properties has been added yet 50 years later: 1) easy endoscopic handling; 2) mesh memory to regain its former shape after being rolled and inserted through a laparoscopic port; 3) visual permeability to allow exact fixing of the mesh to the abdominal wall, avoiding injury to visible vessels and nerves.

Synthetic meshes

We believe that one of the great needs in surgery is some nonmetallic, nonabsorbable material which can be used both for sutures and for prostheses and which will not cause trouble in the presence of infection.

Koontz and Kimberley, 1959

In 1935, after several years of research, Wallace Carothers at DuPont managed to manufacture a polymer which could form a fiber, intended to replace silk. It was named Nylon and became the silk and cotton substitute during the World War II. The polymer era in medicine took a leap forward with Ziegler and Natta, Nobel chemistry laurates 1963, who initially independently, and later together, developed the synthetization of polypropylene in 1954 and polyethylene in 1955 (Kapischke and Pries, 2014). A patent lawsuit began in 1960 and was finally ended in 1983 in a settlement.

The new polymer material displayed favorable properties concerning tissue reaction. In 1958 Usher developed the Marlex mesh (i.e., polypropylene and high-density polyethylene) for use in incisional hernia repair (Usher et al., 1958). Marlex has good properties concerning fibroblast infiltration, infection resistance and suture handling (Koontz and Kimberly, 1960). Usher advocated placement of the mesh posterior to the rectus muscles without any attempt to close the defect, resulting in a tension-free repair and thus decreasing the risk of recurrence. In He reported a 10% recurrence rate, and a 15% complication rate without any need for removal of infected meshes (Usher, 1962).

The polyester Mersilene (Dacron) was created in 1950, also by DuPont. It quickly became popular and gained surgical use in the mid-1960s, particularly in France by Rives and Stoppa, for retromuscular use in inguinal and ventral hernias (Rives, 1967, Stoppa and Quintyn, 1969).

The biological and mechanical properties of polypropylene are well suited for hernia repair. Polypropylene induces a fast fibroblast ingrowth and is around three times more resistant to traction and extremely resistant to pressure, compared to polyester, but may cause a more stiff abdominal wall when compared to polyester. The advantages of polyester are the suppleness and almost physiological traction resistance (Chevrel, 1998). There has been concern regarding the biological stability of polyester, mostly discussed in case reports, but with probably no clinical implications (Klosterhalfen et al., 2000, Zieren and Müller, 2004).

In search for improved mesh ingrowth, long-term biostability and less inflammatory reaction polyvinylidene difluoride (PVDF) was explored (Klinge et al., 2002c). It is a fluoropolymer with properties like PTFE, but can be manufactured as a fiber (unlike PTFE, which is a foil) and hence can be knitted and have textile form and handling. A recent development of this mesh was to add minute amounts of nanoparticles of ferrofluids to make the mesh visible in magnetic resonance imaging (MRI) (Kraemer et al., 2009).

Intraabdominal meshes

The placement of a mesh in the abdominal cavity requires consideration of the biological response to the mesh. The exposed material will adhere to adjacent tissue, whether it is the parietal side of the abdominal wall or the organs of the abdominal cavity. The goal is to achieve a firm ingrowth of the mesh to the wall, without any adhesion to bowels. Such adhesions may cause obstruction and fistulation may jeopardize later abdominal surgery needed for other reasons.

In 1938 the lab at DuPont had invented a synthetic fluoropolymer, tetrafluoroethylene, PTFE. One well-known derivative is Teflon™, a substance with extremely low friction. Thirty years later the expanded PTFE (ePTFE) was refined by Bill Gore. It is manufactured as a foil or a membrane (thus not technically a mesh) and is commercially known as Gore-Tex®. This material was proven biologically inert and was soon used in vascular grafts. With minimal adhesion it had desirable properties for intraabdominal placement in ventral hernia repair. The absence of reaction and ingrowth demanded extensive fixation of the pure ePTFE mesh. A one sided roughened surface was developed by Gore to enable the parietal side to adhere to the abdominal wall.

Another solution was to combine the reactive polypropylene or polyester to the ePTFE into a composite mesh. Other manufacturers combined the polymer meshes with other degradable adhesion-resistant materials, such as collagen (Parietene Composite® or Parietex Composite® by Medtronic) or cellulose (Proceed® by Ethicon Inc.). The protective layer over the reactive mesh material will be absorbed long after the abdominal cavity hopefully has covered the mesh with neoperitoneum with aiming to prevent adhesions. When the polymer mesh is exposed the ingrowth to the parietal wall will occur.

Mesh physical properties

The purpose of the mesh is to stabilize the abdominal wall by permanently reinforcing the surroundings of the sutured hernia defect borders. In cases when the borders cannot be approximated the mesh will act as a fascia substitute bridging the gap. A totally inert mesh material will not stimulate ingrowth and is totally dependent on the mechanical fixation to the wall.

The materials, which stimulate ingrowth, will make use of the surface area in contact between tissue and mesh. The maximum physiological tension in the abdominal wall has been calculated to 16 N/m, assuming a model with spherical constructions and an intraabdominal pressure of 20 kPa (Klinge et al., 1998). The maximum achievable physiological intraabdominal pressure is about 170 mmHg (22.8 kPa) when jumping (Cobb et al., 2005a). Thus the minimal recommended tension for a mesh to withstand is 30–32 N/m. Meshes are many times stronger

than the abdominal wall tissue (Cobb et al., 2006), even after 5 months when resorbable parts of the mesh have disappeared.

Heavy-weight small-pore mesh

Mesh fiber material
(e.g. polypropylene)

Granuloma,
fibrosis

Low-weight large-pore mesh
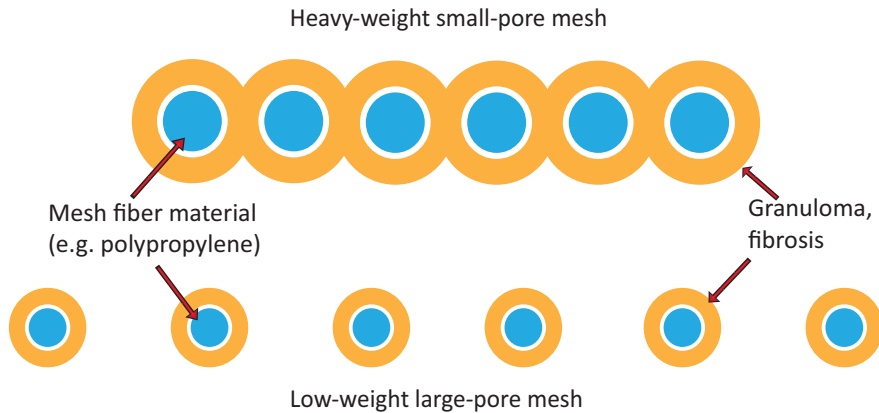
Figure 6. The effect of low-weight mesh and pore size.
Small pore heavy-weight mesh (blue) can induce dense granuloma/fibrosis (orange) when collagen fibrils can bridge over the gap. Large pore low-weight meshes generates less reaction and prevents bridging. After Cobb *(Cobb et al., 2006)*.

The mesh functions as a scaffold for fibroblast ingrowth. Early findings suggested that small pores, greater than 50 μm, would be optimal given the size of the fibroblast, 15 x 50 μm. Too large pore meshes integrate slowly, and an optimal pore size was sought (Goldstein, 1999). Densely knitted polypropylene meshes form a thick fibrous plate causing complaint of local abdominal stiffness.

Further research has shown that large pores, greater than 1 mm, are advantageous (Klinge et al., 2002b, Welty et al., 2001). Also, a large pore mesh has the same tensile strength as a small pore mesh, but may have a more mature collagen in its ingrowth (Greca et al., 2001). By reducing the mesh polypropylene weight, i.e. the fiber thickness, the surface area decreases and the ingrowth as well as the inflammatory response is diminished, but still remained strong enough for physiological loads (Klinge et al., 1998, Klinge et al., 2002a).

Biological and bio-synthetic meshes

Mesh infection is a feared complication, especially in contaminated situations. Biological "meshes" or scaffolds were introduced as an alternative to synthetic meshes to be used in contaminated fields in complex abdominal wall repairs (Novitsky and Rosen, 2012). The hypothesis behind the biological mesh is to function as a time limited scaffold to support the abdominal wall until new collagen tissue is produced by the patient himself to form a permanent stable

abdominal wall, though this function has not been clinically verified (Montgomery, 2013).

Biological meshes are acellular collagen tissues, rich in growth factors, harvested from various collagen-rich tissues (e.g. dermis, pericardium) from animal cadavers. Many meshes with different properties have been launched in the market for clinical use at a very high cost, which has been questioned (Harth et al., 2013). Collagen cross-linking has been introduced to prolong mesh lifespan. Non-cross-linked meshes seem to exhibit more favorable remodeling characteristics to the price of faster degradation.

Bio-synthetic collagen meshes has recently been launched as an alternative to the biologic meshes with the advantages of being a clean 3D collagen transient scaffold. Breakdown takes place by hydrolysis within 6–7 months which is promising with the hypothesis to offer a better resistance to bacteria. It is a much cheaper alternative to the biologics and some promising results have been shown in a prospective study of contaminated and clean contaminated fields when fascial closure were applied (Rosen et al., 2017).

Risk factors for incisional hernia

Prevention (surgeon-related aspects)

The reasons are many to why a patient develops an incisional hernia. The prevalence of incisional hernia after two years is 13%, and the risk of needing an incisional hernia repair after midline laparotomy is 5%, reported in a large meta-analysis (Bosanquet et al., 2015). Several randomized trials report similar levels (Seiler et al., 2009, Justinger et al., 2012, Israelsson and Jonsson, 1996).

Wound infection may be the most common cause, followed by multiple surgical incisions. It is not far-fetched to consider the surgeon's technical skills and decision making in surgical steps chosen at the primary operation performed being an important risk factor. This begins with choosing the site of incision and handling of the abdominal wall all though the operation (Israelsson, 1998). Incisional hernia development can be predicted with accuracy already four weeks after surgery.

A 12 mm distance between fascia borders seen at 1 month predicted hernia development in more than 90% of patients. The last 10% had already had a former operation (Pollock and Evans, 1989). These findings were confirmed by Burger et al, who found that a 25 mm distance between the medial rectus muscle borders on CT scan 4 weeks after surgery predicted an incisional hernia repair within 5 years, $p<0.0001$ (Burger et al., 2005). Recalculating these data results in an OR of 59 (CI95% 9–301) for hernia development when having a detected distance after surgery of at least 25 mm.

A meticulous surgical wound closing technique has been identified as an important step in preventing wound dehiscence and later hernia development. It is recommended to use slowly resorbable or permanent monofilament single line sutures with a relative small curved needle, implementing a secure knot-tying technique (Rodeo knot), and meticulous stitching with a ratio of suture to wound length of at least 4 to minimize the risk of postoperative hernia formation (Israelsson, 1999). The advantages of smaller stitches and higher suture to wound length ratios have been confirmed in later trials to be the most optimal technique (Cengiz et al., 2001, Millbourn and Israelsson, 2004, Deerenberg et al., 2015).

Surgical site infection is associated with increased incisional (and recurrent) hernia development (Carlson et al., 1995, Houck et al., 1989)

There are many studies reporting on different risk factors for postoperative hernia development. Unfortunately, only a few factors pass the statistical sieve. It may well mirror the heterogeneity of surgical technique and procedures together with differences in study design.

Patient-related aspects

Several patient-related conditions have been empirically correlated to incisional hernia development. Easily recognized are patients with collagen disorders. Hernias often run in families, suggesting a genetic disposition, later also suspected in altered ratio of collagen I to III expression and metalloprotease activity gathered conditions coined 'Herniosis' by the Aachen Group (Klinge et al., 2004). Old age, cachexia, emergency surgery, and extended physical strain of chronic cough, possibly caused by smoking were suggested risk factors for hernia development (Butler et al., 2013, Arenal et al., 2002, Hoer et al., 2002a). Obesity or having had an operation for overweight also increases the risk of a later hernia (Sauerland et al., 2004). Other procedures, such as minimal invasive prostatectomy is associated with a three-fold increased risk compared to open prostatectomy (Carlsson et al., 2013); and also vascular surgery for aortic aneurysm procedures (Bosanquet et al., 2015)

Large incisional hernias are more difficult to repair (Helgstrand et al., 2013), and special conditions may occur if a patient has had a large abdominal hernia for a long time. The abdominal support of the respiratory function may fail, and cause a weaning of the thoracic respiratory muscles. In- and expiration will move the hernia sac contents diminishing the air flow and oxygen exchange. The effect is obvious when the patient coughs: instead of forcing air out of the lungs the hernia sack expands making the expectorate clearance less effective. This condition was described and termed "paradoxical abdominal breathing" (Chevrel, 1998). If concomitant respiratory disease, e.g. chronic obstructive pulmonary disease, CO_2-retention syndromes, the replacing the hernia contents and restoration of the

abdominal wall integrity could trigger a respiratory insufficiency in need of intensive care treatment.

The condition of the skin covering the hernia is of importance. An atrophic skin, stretched over a protruding hernia sac or as sequelae from earlier wound healing, can demonstrate ulcers or eczema which increases the risk of wound infection.

Indications

There is no indication for a surgical repair in all incisional hernias. One third of all incisional hernias develop within 6 months, and 54% after1 year, and 75% after two years (Hoer et al., 2002b). About one in three will have symptoms severe enough to require intervention (Mudge and Hughes, 1985). It is advisable to let the healing of the wounds pass well into the maturation phase to facilitate easier adhesiolysis to avoid bowel injury. Empirically at least 1 year should pass after a healed wound before adhesions have become thin and film-like.

One of the most common complaints related to a hernia is pain. It is often associated with dysfunction of the organ in the hernia sac, e.g. obstipation or inflated abdomen, and subsides when the sac is reduced. Pain needs to be evaluated carefully to ensure that the present hernia is the cause.

A hernia location may conflict with clothing and force the patient to avoid wearing tight or close fitting garment. In a younger patient, is even a smaller, slowly growing hernia recommended for intervention. A smaller hernia size makes it easier to operate with better outcomes (Butler et al., 2013).

Surgical Techniques

> *A surgeon can do more for the community by operating on hernia cases and seeing that his recurrence rate is low than he can by operating on cases of malignant disease.*
>
> *— Sir Cecil Wakely, 1948, President Royal College of Surgeons*
> *(Cobb et al., 2005b)*

The repair of a ventral hernia was early recognized as a procedure with a high rate of recurrence. The 5-year recurrence rate was 41% in a study from 1983 (Hesselink et al., 1993), not really different from Eads' statement 1901. As consequence a myriad of surgical techniques has been developed. The objective has been to improve the restoration of the continuity of the abdominal wall by approximating the borders of the hernia defect. The tension in the tissues of the abdominal wall necessitates sufficient suturing and often a tension release by incising the lateral aponeuroses.

A modern suture technique based on tension-releasing incision was published in 1990 (Ramirez et al., 1990). This open component separation technique (CST) divides the aponeurosis lateral to the rectus muscles and opens the plane between the external and the internal oblique muscles allowing the layers of the muscular wall to slide relative to each other. Up to 10 cm on each side can be mobilized, and another 2 to 4 cm if the insertion of the transverse muscle is divided on the posterior side of the abdominal wall (de Vries Reilingh et al., 2003). The study by de Vries Reilingh et al on large incisional hernia repairs with CST reported 33% wound complications and 32% recurrence after a follow up of mean 16 months. Despite high recurrence rates the technique has remained popular, certainly when there has been doubt regarding the safety of mesh implantation in contaminated fields, and among plastic surgeons. A more recent study on CST in 128 patients reported 16% recurrence rate after median 38 months with follow up including 79 (62%) patients (Clarke, 2010). A review on CST including suture closure, minimal invasive lateral release, with mesh reinforcement, and mesh repair of complex incisional hernias revealed recurrence rates between 16% and 24%, mesh reinforced repairs 33%. This can be explained by the meshes used were of PTFE and biological origin (Tong et al., 2011).

With the introduction of synthetic meshes a strong reinforcement was available. In 2000 an RCT comparing suture repair to retromuscular mesh repair showed the superiority of mesh treatment of incisional hernia repair (Luijendijk et al., 2000). The cumulative recurrence rate at 36 months was 24% versus 43% for mesh and suture repair, respectively ($p<0.005$). Only incisional hernias less 6 cm wide were included. Even small incisional hernias, less than 3 cm wide, showed a drastic advantage to the mesh repair: 6% recurrence rate compared to 44% for suture repair. This trial failed to show mesh superiority ($p<0.100$) in recurrent hernia repairs, due to too few (27) patients included. Numbers were striking though: 58% recurrence rate for suture repair and 20% for mesh repair. In a review the ratio between recurrence rates for mesh repair and suture repair vary between 2 and 6 (Cassar and Munro, 2002). Concurring result was the outcome of a metaanalysis where the relative risk was lower for mesh repair in relation to sutured repair (Mathes et al., 2016).

Reinforcing the abdominal wall can mainly be done in four different ways. In the superficial position, *onlay*, the abdominal wall is closed, and the subcutaneous layer is released from external aponeurosis dividing vessels and nerves to the subcutaneous layer and skin. The mesh is anchored to the aponeurosis with multiple rows of sutures. A sufficient overlap of the mesh onto the aponeurosis is warranted. A quite a large surgical field is created. The subcuticular layer and the skin are closed over the mesh.
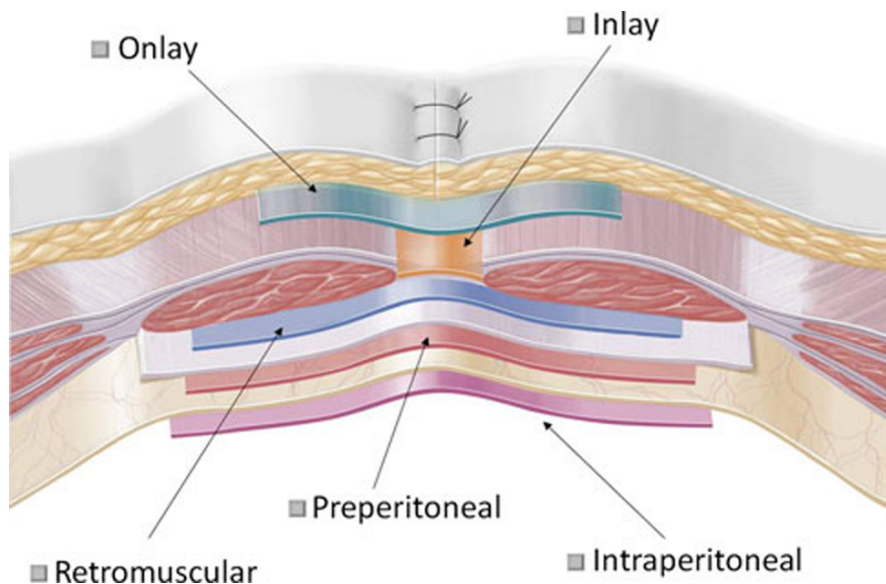
Figure 7. Schematic view over anatomical positions for mesh placement.
Source EuraHS, (Muysoms et al., 2012) Used by permission from the Authors for thesis; non-profit University use

An alternative to onlay placement is the *inlay* position. The mesh is sutured to the borders of the hernia defect, in fact 'filling the hole' with no overlap. The forces on the border sutures must withstand the wall tension and intraabdominal pressure. In a retrospective study this method yielded an unacceptably high recurrence rate of 44% (de Vries Reilingh et al., 2004), later confirmed in a meta-analysis (Holihan et al., 2016), and is not recommended.

Placement of the mesh in a retromuscular position has multiple advantages. The position behind the muscular layer adds the advantage of the intraabdominal pressure forcing the mesh into the posterior abdominal wall rather than running the risk of the lifting the mesh as would happen in the onlay position. The mesh is stabilized without need of extensive suturing (Wantz and Fischer, 1999). The retromuscular space is supported by the posterior aponeurosis from the xiphoid process to the arcuate line, after which only the peritoneum separates the mesh from the abdominal cavity. After oncological surgery the peritoneum may have been excised and the muscles left to be covered by neoperitoneum. In these patients it can be very difficult to achieve a space large enough to place a mesh separated from the intraabdominal organs.

Laparoscopic incisional hernia repair was pioneered by LeBlanc who in 1993 reported on the first five cases (LeBlanc and Booth, 1993). Laparoscopic technique utilizes the abdominal cavity to place a mesh on the peritoneum of the abdominal wall sufficiently overlapping the hernia defect. No extensive dissection is necessary, except for dividing adhesions to the wall blocking the intended mesh placement. An ePTFE mesh was selected and fixed with endostaplers alone. Some

early recurrences led to the use of both endostaplers and transfascial sutures and a recommendation of at least 3 cm mesh overlap (LeBlanc et al., 2000, LeBlanc et al., 2001).

Open Hernia Repair Outcome

The best anatomical placement of the mesh is still unsettled, although the retromuscular technique has become very popular. This technique has in registry studies shown to exhibit lower rates .French surgeons were early investigating the use of a mesh in the abdominal wall repair.

The onlay mesh position, advocated by Chevrel (Chevrel, 1979), necessitates wide dissection to place the mesh. In a review of his 236 patients between 1980 and 1996 (84% midline hernias) treated with a mesh 5.5% suffered a recurrence (Chevrel and Rath, 1997).

The French surgeons Rives and Stoppa researched the use of a polyester mesh placed in the retromuscular plane (Stoppa and Quintyn, 1969, Rives et al., 1973). Unfortunately, most of their publications were in French and did not reached the larger English (non-French) speaking surgical community. In 1989 Stoppa reported on treatment of complicated inguinal and incisional hernias (Stoppa, 1989), a series of 466 patients with incisional hernias, of whom 85% were midline hernias and 28% had hernias wider the 10 cm. Seventy-nine percent received a retromuscular mesh repair, which after a 5.5 year follow-up of 65% of the patients yielded satisfactory results in all but 15% (equal to about 10% of the mesh cohort).

Polypropylen (Marlex®) in the retromuscular plane showed early acceptable outcome. Larson et al reported 11% recurrence rate on their results over 8 years from 1968 and forward (Larson and Harrower, 1978). In this retrospective study on 53 patients the meshes were placed onlay, sublay and intra-abdominally. The recurrences were in patients who had had very large hernia defects, 13–17 cm, and multiple incisions. In a review of incisional hernia repair Cassar & Munro reported recurrence rates between 0% and 10% in open mesh repair studies published after 1980 (Cassar and Munro, 2002). Weighted average recurrence rates for different mesh material returns 2.4% for polypropylene, 3.2% for polyester, and 5.3% for ePTFE.

In a review of 9 studies on retromuscular mesh placement the recurrence rates were 2–12% (Schumpelick et al., 2010). The 5 year risk of a needing repair of a recurrent hernia after primary repair was 12% in a report from the Danish Hernia Register (Kokotovic et al., 2016). In this study the included open mesh operations were 40% onlay, 29% sublay, and 23% intraabdominal mesh placements. Holihan et al concluded the sublay position to be superior in a meta-analysis on hernia recurrence and surgical site infections following open mesh hernia repair (Holihan et al., 2016).

Fixation techniques

In description of the onlay procedure a mesh is placed on the anterior aponeurosis, after closing the defect, covering the rectus muscles. Chevrel recommended using flaps from the anterior aponeuroses to reinforce the repair, prior to placing the mesh (Chevrel, 1998). The mesh was then fixed with permanent sutures in the periphery and in the midline to the flaps. Recurrence rate after sutures alone were 9% and suture combined with fibrin glue 1% (Chevrel and Rath, 1997).

Kingsnorth described an onlay sutured mesh repair overlapping the defect with 4 cm in three rows with running suture, quilting the mesh. After fixing the mesh on both sides of the defect a final suture closes the wall. The tension was to be evenly distributed to the aponeurosis (Kingsnorth et al., 2003).

Regarding the retromuscular position of the mesh, Rives et al used lateral fixation of the mesh, which seemed necessary with a supple, flexible polyester mesh. When fixing the mesh to retroperitoneal tissue absorbable sutures were used, only permanent attachment was used in hernias close to bony structures. The more rigid polypropylene meshes do not need more than midline fixation when the abdominal wall is closed in front of the mesh (Wantz and Fischer, 1999).

Laparoscopic Repair Outcome

Recurrence after early laparoscopic hernia repair was 9%, LeBlanc concluded that the implanted ePTFE mesh was not adequately fixed, at the time using only endostaplers. In addition the overlap of the mesh was too small (LeBlanc et al., 2000, LeBlanc et al., 2001). Endostaplers were replaced by metal spiral tacks after their introduction. LeBlanc noted that about 50% of his recurrences occurred after more than two years, which is longer man the follow up period reported in many papers. Recurrence rates in later studies between 1997 and 2000 comparing open repair to laparoscopic incisional hernia repair vary between 0 and 9% after at least 22 months (Cassar and Munro, 2002). In a large series of 850 patients which included 34% had recurrent hernias, most patients received an ePTFE mesh. Recurrent hernia developed 4.7%. However, the follow up was short; 21 months (range 1–94).

Fixation techniques

A mesh placed on the peritoneal surface covering a defect must be fixated otherwise a recurrence is imminent. The initial endostaplers were not fixing the mesh to the aponeurosis, but only keeping the mesh border close to the wall surface. The use of transfascial sutures at the mesh border also assisted in placing the mesh in a correct position before anchoring it to the wall.

When passing the suture through the abdominal wall the surgeon was blind to the location of the blood vessels and the intercostal nerves reaching laterally into the rectus muscles. A bleeding must be dealt with using cautery or ligatures;

standard ways which both risk an injury to the nerve adjacent to the vessel. There is a risk of tying the suture around a nerve causing long lasting pain as the inert mesh needs permanent fixation. Placing the staplers through the mesh may still cause bleeding, particularly when the wall is not visible through the mesh.

With tackers able to better penetrate mesh and tissue the fixing is more secured. A technique launched by Morales-Conde, the double-crown technique, uses permanent tackers in two circles, one around the periphery, and one around the hernia defect (Morales-Conde and Morales-Méndez, 2003a). In a series of 135 patients the recurrence rate was 2%. In a RCT on the double-crown (DC) technique versus transfascial sutures in combination with tackers, the DC led to shorter operating time and less pain after 3 months (Muysoms et al., 2013). Recurrence rate after 24 months was 7.9% and did not differ between the fixing methods. The trial was stopped due very slow recruitment, and thus underpowered.

Modern meshes strengthen the repair by ingrowth of the overlapping surface to the wall. With such properties the necessity of a permanent fixation has been questioned, and resorbable tackers developed.

One RCT has evaluated postoperative pain after polyester mesh fixation with fibrin sealant or tackers (Eriksen et al., 2011). Fibrin sealant showed less postoperative pain and quicker return to daily activities. However, follow up (30 days) is too short a time for evaluating recurrence rate. A small study including 19 patients with incisional hernias had a repair with polyester mesh and fibrin glue with no recurrences after 16 months.

Laparoscopic midline closure

In open incisional hernia repair is it conventional to restore the abdominal wall as far as possible. Only in extreme cases are the hernia defect borders left laterally and the mesh has to bridge the gap. The original laparoscopic technique did not include an attempt to close the gap.

In an attempt to reduce the postoperative complications of seroma formation and to prevent the mesh from protruding through the hernia defect, a closure of the defect was sought before attaching the mesh like in the open procedure (Chelala, 2002). Permanent transfascial sutures stretched the hernia defect borders to proximity, sometimes even requiring a mini-laparotomy to succeed, before attaching the polyester mesh with 10–12 permanent sutures. A follow up on 1326 patients (40% incisional hernias, 8% recurrent hernias) for mean 78 months shows an overall recurrence rate of 4% (Chelala et al., 2016).

Conclusion of a meta-analysis on laparoscopic closure versus non-closure of the fascial defect showed that fewer adverse events (recurrence, pseudo-recurrence, mesh eventration, tissue eventration or clinical eventration/bulging) followed closure in 5%, versus 22% in non-closure procedures. Also advantageous for fascia closure were fewer seromas and shorter length of stay. The Chelala material was the largest contributor in the meta-analyses (Tandon et al., 2016).

Complications

There is a wide panorama of short term complications after incisional hernia surgery, which is related to the surgical reduction of the hernia sac contents, dissection and resection of the hernia sac, dissection of adhesions, and the techniques for placing and fixing a mesh. Long-term complications are mainly recurrences. Long term mesh complications after ingrowth are few.

In most instances the hernia sac will be either empty or spontaneously return to the abdominal cavity at the relaxation during induction of the anesthesia. In more severe cases, when the defect is narrow, the hernia border might need to be cut for hernia content reduction. In open surgery this is fairly easy, as the sac is usually dissected free before it is opened. Using the laparoscopic technique the intraabdominal bowels and *omentum* may have dense adhesions, blocking the view to the hernia.

If dissection causes a bowel perforation with bowel content passing to the abdominal cavity usually the intraabdominal mesh must be explanted, and conversion to open surgery may be necessary. Bowel injury more is more common in laparoscopy, 4.3% in relation to 0.81% in open repair according to a meta-analysis (Zhang et al., 2014). A prospective study conducted in a referral center for complex hernia repair reported a higher rate of 13% inadvertent enterotomies during elective open hernia repair (ten Broek et al., 2012).

Dissecting the space intended for onlay mesh placement will divide perforator vessels and nerves with, albeit low, risk of pain. Seromas are common in this large dissected space and drains are often placed in subcutaneous mesh area. There is a potential risk of a surgical site infection including the mesh. Seroma formation is common in all repairs, with the lowest incidence reported in laparoscopic technique with sutured defect (Chelala et al., 2016).

The decreased blood circulation to the skin and subcutaneous borders may cause skin necrosis and impaired healing. It is more common when using component separation techniques. The incidence of skin necrosis was 25% and chronic pain in 13% (all with onlay mesh reinforcement) in 'classic' non-perforator preserving CST (Clarke, 2010). A meta-analysis on variations of CST found an overall complication rate for open CST to be 59% without mesh and 21% with mesh and 32% using minimal invasive CST.

In a meta-analysis including 11 studies with 1000 patients comparing open hernia repair to laparoscopic repair concluded that no difference in complications regarding the incidences of hernia recurrence, postoperative seroma, hematoma, bowel obstruction, bleeding, and reoperation (Zhang et al., 2014, Forbes et al., 2009). However, a mesh related mortality of 0.1% after laparoscopic repair has been reported from the Danish Hernia Register, related either to blood vessel injury when fixing the mesh with tackers, to mesh migration into the bowel or to bowel obstruction (Kokotovic et al., 2016).

Treatment options for complications

When treating a major complication the handling of the mesh must be considered carefully. Most important is the material per se, particularly the porous ePTFE. The micropores are <10 μm, smaller than the macrophages and neutrophilic granulocytes, but larger than bacteria (Amid, 1997). Such a mesh will protect and sustain an infection and must be removed.

This is not the case with solid or knitted meshes from polypropylene or polyester. Adequate choice of antibiotic treatment, verified by cultures, will usually cure the mesh infection (Krpata et al., 2013). The risk of a wound infection not requiring mesh removal was lower in laparoscopic repair, 1.5% versus 10% in open repairs (The authors remark that rates are difficult to interpret depending on heterogeneity in a few, fairly small, randomized controlled trials and the handling of different meshes (Forbes et al., 2009).

Treatment of contaminated abdominal wounds has changed over the last decade. The concept of negative wound pressure dressing has been introduced, and in combination with mesh traction it has markedly decreased the number of cases with open abdomen and a planned large incisional hernia (Petersson et al., 2007, Kleif et al., 2012). Extending the indications for negative wound pressure treatment to include mesh infection comes natural. Using negative wound pressure dressings seem to decrease wound dehiscence and postoperative wound complications (Swanson et al., 2016).

Clinical Registers vs Trials

In contrast to different clinical cohort trials clinical registers intend to collect relevant data on *every* day patient who fits the profile for inclusion. With large amounts of data it is possible to assess the efficiency (outcome in public use) of a technique in resolving a defined problem. The high volume of data in registers allows the detection and possible association of rare adverse events, which otherwise might have been undetected. A register gets data from all performing surgeons, from newbies to senior experts, and can track the experience, in terms of number of attended procedures over time.

A clinical cohort trial is similar to a registry, but usually delimits in time for inclusion an may not collect data on altered techniques or changed indications. The randomized controlled trial has a strong solid theoretic base and is designed to evaluate the effect while levelling influential factors between study groups by randomization.
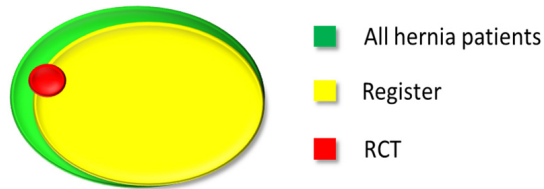
Figure 8.
The potential coverage of patients operated for a hernia reported in a register compared to a randomized control trial.

Several registers are active in collecting data. The Danish Hernia Database, founded 2007, is one the larger databases and has active research delivering important facts (Helgstrand and Jorgensen, 2016). The European Hernia Society developed and launched the European Registry of Abdominal Wall Hernia AHS (EurAHS) in 2015. It aimed towards pan-European users without having national databases. The German HerniaMed collects data from mostly the German-speaking community and has a very large database.

The Swedish Ventral Hernia Register is building the user database and has about 5000 registrations on the different types of ventral hernias (groin hernias excluded).

In these types of registers only operated patients are entered, usually at the time of operation and followed during a predefined time period. Data on indication for surgery, perioperative facts on the procedure and used material, and postoperative event are commonly registered.

The European Hernia Society has agreed on a classification of ventral hernias in order to make future research better. With a common description of hernias will stronger conclusions be possible (Muysoms et al., 2009). The classification is displayed in figure 9.

Depending on external factors, data can be collected and joined with other databases to extend the number of variables to analyze. In Sweden and Denmark the personal identification number can be used for this purpose. Major concern over personal data and the communication of such data exists. Their use of external database connections is regulated by national law. A new Data Protection Directive from the EU which entered into force 2016 and shall be nationally implemented by May 2018. The objective is to return control over personal data to the citizens and simplify regulatory environment for business.

EHS Primary Ventral Hernia Classification		Diameter (cm)	Small <2 cm	Medium 2–4 cm	Large >4 cm
Midline	Epigastric				
	Umbilical				
Lateral	Spigelian				
	Lumbar				

Figure 9A.
The EHS Classifications for Primary Hernias. (Muysoms et al., 2009)

EHS Incisional Hernia Classification				
Midline	Subxiphoidal	M1		
	Epigastric	M2		
	Umbilical	M3		
	Infraumbilical	M4		
	Suprapubic	M5		
Lateral	Subcostal	L1		
	Flank	L2		
	Iliac	L3		
	Lumbar	L4		
Recurrent hernia		Yes		No
Length (cm)		Width (cm)		
Width	W1 (<4 cm)	W2 (4–10 cm)	W3 (10– cm)	

Figure 9B.
The EHS Classifications for Incisional Hernias. (Muysoms et al., 2009)

Quality of Life

The concept Quality of life is an elusive property which has many definitions. The WHO defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (United Nations World Health Organization Interim Commission, 1948), and later as "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns". Rebuilding health care after World War II called for measures of how to balance different health care interventions to optimize the use of resources (i.e. money). It has often synonyms in *functional status* or *health status*, which refer to negative aspects such as disease, dysfunction and death, and to positive aspects such as happiness, safety and social context. To separate Quality of Life related to disease

and disability from other socio-economic and environmental definitions the term *health related* QoL (HRQoL) was coined.

A more appropriate description could be patient-reported outcome measures: PROM (Fitzpatrick et al., 1998). The goal of health care is to relieve the cause of impaired health for the individual. To evaluate the impact of surgery it is necessary to include the functional status together with the medical outcome, certainly when surgery may leave chronic conditions as sequelae (Urbach, 2005).

In practice, the quality of life measurement is narrowed and often in context of the research being done. The construction of a quality of life instrument is complex and laborious, and therefore expensive. In surgical journals 1996–1999 the use of appropriate quality of life instruments was less than 50%, as was the use of correct statistical analysis (Velanovich, 2001).

Quality of life instruments can be divided into two *generic* and *disease-specific* groups. Briefly, the generic instruments are used in wide populations with all sorts of comorbidities, and the disease-specific are targeted to population subgroups with a certain condition (e.g. cancer, diabetes) or dimension (depression, pain). The generic instruments are usually constructed from a broad range of questions to assess the many dimensions of life quality. The array of questions are the distilled and reduced to a questionnaire of manageable size. In its nature questions will not be specific to certain conditions unless it is a very important dimension (e.g. mobility, personal hygiene). There is an inherent risk that the general instrument is insensitive to the changes of the studied intervention.

In many outcome studies there is an interest of the impact of an intervention on a specific symptom, such as bowel function after bowel resection. Assessment of such symptoms will need a specifically designed questionnaire. If this field of interest is narrow there might not be an appropriate choice of instrument. Often the researchers then need to create an ad hoc questionnaire. These questionnaires may not be validated correctly (Velanovich, 2001).

All instruments grade the symptoms or aspects on a standardized scale, which then may be part in a summary measure (e.g. mobility, pain), which in turn may be a dimension factor of an overall score. This construct implies that perfect quality of life is just absence of quality-diminishing factors. The interpretation should always include the context of the instruments target population. If the instrument is validated there is a standard to compare the outcome of the trial against. The well-constructed general instrument is appropriate for comparing the burden of disease or treatment between groups of patients with different conditions, or for comparing the outcome to a norm group, usually the population. Disease-specific instruments can work in patient groups over time, being more sensitive to changes within the individual (Patrick and Deyo, 1989). The different scopes allow generic instruments to detect unknown effects, whereas the specific instruments are focused on predicted changes.

SF-36

In 1989 the RAND Corporation conducted the Medical Outcomes Study (MOS), an attempt to assess the performance of the medical treatments from the patient's point of view (Stewart et al., 1989). Several screening instruments were developed, among these the RAND 36-item Health Survey. The full length MOS survey was very long (McHorney et al., 1992). After careful selection, balancing the breadth and depth to cover each dimension, 36 questions remained. The RAND 36-

SF-36 Quality of Life Dimensions
Physical Functioning
Role Functioning
Bodily Pain
General Health
Vitality
Social Functioning
Role Emotional
Mental Health

Summary Scores:
Physical Composite Score
Mental Composite Score

item survey was developed into the Short-Form-36, the SF-36 questionnaire (Ware and Sherbourne, 1992). The questionnaires are similar in wording and response alternatives, but scoring procedures differ.

With the experience of developing and validating a generic questionnaire the SF-36 was translated to several languages and validated in many countries during the 1990s, making it one of the most spread and validated quality of life instruments (Ware and Gandek, 1998). In Sweden the translation and validation was performed by the HRQOL group at Gothenburg University (Sullivan et al., 1995, Persson et al., 1998, Sullivan and Karlsson, 1998). The Swedish norm data base consisted of 8930 men and women collected 1990-1991 (Sullivan et al., 2002).

Eight dimensions are assessed with SF-36 representing distinct health concepts, although some are excluded: health distress, role functions of family and sexual relation, cognitive functioning, and sleep disorders (Ware and Sherbourne, 1992).

The SF-36 consists of 36 questions with Likert response boxes graded from 1 to 3, 5 or 6. When scoring the responses they are transformed to a 0–100 scale, in some questions minor adjustments are performed prior to transformation. Each question relates to an assessed dimension, and a summary measure is calculated from the designated responses.

Two composite scores have been developed representing a physical (PCS) and a mental (MCS) component as underlying factors to the perception of quality of life. Computing these scores using identical (US) factors facilitates international comparison. The mean was set to 50 and standard deviation to 10. There have been arguments on whether this is correct data handling (Taft et al., 2001) and national factors has been computed (Hawthorne et al., 2007, Hann and Reeves, 2008).

Original scores are reported as values between 0 and 100. Dimensions have different means and dispersion, making comparison difficult. With the composite scores defined with mean and standard deviation, the developers of SF-36 recommend norm-based scoring, aligning all means to 50 with a standard deviation of 10 (QualityMetrics, 2002).

The development of SF-36 has continued with an updated form with changed words in some questions, higher resolution in some dimensions, but without changing the outcome over all, making the versions virtually comparable (Ware, 2000). An interpretation guide and improved statistical handling of missing data have been developed (Bjorner and Ware, 1998, Bjorner et al., 2013). In an effort to minimize the burden on the patient an even shorter forms of SF-36 has been created. SF-12 and SF-8 have fewer questions and naturally the resolution of the measure of quality is somewhat coarser, but they are backwards comparable to SF-36 (Optum Inc., 2017, Gandek et al., 1998).

In 2017, copyright to SF-36v2 belongs to Optum Inc., USA, and it is no longer virtually free to use, even though academic use is encouraged and supported.
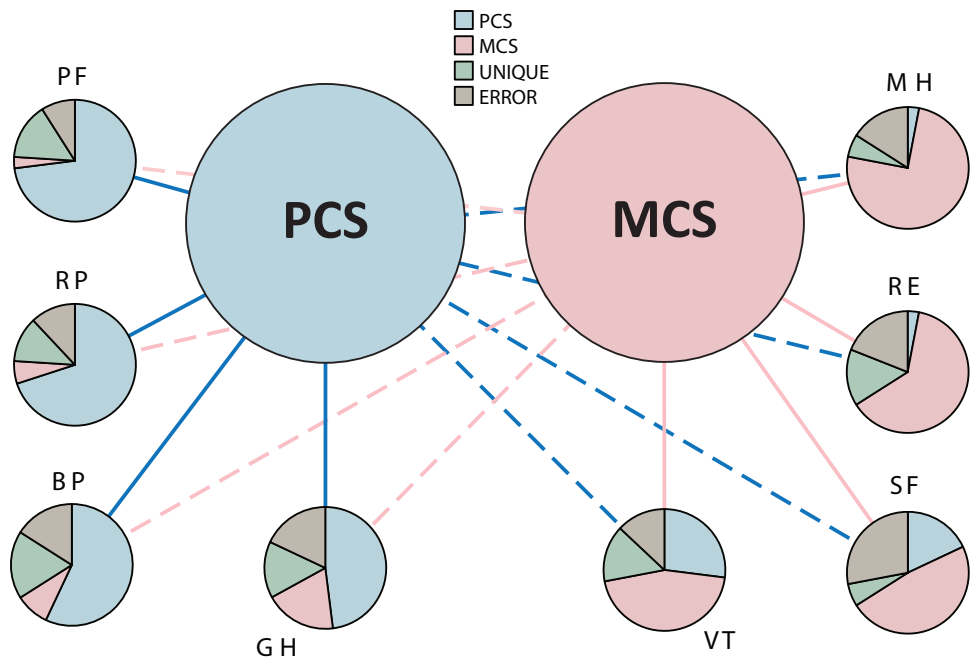
Figure 10.
SF-36 Quality of Life model. The eight subscales have different weights when calculating the Physical and Mental Composite Score. Solid lines indicate dominant trait (Ware et al., 1994).

Other instruments

A well-reputed generic quality of life instrument is the EQ-5D (The EuroQol Group's International Task Force on Self-Reported Health, 2004). It was developed by EuroQol to deliver a single quality of life index, useful for comparison and economic computations.

EQ-5D is constructed of 5 questions with Likert box answers and one visual analog scale (VAS) ranging from 0 (best) to 100 (worst). The five dimensions are mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Initial version allowed 3 and later version 5 levels, with low value (1) meaning no problems and highest value (3 or 5) meaning severe problems. The 5 Likert responses form a health state, and there are 3^5 =243 possible states. The best possible is obviously '11111' and worst '33333'. A 5 level response generates 5^5 = 3125 possible states. The Health states have been mapped to a single value through VAS or TTO valuation techniques.

It is difficult to translate between EQ-5D and SF-36 because underlying dimensions are different (Nordlund et al., 2005).

The EQ-5D was developed to be a fast, easy and reliable survey on quality of life. However, from the patient's point of view they are similar, actually, more patients preferred the SF-36, even if satisfied with EQ-5D (Nilsson et al., 2007).

EuroQol (EuroQol, 2017) owns the copyright and licensing rights.

Ventral Hernia Pain Questionnaire (VHPQ)

This Swedish disease-specific questionnaire was published in 2012 (Clay et al., 2012). It is constructed of 18 questions with response alternatives based on pain behavior and how the patient is affected by pain. Six pain grading questions have a 7 level scale, and following questions assess frequency, duration, inflicted limitations, and finally questions on outcome of surgery and development of symptoms over time. An earlier published questionnaire on inguinal pain questionnaire after hernia surgery was the basis of this work (Fränneby et al., 2008), and the underlying foundation has been the work on postherniorrhaphy pain by Kehlet et al (Kehlet et al., 2002).

Face validity, i.e. scope of the questionnaire, was performed in focus groups of 10–15 patients and repeated 7 times until consensus on wording and content. Construct validity, i.e. congruence with theory, and criterion validity, was performed with 70 patients operated for ventral hernia and who completed the VHPQ and the Brief Pain Inventory (BPI, former BPQ) with a 3 week interval and yielding satisfactory validity. A control group on 100 non-operated patients created the norm data.

Although theoretically solid it is difficult to handle as it focus on pain in several dimensions, with scales level intervals undefined, making comparisons difficult. A useful instrument would also need a manual on how to deal with missing data.

This questionnaire, though interesting, was not available for consideration when our trials were designed.

Carolinas Comfort Scale, CCS

The CCS is a hernia mesh repair-specific questionnaire published in 2008 from the Carolinas Hernia Center, NC, USA (Heniford et al., 2008). It consists of eight questions on specific physical activities. Each question requires three answers graded from 0 none to 5 worst on mesh sensation, pain, and movement limitation. The eight dimensions are: laying down, bending over, sitting up, activities of daily living, coughing or deep breathing, walking, stairs, and exercise. Scoring is summing each of the 23 items, producing a range from 0 to 115.

Validation was performed on mesh operated patients returning both CCS and SF-36. Only 137 (13%) of 1048 patients returned the questionnaire, the majority inguinal hernias (46) and ventral hernias (43). Only 4 incisional hernias were included. Missing data was more common in SF-36 than in CCS, 22% and 15% incomplete forms, respectively. No instructions are given on how to handle missing data in the CCS, which do regarding SF-36.

One third of CCS score is related to mesh sensation. This prevents the CCS to be used before surgery to assess the effect of mesh repair.

HerQLes Questionnaire

The HerQLes questionnaire was presented in 2012, originating from the Case Comprehensive Hernia Center, Cleveland, OH, USA (Krpata et al., 2012b). It is focused on the impact of the abdominal wall on physical activity with 7 questions, and another 5 questions on the impact on psychological effects, in all 12 questions.

The response is Likert boxes graded from 1 'Strongly disagree' to 6 'Strongly agree'. It uses statistical rating methods (Rasch Rating Scale Model and Wright item-person map) to get a final score.

It was validated on 88 ventral hernia patients with retest 4 times with a two week interval. The authors argue that the HerQLes could serve as a hernia-specific add-on to generic quality of life instruments.

The questionnaire was not available when our trials were designed.

Figure 11.
Incisional hernias. Row 1 and 2 are large primary hernias. Row 3 are planned incisional hernias after open abdomen treatment. Row 4. Complications to incisional hernia repair: Infected intraperitoneal mesh; Postoperative bleeding; Failing skin coverage after infection and umbilical necrosis.

Aims of the Thesis

To investigate:

- ❖ recovery after incisional hernia surgery using open and laparoscopic mesh repair.

- ❖ quality of life in short and long term perspective after open and laparoscopic mesh repair.

- ❖ wound complications and recurrence rate one year after open and laparoscopic mesh repair.

- ❖ clinical predictors for an uneventful recovery after open and laparoscopic mesh repair.

- ❖ mesh contraction in a clinical setting: the retromuscular and the intraabdominal location.

- ❖ long term recurrence rate after open retromuscular mesh repair of primary and secondary midline incisional hernias.

- ❖ long term quality of life after open retromuscular mesh repair of primary and secondary midline incisional hernias.

PROLOVE Randomized Controlled Multicenter Trial

The PROLOVE (Prospective Randomized trial on Open versus Laparoscopic Operation on Ventral Eventrations) trial recruited patients from six Swedish surgical units. All patients over 18 years old seen in the office were considered for inclusion if criteria were met. Only planned midline incisional hernias were eligible with a transverse width of maximum 10 cm, and no previous mesh repair. Further criteria were American Society of Anesthesiologists (ASA) grade I or II, BMI < 40 kg/m², loss of domain hernia with risk of respiratory insufficiency, and social or psychiatric conditions prohibiting adherence to the trial protocol.

Randomization to either treatment was stratified to each participating unit. The randomization sequence was created with Microsoft Excel® 2003 with a 1:1 allocation using random block sizes of 4, 6, or 8. The recruiting surgeon was masked to the stratified group size, allowing for a faster closing of patient inclusion when planned study group size was reached. The actual randomization occurred when scheduling the patient for operation.

The trial group size was calculated from the SF-36 subscale Bodily Pain. To detect a medium size difference with 80% power and α at 5%, 57 patients were needed in each group.

With a new treatment option for abdominal wall hernias, a randomized trial was designed to evaluate the long term efficiency of a mesh repair, and to compare the introduced laparoscopic technique to the established conventional open technique. Reports had already indicated acceptable recurrence rates for both techniques, which forces a randomized trial to include many patients to be able to find a difference.

Prospective Mesh study

Studies on explanted meshes after complications indicated that meshes contracted with fibrotic scar tissue. A considerably smaller contracted mesh may be the cause of pain and recurrence. It also demands consideration of implanted mesh size to compensate for this contraction. This study was part of the PROVLOVE trial comparing mesh behavior in the two most commonly used. A cohort received radio-opaque metal clips at the mesh borders and at the medial borders of the hernia defect. In the immediate postoperative time, within two days, an abdominal low dose x-ray examination was performed with the patient in supine position and a standardized marker for measurement calibration, which then was repeated after one year. Data on pain (VAS) and recurrence was collected at the planned visits in the PROLOVE trial.

The distance between the metal clips placed at the time of the incisional hernia repair were measured independently and the results compared and differences

sorted out by consensus agreement. The ratio between the follow up distance to the initial distance was calculated and used for area calculations. Area was a rectangular with the transverse and longitudinal dimensions.

Retrospective FU

The retromuscular implantation of a mesh, as described by Rives and Stoppa, has proven its low recurrence rate in the short term perspective. The introduction of this technique in Helsingborg in the mid 1990's by Smedberg was taken up in Malmö within a few years. Since 1998 the procedure has been concentrated on a small group of surgeons performing a highly standardized operation technique for midline incisional hernia repair.

Operation databases in the two centers were searched for ventral hernia repairs to include patients with midline incisional retromuscular mesh repair. All living patients were contacted and mailed questionnaires and offered a clinical physical examination of the abdominal wall. Medical records of deceased patients were removed and unavailable for examination.

The clinical examination, specific questionnaire and SF-36 QoL were collected in the office or by mail. Patients' complaints were recorded and any suspicion of chronic pain or recurrence was referred to a computer tomography scan and back to the ordinary surgical team.

Results

Paper I–II

Seven Swedish surgical units recruited 157 patients between 2006 and 2010, and 133 actually received an intervention 69 open and 64 laparoscopic hernia repairs. Slightly more women than men, average 58 years old. Baseline characteristics were similar regarding comorbidities, health status and previous surgical incisions. Previous upper midline incisions were more common in the laparoscopy group, and lower midline incisions were more frequently found in the open repair group, also reflected by the locations of the hernias.

SF-36 quality of life showed a nonsignificant higher baseline value for the laparoscopy group, particularly in the physical dimensions. Preoperative levels of the SF-36 dimensions were all well below the Swedish norm, except Mental Health 48.5, and the Mental Composite Score 49.4. The Bodily Pain was 46.4, Physical Function 36.1, and Physical Composite Score 41.1. The result is norm based with mean 50 and standard deviation 10. Deviations were measured against the standard deviation.

At 3 weeks no difference was detected ($p<0.796$) between the groups in Bodily Pain, the primary endpoint. In fact BP was at base line level.

To assess the recovery we analysed the Area Under the Curve in each dimension up to 8 weeks comparing between groups. In Physical Function ($p<0.001$), Role Physical ($p<0.012$), Mental Health ($p<0.022$) and Physical Composite Score ($p<0.009$) were significant differences found. Subscale Vitality ($p<0.054$) and Role Emotional ($p<0.059$) failed the statistical significance limit (0.05).

During the first postoperative month, surgery pain, fatigue and movement limitation was assessed daily with a visual-analog scale, and questions on the use of analgesics. After analysis no differences between the operated groups were found regarding daily pain, movement limitation and fatigue, nor were a difference found on days with analgesics. Half of the patients stopped using analgesics after 10 days, and 90% after 23 days, in both groups. In open repair group days until recovery showed identical pattern to the laparoscopic group during the first 3 weeks. After 30 days 38% in the open repair group felt recovered versus 59% in the laparoscopic repair group.

Recovery was assessed after 8 weeks. Uneventful recovery was similar in the groups, 67% among laparoscopic repairs and 58% in open repairs.

Wound infections were the only complication that differed 23% in the open repair group and 1.5% in the laparoscopic repair group ($p<0.001$). Surgical Site Infections included superficial and deep (mesh) infections. Complications graded according to the Dindo-Clavien classification (Dindo et al., 2004) did not differ ($p<0.092$). As this classification originally describes retrospective use in an in-hospital setting, we modified it to severe and non-severe complications and reclassified percutaneous seroma draining to a lower grade. No difference was found in severity of complications between the groups.

Indications for reoperation within 8 weeks differed. One patient (1.6%) in the laparoscopic repair group demanded a seroma evacuation, the only operation in this group. In the open repair group 7 (10%) reoperations occurred: two laparotomies due to bowel obstruction (in the same patient), 1 subcutaneous bleeding, 1 necrotic umbilicus, 1 exploration for neuralgia, and 2 deep wound infections.

At the 1-year follow up 124/133 patients remained, 61 in laparoscopic repair group and 63 in the open repair group.

In the SF-36 quality of life instrument all dimensions had increased, except the Mental Composite Score. The dimensions were normalized already at 8 weeks after surgery, and this level was maintained at 12 months. Compared to preoperative levels the median increase was 5.2 points (0.5 standard deviations) in all dimensions.

Monthly or more frequent complaints on the abdominal wall function was reported from 81% of the patients before surgery and had decreased to 18% ($p<0.001$) at 1 year, with no difference between the groups. Eight patients in each group still had complaints.

The visual-analog assessments of pain, movement limitation and fatigue also displayed a decrease compared to peroperative levels for all patients; pain from 28 to 6 ($p<0.001$), movement limitation from 23 to 5 ($p<0.001$), fatigue from 22 to 5 ($p<0.001$). There were no differences between the groups.

Satisfactory surgical result was reported by 82% of the patients, and 13% did not consider themselves recovered at 1 year. Only 6% would not, given their current experience, consider incisional hernia surgery again.

Variables considered clinically important; sex, age, obesity (BMI over 30 kg/m^2), smoking habits, ASA risk classification, hernia width, and type of planned repair were used for calculating odds ratios for 4 important surgical outcomes. These were an event-free recovery, absence of recurrent hernia, a satisfied patient, and an increase in quality of life of at least 5 points in the Physical Composite Score.

Male sex and laparoscopic surgery was associated with an event-free recovery. Neither recurrence nor satisfied patient was associated with any of the predictors at 1 year. The only predictor of a SF-36 PCS increase was obesity. In the four multivariable logistic regression analyses only laparoscopic surgery (OR 2.70, 1.03–7.07; P<0.044) remained positive for event-free recovery.

Paper III

A cohort of 52 patients from the PROLOVE trial received metal markings in the implanted mesh and at the hernia defect border. After 1 year 37 patients were available for analysis. The laparoscopic repair group contained 20 patients and the open repair group contained 17.

At 1 year the longitudinal distance between markers decreased by 2.8% SD 5.2 in the LHR and 2.6% SD 6.9 in the OHR groups (p<0.278). The transverse distance decreased by 1.6% SD 5.4 in the LHR group but increased by 3.1% SD 4.0 in the OHR group (p<0.002). Mesh area decreased by 4.4% SD 6.6 in the LHR group (p<0.008) but increased by 0.5% SD 8.9 in the OHR group (p<0.826).

VAS pain levels before surgery and after 1 year did not differ between the groups. No correlation was found between mesh area change and change of the level of pain.

A review of the literature revealed only 4 human studies of mesh contraction in incisional hernias and 2 human studies in inguinal hernias. A mixture of linear and area scale changes are compared, but when recalculated all contractions are fairly small, 6.4% area decrease corresponding to 3.3% in linear scale.

Paper IV

The database search for ventral hernia repairs returned 596 patients and after exclusion of non-incisional midline interventions and deceased patients with unavailable medical records were 301 patients with retromuscular intervention considered for inclusion. After invitations and remainders 217 remained. In the first response 29 patients declared no problems at all concerning their abdominal wall and former operation, and declined further participation. A clinical examination was accepted by 117 but only 103 actually came.

Follow up was mean 87 (SD 31) months, and a medical review was performed after 137 months in search of notation of recurrence or reoperation.

At time of surgery patients were 61 (SD 13) years old, 90% were ASA class I or II. A total midline repair was performed in 34% of the patients. Five surgeons performed 79% of the operations, and were assisting in 20%.

Postoperative complications were recorded in 27% of the patients. Graded according to Clavien-Dindo they were grade I in 12%, grade II 14%, and grade IIIb 1%, a patient with respiratory insufficiency in need of intensive unit care. Nine patients (4%) were reoperated, three within 30 days due to bleeding, hematoma, and umbilical skin necrosis, respectively. The other six patients indications were 3 deep wound infection, small bowel obstruction in a parastomal hernia (1), migrant thrombophlebitis (1), and exploration due to severe neuropathic pain (1). No meshes were explanted.

The overall recurrence rate was 8.1%, 3.3% (6 patients) were diagnosed from the medical records and the 4.8% (11 patients) remaining recurrent hernias were found at the clinical examination, being minimal symptomatic. After primary incisional hernia repair we found 7.1% recurrence, compared to secondary, recurrent, hernia repair 10.9% (p<0.366), i.e. no difference.

At follow up the SF-36 quality of life scored around 3 to 5 points (0.3–0.5 standard deviations) lower than the Swedish norm, comparable to patients with 2 chronic conditions. Daily or weekly symptoms were reported by 19%, and 25% reported not having recovered after abdominal wall repair.

Discussion

Study design considerations

Surgery of abdominal wall hernias has evolved at a dramatic speed over the last 20 years with the development of synthetic meshes and introduction of the laparoscopic techniques. Barely had a gold standard been proclaimed before modifications were considered: a new mesh, a new fixing device or expanded indications for the technique. The evaluation of current techniques was lacking and reports difficult to aggregate as few techniques were comparable. The rapid introduction and spread of the laparoscopic procedures for intraabdominal mesh placement mimics the chaotic situation when the laparoscopic cholecystectomy was introduced where also clinical trials lagged behind for safe introduction.

At the time of the design of the studies reported in this thesis, mesh inguinal hernia repair techniques shown remarkable improvements in terms of decreasing recurrent inguinal hernia rate. Incisional hernia mesh repair techniques were in desperate need of evaluation, particularly the laparoscopic route. The introduction of laparoscopy had shown shorter operating times, less postoperative pain, faster return to daily activities, shortened hospital stay, and recurrence rates similar to open repair. However reports on rare events were scarce at that time.

When designing the PROLOVE trial pain and return to daily activities was set up as primary endpoint. To avoid the immediate postoperative wound pain we chose 3 weeks after surgery to be an adequate short term outcome.

Incisional hernia is a condition that limits the patient from a normal life from several perspectives. Even if the original disease that led to the initial surgical intervention is cured, the hernia will impose pain, movement limitations, bad cosmesis and difficult selection of garments to wear. This might lead to social limitations and avoidance of activities enjoyed before the operation, e.g. sports, sunbathing, saunas. Assessing pain and all the other affected dimensions led us to choose to describe the outcome from a quality of life perspective using the SF-36 quality of life instrument. One of its dimensions is pain, and further, physical and emotional aspects are included. Not trusting the SF-36 to be sensitive enough to capture the effect of an incisional hernia, complementing questions were added on patient satisfaction and local symptom grading. Visual-analog scales, a well-known instrument for grading pain, was also used for movement limitation and fatigue.

Concerning the frequency of follow up using clinical examination, the VAS scores, analgesic/recovery questions and SF-36 questionnaires a recall bias cannot be the disregarded.

Pain

The laparoscopic procedure was more painful in the short-time outcome than expected, without any correlating to complications. It was more painful than other laparoscopic procedures, even if the immediate wound pain dissolves within a few days.

A possible explanation is that other surgical procedures just pass the abdominal wall to reach other target organs, whereas abdominal wall surgery engages the peritoneum and the muscular wall. Fixation of the mesh with up to 40–50 tackers in a healthy abdominal wall with local reaction around each tack, with tension from the mesh in addition might be part of the explanation.

In open retromuscular repair it is easy to get access to the posterior aponeurosis and preparing a flat surface for mesh placement. When the hernia defect is located near the lateral borders it is often necessary to continue the dissection laterally into the compartment of the oblique muscles to get a sufficient mesh overlap. This disrupts the insertion points of the lateral muscles which may increase pain. Some intercostal nerves are at risk if not a thorough nerve preserving dissection using the TAR technique (Transversus Abdominis Muscle Release) is performed to enter the lateral oblique muscle plane.

Quality of life

Surgeons want their efforts to be efficient in solving the sequel of a hernia. Recurrence is the most estimated outcome parameter. On the other hand, the patient wants to be relieved of a problem, not getting it replaced by another, e.g. chronic pain.

SF-36 proved to be sensitive in measuring the diminished quality of life in incisional hernia patients. It also displays the return to norm levels after the incisional hernia repair, indicating the positive effect of the intervention. No differences between the two techniques in time to recovery, and in use of postoperative analgesics were surprising. It was unexpected to find that after three weeks had pain returned to preoperative levels and at 8 weeks to the norm level of the population.

The long term follow up after 11 years indicating quality of life levels to be compared with patients having 2 chronic conditions. These patients were average 72 years old and the levels are probably adequate at that age, with at least two operations in their medical history.

The assessed levels of satisfaction with the incisional hernia repair were similar at 1 year as after 11 years. It is interpreted as an important problem for these patients was solved.

Recurrence

Patients who were dissatisfied at follow up all had remaining complaints, most often pain, and sometimes also recurrences. In the PROLOVE trial, Paper I and II, the all recurrent hernias occurred in the laparoscopic group. Four were recurrent hernias regarded as technical failures, and one was a new port-site hernia. Three recurrences were reoperated during the first year.

The PORS trial, Paper III, found 8.1% recurrences, 6/17 recurrences were diagnosed and repaired at the follow up, the other 11 (65%) were asymptomatic. The recurrence rate is low and that no difference was found between primary and recurrent incisional hernia incidence indicating the efficiency of the retromuscular mesh repair.

There has been concern on mesh contraction causing pain and recurrence. Several animal studies have shown contraction in meshes as a result of fibrous ingrowth. Explanted human meshes, most often due to a complication after inguinal repair, have shown similar contraction and persistent inflammatory reaction. Inguinal meshes have other types of tissue in the surroundings compared to retromuscular or intraabdominal placement. It is not evident that the tissue response is equivalent. Placing a modern large pore mesh flat minimizes wrinkles and folds that may induce fibrous overgrowth and contraction.
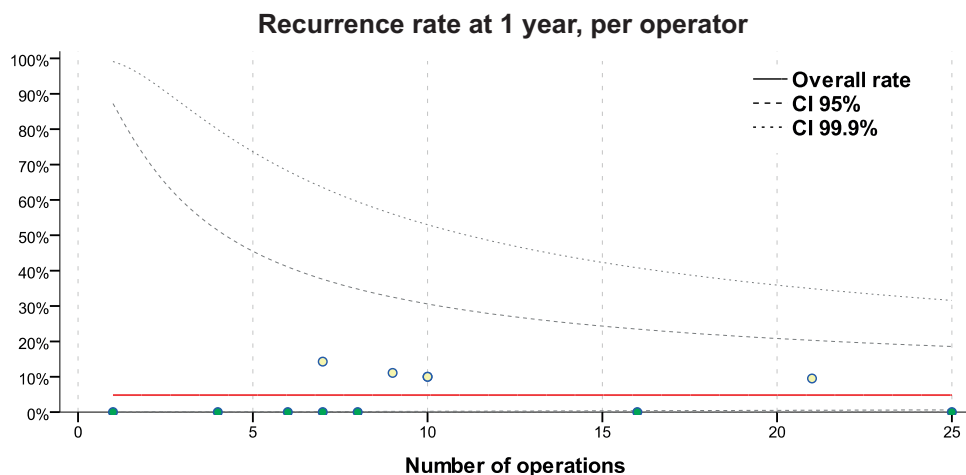
Figure 11.
Funnel plot. Proportion of recurrence per operator. All operators were inside the expected limits

Our experimental study did not show any significant mesh contraction, in line with previous findings, leading to the interpretation that contraction is not the cause of having a recurrent hernia. Even a 20% linear contraction, equivalent to a 36% area reduction will only retract the 10 cm mesh 2 cm. One cm in every direction is less than the modern recommendations of 4–6 cm mesh overlap. Inadequate mesh size and incorrect positioning and failing fixation must be far more credible as an explanation to recurrence!
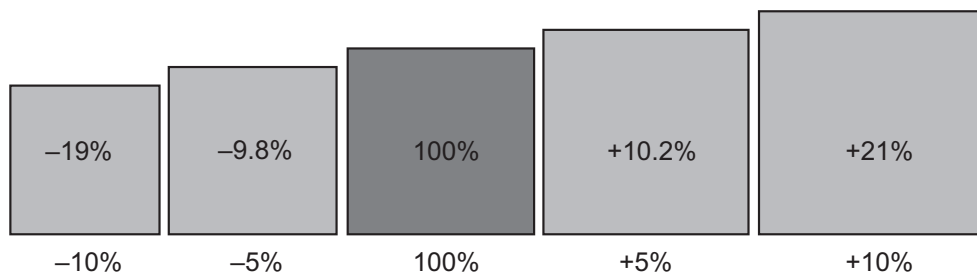
Figure 12.
Visual demonstration of linear and area (quadratic) scale

Surgical outcome predictors

The intention was to help the surgeon in counseling the patient at hand in selecting what technique to use. Only facts available at hand outside the operating theatre were chosen, without an initial statistical selection analysis. Due to the size of our trial the number of predictors to analyze was limited.
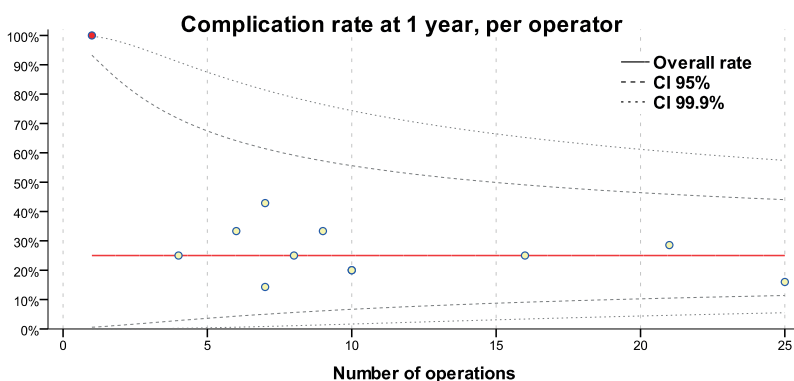
Figure 13.
Funnel plot. Complication rate at 1 year per operator. One operator performed worse than the others.

From experience were sex, age, obesity, smoking, ASA risk classification, and hernia width selected. The latter data was taken from peroperative findings, but were actually available in the routine computer tomography of the standard workup for incisional hernia repair. ASA risk classification was a strong proxy for all comorbidities. The four outcome variables chosen: an event-free recovery, a satisfied patient, an increased quality of life, and absence of recurrent hernia. The only significant predictor in the multivariable logistic regressions was the technique used in achieving an event-free recovery, the underlying factor being the massive difference in surgical site infections. In univariate analyses did male sex and laparoscopy predict event-free recovery and obesity predicted increase of quality of life. Almost but not reaching significance were hernia width <5 cm predicting absence of recurrence, known from experience with large hernias having a high recurrence rate. It is possible that larger data set would have produced more clear results.

Conclusions

❖ No differences are seen in postoperative recovery regarding pain, movement limitations and fatigue between open and laparoscopic incisional hernia mesh repair.

❖ No differences are found in quality of life between open and laparoscopic incisional hernia mesh repair, in short and long term perspective. Both surgical procedures restores quality of life to norm level after eight weeks, which remains after one year.

❖ Open mesh repair results in more surgical site infections compared to laparoscopic repair. Reoperation rate is similar, but indications differ. Open repair reoperations concern early wound complications, and in laparoscopic repair late recurrences are more frequent. Recurrence rate at one year does not differ.

❖ Laparoscopic technique is a predictor for uneventful recovery.

❖ No relevant clinical mesh contractions occur in the retromuscular or the intraabdominal position one year after operation.

❖ Recurrence rate after more than 10 years following midline retromuscular mesh repair is low and do not differ between primary or recurrent hernia repairs.

❖ Quality of life after more than 10 years after midline incisional hernia retromuscular repair is lower than the norm, similar to people with two chronic conditions.

Future Perspectives

Ten years ago about 1500 incisional hernia operations were performed annually in Sweden. In 2015 it was almost 2500, a 67% increase. This increase reflects the increasing amount of complex abdominal surgery being performed in older and in high risk patients. The volume of incisional hernia repair mandates every surgical unit to have the basic knowledge on how to treat an uncomplicated incisional hernia.
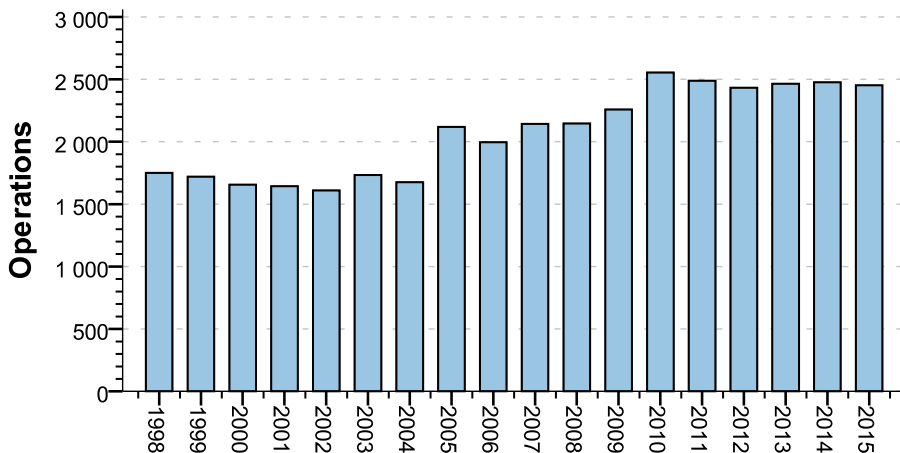
Figure 13.
Incisional hernia repairs in Sweden 1998–2015. Source: www.socialstyrelsen.se/statistik/statistikdatabas/

Incisional hernia repairs are challenging and unfortunately one of the more common procedures to be performed in the world. From a forgotten corner in every day surgery it has been raised from the young surgeon's first operation to a specialist procedure. The scientific work on the subject has multiplied. Publications indexed in PubMed as increased from about 20 papers per year in 1990 to almost 300 last year.
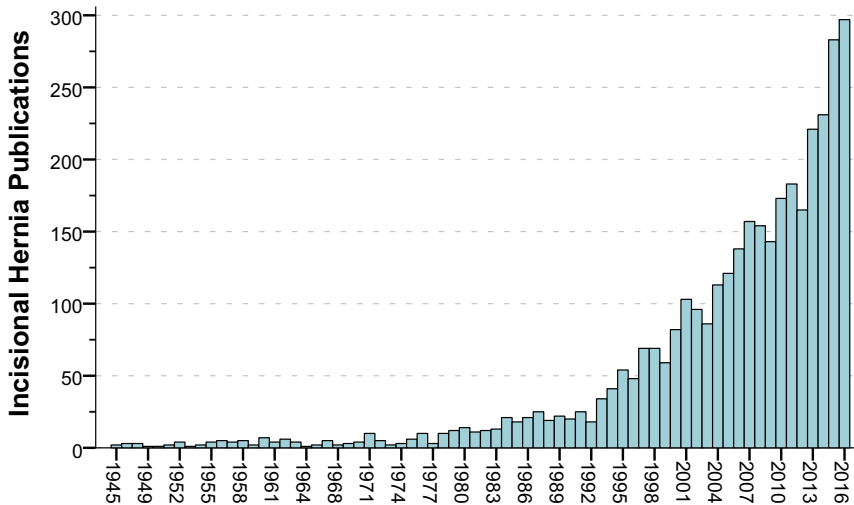
PubMed Indexed Incisional Hernia Publications 1945-2016

Figure 14.
PubMed search for incisional hernia 2017-01. Source: PubMed. https://www.ncbi.nlm.nih.gov/pubmed

Technical Future

The retromuscular technique has proven its value over time, and is often thought of as the gold standard procedure, albeit not applicable in all situations. However, the debate over what mesh to use in what situation is still open.

The ideal mesh does not exist. The concerns on a foreign material in a contaminated environment have led to the development of biological meshes/scaffolds as one bridge to "salvage" a complex case. Modern wound treatment may partly solve the deep mesh infection using negative pressure dressing. It may soon be standard dressing if early findings hold true. The growth factors attributed to the biologicals may find a way to the synthetic meshes. Gentamicin-loaded PVDF-meshes have shown positive effects on ingrowth. Other substances yet to discover may be protective against adhesions, more than the coated composite meshes of today. Knitting technology has been innovated to give meshes different textile properties; elasticity matching different hernia locations.

Intraabdominal mesh placement may not be the optimal placement. Laparoscopic techniques for mesh placement in the retromuscular space are under development facilitated by using the robotic technique. It can also be used for performing relaxing incisions needed to approximate large hernia defects, without

creating large surfaces of dissected aponeurosis prone to have seroma formation and infections.

In the open hernia mesh repair complications of seroma and infection can be reduced, and simultaneously lessening the tension in the abdominal wall. By dividing the hernia sac in the midline and saving it, still attached to the base it can be used as filler if the dorsal and ventral aponeuroses do not reach to bridge the gap without severe wall tension. The hernia sac protects the mesh from contact with the abdominal content. Lateral release may then not be needed. The contralateral side can be used to cover the corresponding gap between the ventral aponeuroses protecting the subcutis from the reactive mesh.

A new technique for release of the rectus muscles to facilitate approximation and midline closure, the Transverse Abdominis Release (TAR), has been presented from Cleveland (Krpata et al., 2012a, Gibreel et al., 2016). With an incision in the dorsal aponeurosis laterally, but medially of the entering intercostal nerves and blood vessels, the space between the transverse muscle and the internal oblique is entered. This permits the dorsal aponeurosis to slide medially and all nerves to the rectus muscle are spared.

Recently robot-assisted incisional hernia repair has been introduced. As a laparoscopic procedure it shares the advantages and disadvantages with ordinary laparoscopic repair. Whether or not it will facilitate technique developments for hernia repair remains to be shown also form a cost perspective (Finan et al., 2009). It will have stiff competition from open repair that will include also the repair of the skin problems associated with incisional hernias.

The highly specialized hernia surgeon needs a toolbox of techniques to handle possible variations of incisional hernias. Education of surgeons and postoperative wound care personnel will increase quality. There will be need of competence centers with skilled herniologists for treating the most complex hernias with fistulas, abdominal wall reconstruction after severe trauma or infections, parastomal hernias, plastic surgery abdominal wall flaps in conjunction with other reconstructive surgery. A team of experts is needed to handle these patients, including surgeons, physiotherapists, nutritionists, and wound dressing experts in the wards and in the out-clinic.

Open or Laparoscopic hernia repair?

In our perspective the laparoscopic repair have advantages with short operating time and few wound complications. The disadvantages are the dissection of the adhesions in the abdominal cavity, the lack of skin scar correction and the short term pain. For selected patients it is still an excellent choice. Closure of the defect may be required for better cosmesis.

The open repair, on the hand, always lends itself to easy skin and scar correction, has excellent long-term outcome and is easily adapted with other

techniques to solve unforeseen challenges. On the down side, operating time is longer, and wound complications more frequent.

Prevention

Most beneficial for the patients would be if incisional hernia rates were lowered. Careful consideration when planning incisions will be necessary. The optimal incision for the surgeon may not be the optimum scar for the patient in the long run. Incisional hernias outside the midline compartment, i.e. lateral to the rectus muscles, are more difficult to repair as there is no given space to place the mesh and no firm tissue to anchor it in. Most incisions are unaltered since the invention of that procedure. Further, using optimal technique for closure of the abdomen should be every surgeon's duty.

The abdominal wall must be carefully treated and not routinely injured with subsequent loss of function and hernia protrusion.

Populärvetenskaplig sammanfattning

Ärrbråck är kirurgins tråkiga följeslagare. Allt sedan operationer i bukhålan varit möjliga har komplikationer och defektläkning i bukväggen gjort att bukväggsmuskulaturen glipar och släpper fram de intraabdominella organen, oftast tunntarm, ut i det subkutana rummet. Detta är definitionen på ett bråck (lat. hernia); en bristning i väggen kring ett format hålrum i kroppen genom vilket hålrummets innehåll tillåts tränga fram. Bråck kan indelas i primära och sekundära typer. Vid de primära bråcken är det uppkomna hålet inte orsakat av någon sorts vävnadstrauma. De utgörs av uttänjd vävnad kring en befintlig passage genom bukväggen. De sekundära bråcken, ärrbråck och parastomala bråck, är resultatet av kirurgisk incision där efterföljande förslutning inte lyckats hålla emot de dragande muskelkrafterna och det intraabdominella trycket.

Ärrbråck efter abdominell kirurgi inträffar hos 5–20% av patienterna. Historiskt har rekonstruktion av bukväggen varit mycket svårt då den hållfasta lastbärande vävnaden inte längre finns kvar eller har trasats sönder. Sedan några decennier har konstgjorda nät introducerats för att förstärka reparationen och därmed revolutionerat kirurgin. De första konstgjorda näten implanterades i början av 1960-talet av Usher i USA.

Utvecklingen av den modern bukväggsreparation med konstgjort nät drevs i Frankrike. Chevrel förordade en teknik med nätplacering utanpå bukmuskulaturen för att nå ut till frisk bärande vävnad. Rives och Stoppa förordade en nätplacering direkt bakom rektusmuskeln. Stoppa var specialist på stora komplicerade ljumskbråck och behövde stora områden för att överlappa defekterna i ljumsken. Gastrokirurgen Rives åtgärdade bråck i övre delen av buken. Anatomiskt kom de båda fram till att området bakom muskeln väl lämpar sig för placering av implantat utan att behöva dela kärl och nerver, åtminstone inom muskelns område. Det bakre bladet till muskellogen upphör några centimeter nedom navelnivån där muskeln endast täcks av peritoneum.

Laparoskopins intåg under 1980-talet lovade förändringar för många kirurgiska ingrepp. Med minimala operationssnitt kunde man genomföra avancerad kirurgi. Det postoperativa förloppet präglades av kortare vårdtider och avsevärt mindre smärta för patienterna som därmed snabbt återkom till dagligt liv. Små operationssår innebar också lägre risk för sårkomplikationer, framför allt infektioner. LeBlanc publicerade 1993 en av de första artiklarna om laparoskopisk reparation av bukväggsbråck. Fördelen med laparoskopisk teknik var att placeringen av nät med tillräcklig överlappning för att täcka bukväggsdefekten

underlättades avsevärt då hålrummet redan fanns. Placeringen av konstgjort material i bukhålan har dock ett annat problem: inväxt eller integration. De nät som använts vid öppen kirurgi är mycket retande i vävnaden och stimulerar till fibroblastinväxt och ärrbildning kring nätfibrerna. I bukhålan innebär detta stora risker för adherenser, sammanväxt, mot tarmar med ofta obstruktion (tarmvred) som följd. Genom att använda ePTFE (Gore-Tex®) som är biologiskt mycket inert fick man ett membran ("nät") till plastiken, men för att få det på plats användes transmurala suturer genom bukväggen vid varannan centimeter. Risken för att en sensorisk nerv skulle fångas och skadas var påtaglig och smärtproblematiken uppmärksammades snart. En teknik för infästning av nätet med titanspiraler i nätets periferi och kring själva defekten lanserades av Salvador Morales-Conde i Spanien i början av 2000-talet. Risken för neuralgiska besvär minimerades på så sätt.

År 1999 publicerade Carbajo en liten randomiserad studie jämförande laparoskopisk och öppen nätplastik. Den antydde fördelar för laparoskopi avseende operationstid och vårdtid, men var inkonklusiv avseende recidiv och komplikationer. Luijendijk et al publicerade 2000 den första randomiserade studien jämförande suturplastik mot nätplastik vid ärrbråck. Denna talade starkt för att nätplastik är överlägsen suturer vid ärrbråck i medellinjen. Flera center rapporterade om de olika nätteknikernas för- respektive nackdelar i fallstudier, alla samstämmiga i att recidivfrekvensen minskades till under 10%.

De ursprungliga polypropylennäten är belastade med komplikationer som härrör från materialets fysiska egenskaper. Polypropylen är mycket retande i vävnaden och stimulerar till kraftig kollageninväxt. Ärrvävnad har egenskapen att vid utmognad kontraherar fibrillerna och ärret skrumpnar. Det har visats in vivo och in vitro att ärrvävnad kring nät kan medföra upp emot 50% skrumpning resulterande i recidiv, återfall av bråcket. Grovleken på polypropylenfibern och vävtekniken är också av betydelse. Nätstyrkan i gamla nät är 100 gånger bukväggens egna och således överdimensionerad. Porstorleken är ännu viktigare; fibroblasterna kring nätfibern kan inte överbrygga porer som är över 800 μm. Med tillräckligt stora porer förebyggs skrumpningsrisken.

Under de senaste två decennierna har nya nät introducerats på marknaden i en snabb takt, så snabb att utvärdering av det tidigare nätet aldrig hinner utföras. Tekniken för nätfixering har löpt i samma spår med nya material och principer lanserade med några års mellanrum.

Vi beslutade att starta en prospektiv randomiserad multicenterstudie mellan öppen och laparoskopisk nätplastik av ärrbråck. Båda ingående operationsmetoder skulle standardiseras hårt avseende bråcktyp, nät, fixeringsteknik och operatörskompetens. Svenska enheter med både öppen och laparoskopisk teknik i portföljen inbjöds. Hypotesen var att laparoskopisk nätplastik är mindre smärtsam för patienten, ger snabbare återgång till daglig verksamhet, samt ger högre livskvalitet på konvalescensen är mindre belastad med komplikationer och det kosmetiska resultatet är bättre.

Primary endpoint beslöts var smärta tre veckor postoperativt, för att undvika de omedelbara operationsrelaterade smärtorna. Mätning av smärta bestämdes vara dimensionen Bodily Pain i livskvalitetsinstrumentet SF-36, som dessutom i sin helhet kunde ge svar på frågan om i vilken grad ärrbråck påverkar livskvalitet, och vidare om kirurgi har någon effekt på detta.

Livskvalitet är ett enkelt ord men betydligt svårare att definiera. WHO:s definition från 1948 lyder: *A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*. Enighet råder om att begreppet är multidimensionellt och omfattar 6 till 10 domäner. Inom hälso- och sjukvård brukar begreppet hälsorelaterad livskvalitet användas synonymt, men man avgränsar yttre faktorer av betydelse för livskvalitet (t.ex. ekonomi, miljö, politisk struktur, etc.). Ofta kan de olika domänerna samlas under två huvudgrenar: en fysisk och en mental faktor. Bland de fysiska domänerna brukar räknas fysisk rörelse och funktion, smärta, prestationsförmåga, och till de mentala läggs psykisk hälsa, uthållighet, socialt nätverk. Vissa domäner kan räknas till både fysisk och mental faktor, t.ex. oberoende av andra, samt välbefinnande. Det amerikanska livskvalitetsformuläret SF-36 (Short-Form; av 147 frågor) som översatts och validerats internationellt använder 8 delskalor: Physical Function (PF), Role Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VI), Social Function (SF), Role Emotional (RE), Mental Health (MH). Dessa åtta skalor kan sedan sammanfattas i 2 ortogonala kompositskalor Physical Composite Score (PCS) och Mental Composite Score (MCS). SF-36 redovisas numera norm-baserad, dvs relaterat till en standardbefolkning vilket gör att olika patientgrupper kan jämföras enkelt och direkt, även mellan olika länder och kulturer. De olika dimensionernas värde har alltid medelvärdet 50 med standardavvikelsen 10.

För en patient som opererats akut för benign sjukdom, eller som genomgått behandling för tumörsjukdom och sedan friskförklarats är ett ärrbråck ett problem. Det vanligaste symptomet är smärta i bråckporten. Med större bråck tillkommer ofta tarmstörningar och rörelsebegränsningar. Synliga bråck kan vara mycket missprydande och gör ofta att sociala aktiviteter med lättare klädedräkt undviks. Ofta kommer bråcket i konflikt med kläderna (byxlinningen) och tvingar om klädstilen. Patienten lider av således av restsymptom från operationen och besvikelsen är ofta påtaglig eftersom de är botade men inte återställda efter sin operation. Det föreföll som om ett generellt livskvalitetsinstrument passar utmärkt för att fånga många aspekter på ärrbråck hos patienten.

Sjukdomsspecifik livskvalitet är ofta diskuterat – man önskar påvisa sjukdomens inverkan och svårighetsgrad, och att mäta en specifik åtgärds effekt på patientens symptom. Några bråckspecifika instrument har utvecklats sedan multicenterstudien startades, men samtliga lider av bristande validering och normering. Ur ett större perspektiv kan inte ett specifikt instrument användas för jämförelser mellan olika patientgrupper, och har svårigheter med tillstånd med mycket stor spännvidd av symptom.

Den retromuskulära nättekniken infördes i Sverige av Sam Smedberg i Helsingborg omkring 1995. Sedan 1998 har tekniken använts även i Malmö. De långtidsstudier som publicerats om retromuskulär nätplacering har sällan mer än 6 års uppföljning. Det är dessvärre mycket vanligt i retrospektiva studier om bukväggsbråck att man enbart följer upp operationen utan att skilja på indikationen. Ofta inkluderas en stor mängd primära bråck (navel- och epigastrikabråck) som har annan genes och sannolikt annan risk för recidiv. Flera publicerade studier indikerar att recidivfrekvensen efter ärrbråcksplastik är konstant över tid. Enligt några fördröjer implantationen av nät bara recidivet.

Vårt intresse var att följa upp en metod som visat på goda korttidsresultat och som nu använts under nästan standardiserad form under 8 år. Omoperations-frekvens och livskvalitet med inplanterat nät, särskilt som den tidens nät rapporterades lämna mycket främmande-kroppskänsla i bukväggen.

För att jämföra två operativa tekniker valde vi en randomiserad kontrollerad studie. Detta möjliggör att kontrollera kända faktorer som anses kunna införa bias i resultatet. Målet sattes till smärta enligt BP i SF-36. Manualen till SF-36 specificerar studiegruppens storlek efter hur stor effekt som man önskar påvisa och med vilken metod. Vi ville också påvisa förloppet under konvalescenstiden och samlade därför in formulären med täta mellanrum (14 d) inledningsvis. Area under kurvan (tid*smärta) användes för att beskriva förloppet. Randomiseringen utfördes gruppvis i storlekar om 4 till 8 patienter. Mottagande kliniker visste inte om gruppstorleken. Tanken var att kunna avbryta inklusion så fort powerberäkningen uppfyllts. Effektmåttet bestämdes till 0.5 SD, d.v.s. en medelstor effekt enligt Cohen. Han hävdar att man empiriskt inom psykometrisk forskning funnit att kliniskt betydelsefulla effektmått brukar vara <0.2, 0.5, respektive >0.8 SD. Begreppet Cohen's *d* har kritiserats, men är användbart om inte annat kliniskt effektmått kan användas.

En svår punkt i upplägget av kirurgiska studier är blindning. Det är omöjligt att blinda både patient, opererande kirurg, och uppföljande personal för vilken behandling som gavs. Även klinisk uppföljning blir svår när de som handlägger patientgruppen är få på respektive enhet. I möjligaste mån görs recidivbedömning av annan är operatören.

Den retrospektiva studien är en kohortstudie med ingångspunkt operation. Patienterna följs över tid för att utröna risken för recidiv. Risk för bias och confounders finns i metoden, men är kanske den enda tänkbara för att hitta sällsynta komplikationer eller tillstånd. Det är också svårt att i efterhand återskapa missing data. Extremformen är registerstudier där alla inkluderas vid en tidpunkt och följs tillsvidare. Med registerformen garanteras att alla ingångsdata samlas in, vilket ger bättre statistisk styrka.

Den randomiserade ärrbråcksstudiens korttidsresultat och 1-års resultat har publicerats i Annals of Surgery. I korthet är båda metoderna likvärdiga vad gäller återställande av bukväggsfunktion och livskvalitet. Samtliga ärrbråckspatienter har

kraftigt sänkt livskvalitet som återställs helt av kirurgi redan efter 8 veckor. Öppen kirurgi är behäftad med fler sårkomplikationer jämfört laparoskopisk.

På de patienter som opererades i Malmö markerades bråckportarnas kanter med metallclips (samma typ som vid gallkirurgi), likaså placerades clips i kanterna på det implanterade nätet. Inom några dagar postoperativt togs en översiktsbild på röntgenavdelningen. I samband med ett-års kontrollen togs en motsvarande bild för jämförelse. På samtliga bilder fanns en 25 mm stålbricka som måttstandard. Vid jämförelse av bilderna kan avståndet mellan clipsen beräknas och en indirekt uppskattning av nätets skrumpning kan erhållas. I litteraturen är förvirringen stor, ömsom används längdskala ömsom ytskala. Man har oroat sig för att en skrumpning av nätet i bukhålan skulle medföra att bråckporten blottas och bråcket återkommer, alternativt att nätet inte längre täcker det försvagade partiet i bukväggen.

I studien påvisas minimal nätskrumpning; ytan minskade med 4.4% i bukhålan och med 0.5% i det retromuskulära rummet. Krympningsmått i längdskalan var i bukhålan 2.8% på längden och 1.6% på bredden. Räknat på ett 10x10 cm nät betyder det att nätet minskar med 2.8 mm respektive 1.6 mm. Dessa små avstånd saknar klinisk betydelse då den rekommenderade överlappningen är cirka 50 mm på alla sidor. Nätkrympning med dessa mått förklarar inte recidiv av bråcken.

Långtidsuppföljningen av patienter med medellinjeärrbråck som opererats mellan 1998 och 2006 genomfördes med enkäter och livskvalitetsformulär under 2011−2012. Av 596 identifierade patienter levde 402 och 301 kunde sållas fram enligt kriterierna. Trots två påminnelser svarade inte 52 patienter och 32 avböjde totalt deltagande, avstod men 29 hänvisade till att de var helt besvärsfria. Resterande 217 erbjöds en kostnadsfri klinisk undersökning som 103 kom till.

Uppföljningstiden var 11 år. Recidivfrekvensen var 8.1% i hela kohorten, och av de som opererats för första gången för ärrbråck var recidivfrekvensen 7.1% och för en recidivoperation var frekvensen 10.9%. Vid den kliniska undersökningen hittades 11 asymptomatiska recidiv, utöver de 6 som hittats vid journal-genomgången.

SF-36 visade på sänkt livskvalitet i nivåer som för patienter med 2 kroniska sjukdomar, förmodligen adekvat hos 71 åriga multipelt opererade svenskar.

Sammanfattningsvis är recidivfrekvensen efter retromuskulär ärrbråcks-operation låg, även om patienten har haft multipla tidigare operationer, mycket lägre än efter primärkirurgin.

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Papers I – IV
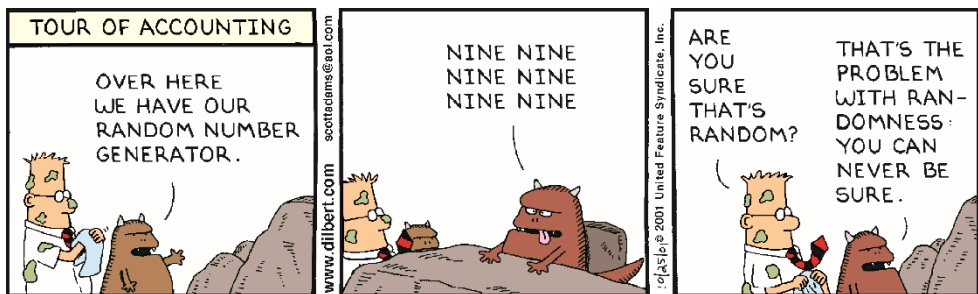
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Paper I

Paper II

Paper III

Paper IV

I rörelse

Den mätta dagen, den är aldrig störst.
Den bästa dagen är en dag av törst.
Nog finns det mål och mening i vår färd -
men det är vägen, som är mödan värd.
Det bästa målet är en nattlång rast,
där elden tänds och brödet bryts i hast.
På ställen, där man sover blott en gång,
blir sömnen trygg och drömmen full av sång.
Bryt upp, bryt upp! Den nya dagen gryr.
Oändligt är vårt stora äventyr.

ur Härdarna (1927) av Karin Boye

Barbro Bäckström (1939-1990).
Mynoria No. 2, 1982. Ironmesh.
Museum of Art. Photographer Matilda
Thulin, Malmö Museum of Art.

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