Incisional Hernia

risk factors, prevention, and repair

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Littekenbreuken

risicofactoren, preventie en behandeling

PROEFSCHRIFT

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OP GEZAG VAN DE RECTOR MAGNIFICUS

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We zijn omsingeld door onbeantwoorde vragen.
Herman Brood.

Voor Madeleine en Coen
Voor mijn ouders

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CHAPTER 1

Introduction

1.1 General Introduction, Outline of the Thesis

Incisional hernia is a major health care problem. It is one of the most frequent long-term complications of abdominal surgery and it continues to be a significant problem for patients as well as surgeons. As a result of advances in surgical knowledge and increase in the variety and number of abdominal incisions, the incidence of postoperative incisional hernias has increased rapidly. Unfortunately, attempts of repair of these hernias have not been uneventful, with high rates of hernia recurrence, and considerable rates of morbidity and mortality, making many surgeons hesitant to undertake incisional hernia repair. On the other hand, however, delay in repair may have serious clinical consequences. Apart from discomfort and pain, incisional hernias may predispose to incarceration or strangulation of primarily small bowel, which is almost certainly fatal if not promptly reduced. Also, as a consequence of the impact on health, incisional hernias have enormous economic consequences.

At this time no consensus has been reached about whether, how, and when to operate on a patient with an incisional hernia. To solve the incisional hernia problem, first of all methods of prevention are needed. Furthermore, once an incisional hernia has developed, ideally, methods of repair that do not lead to recurrence or other complications should be available. In this thesis, several clinical studies have been undertaken in an attempt to determine the most effective way to repair and prevent incisional hernia herniation and recurrence.

Chapter 1 contains the introduction. The literature is reviewed, incisional hernia is defined, and the historical background, incidence, mortality, etiology, potential risk factors, and the various techniques of repair are discussed.

Chapter 2 contains a review of the incisional hernias repaired between 1981 and 1990 at the Sint Franciscus Gasthuis Rotterdam. Patients with a primary hernia of the midline were selected for analysis, and the *vertical "vest-over-pants" Mayo repair* was evaluated. In addition, potential risk factors for recurrent incisional hernia were analyzed.

In *Chapter 3,* the incisional hernias repaired between 1980 and 1989 at the University Hospital Rotterdam were reviewed. Patients with a primary incisional hernia of the midline were selected for analysis, and the *approximating "edge-to-edge" hernia repair* was evaluated. Again, potential risk factors for recurrent incisional hernia were analyzed.

In *Chapter 4*, seeking for an incision that prevents incisional herniation, the *low transverse "Pfannenstiel" incision* was evaluated in all women, operated upon between 1986 and 1992 at the Department of Gynecology of the University Hospital Rotterdam. The prevalence of incisional hernia as well as nerve entrapment was studied.

In *Chapter 5*, to define the indications for use of prosthetic materials in incisional hernia repair, a prospective randomized multicenter trial was conducted, comparing *suture closure* with *retromuscular retrofascial prosthetic incisional hernia repair.*

Chapter 6 contains the general discussion, the recommendations, and the conclusions based on the results of the performed studies and the literature.

Chapter 7 contains the summary.

1.2 Definition

A protrusion of any viscus from its proper cavity is denominated a hernia.
Sir Astley Cooper, 1804.

A ventral postoperative or incisional hernia (Latin: hernia cicatricalis or hernia cicatricialis) is a partial internal abdominal wall defect that is in close proximity to the scar of a previously closed full thickness ventral abdominal wall incision. Groin hernias are excluded, because of their special characteristics. The intraabdominal contents like omentum, intestines, or bladder may protrude through the defect,[95] and a hernial sac is formed.[204] The protrusion may or may not be permanent. Contents may return to the abdominal cavity or protrude only with raised intraabdominal pressure, or may be immobile and adherent to the wall of the sac.

From inside out, the transversalis or endo-abdominal fascia that lines the entire abdominal cavity and lies just superficial to the peritoneum, is one layer through which all hernias must pass.[323] Then, the composition of the abdominal wall varies with the level under consideration, and different musculofascial layers may be present and may or may not join in the fascial defect (e.g. posterior and anterior rectus sheath, internal and external oblique muscle or aponeurosis).[38] The scar of the skin, the skin itself, and a variable amount of abdominal layers, such as subcutaneous tissues and superficial fascial layers (e.g. Scarpa's fascia), remain intact.

A complete rupture of the abdominal wall, a 'platzbauch', 'burst abdomen' or 'postoperative abdominal wound disruption and evisceration', is generally defined as a different entity, although in many ways the genesis is similar to (early) postoperative herniation.[129, 204, 323] A complete wound disruption takes place in the first days to approximately four weeks postoperatively.[129] There is no hernial sac and the intraabdominal contents protrude through the gaping wound. Definitions in the literature are not very strict, however.[129] Sometimes, early incomplete subcutaneous ruptures are classified as wound disruption. However, when these defects become clinical after a longer postoperative time, they are almost invariably classified as incisional hernias. Thus, some overlap is evident.

In this thesis, every fascial defect with its hernial sac covered with intact scar and skin is classified as an incisional hernia, independent of the postoperative day. In studying hernia recurrence, a 'platzbauch' is considered as a most dramatic type of recurrence.

1.3 Historical Background

The early literature on treatment of incisional hernia can be appreciated from the following historical summary taken largely from the books by Doeven (1973),[95] Ponka (1980),[323] and Van Geldere (1986).[129] As a result of advances in surgical knowledge and increase in the variety and number of abdominal incisions, the incidence of postoperative incisional hernias has increased rapidly. Some major events, which eventually resulted in contemporary incisional hernia repair, are indicated.

In 1738 Mary Donally performed a cesarean section. Apart from an incisional hernia, the patient recovered well. A spontaneous rupture of an incisional hernia was described in 1787 by Bartholomeus Franken, which was treated conservatively. In 1836 the first report of a successfully repaired incisional hernia was published by Gerdy, which was followed by the report of Henry who successfully operated a strangulated incisional hernia in 1851. The first incisional hernia closure in layers came from Maydl in 1886. One year later, John Homans reported nearly 10 percent ventral hernias in 384 laparotomies. In 1899 William J. Mayo described the transverse overlapping technique for repair of umbilical hernias.[267] In an attempt to prevent for incisional hernia to occur, Hermann Johannes Pfannenstiel described a low transverse abdominal incision in 1900.[313]

Several autologous, heterologous, and foreign body materials have been used to repair abdominal wall defects and incisional hernias in the last century. In 1909 Kirschner used heterologous, homologous, and autólogous fascia, of which the latter was reported to have good results.[323] In 1912 Judd described an overlapping flap of peritoneum, muscle, fascia, and scar tissue.[196] In 1913, cutis grafts with or without epidermal covering were used by Loewe.[247] To be able to approximate the remains of the rectus abdominis muscle, 'relieving incisions' in the anterior rectus sheath were used by Gibson in 1920.[131] Nutall described a repair using rectus muscle transplantation in 1937.[323] He released both origo's, crossed them, and sutured them to the opposite pubic bone. In 1951 Lutz used gracilis muscle transplantation for repairs close to the symphysis.[323] Braided local peritoneal flaps were described by Langenskiöld in 1944.[323] Homologous freeze-dried human fascia lata (1954) and dura mater (1955) were utilized by Usher.[430] In 1966, Von Brücke mobilized the iliac bone to repair lower midline hernias.[49]

In 1976 Karipineni stated that the peritoneum does not contribute to the reinforcement of the repair and may actually cause harm by increasing adhesions to the back of the wound, and therefore should not be used in incisional hernia closure, which was later confirmed by others in randomized trials.[105, 132, 172 199] In that same year, Jenkins demonstrated that abdominal wounds may lengthen up to 30 percent during postoperative abdominal distension.[190] As a consequence he stated that the suture length used to close a fresh abdominal wound should be at least four times the length of that wound to prevent suture cut-out, which was later confirmed by Israelsson in several prospective trials.[180-183, 186] In recent years, several promising 'rectus sheath techniques' have been described for closure of large defects, like the 'components separation method' by Ramirez in 1990.[326] In 1999, Matapurkar demonstrated the transformation

of (pluripotent) peritoneum into what is histologically indistinguishable from aponeurosis, by transplanting a segment of peritoneum to a fascial defect in dogs, which may have future implications for human incisional hernia repair.[265]

With regard to implantation of *foreign body materials* to reinforce an incisional hernia repair, Goepel and Witzel used silver wire braided to meshes in 1900.[136] Stiffness, fragility, and forming of sulfur-silver were found as serious objections to its use. In 1933, Goepel used stainless steel wire braided to meshes, and in 1948 Throckmorton and Koontz used tantalum gauze, a metallic mesh.[323] Fragmentation and wandering were found, however. Then, perlon and nylon mesh were used by Seyfarth in 1951, but inflammatory responses were described with perlon, and nylon was found to lose its strength and to fall apart.[6] In 1956, Wolstenholme used polyester mesh (Dacron®, Mersilene®), which was found to be an effective prosthetic material.[6] This was followed by Marlex® mesh used by Usher in 1958, which at first consisted of high-density polyethylene but since 1963 of polypropylene.[426, 433] In 1959, Ludington made use of Teflon® mesh (polytetrafluoroethylene). With regard to the anatomical positioning of these meshes, Rives described the large retromuscular prefascial mesh placement and Stoppa the large retrofascial and preperitoneal mesh placement, both in 1973.[340, 403] Since 1985 also expanded polytetrafluoroethylene mesh (ePTFE, GORE-TEX®) is in use.[153] In 1986, the first fascia stapler was used instead of sutures to secure a prosthesis (Auto Suture® Fascia Staple Gun®).[357] Most recently, in the last three years, several new meshes have been promoted (e.g. DualMesh®, Vypro®, Composix®).

In 1967 Ton designed an extractable stainless steel prosthesis.[415] Boerema used the same design with flexible Teflon rods in 1970.[42] Doeven, however, reported a high rate of wound complications in his thesis in 1973.[95] More recently, in 1992, Siebbeles reported 32 cases with a recurrence rate of 21 percent and an infection rate of 19 percent.[376] In 1997, Yamataka successfully used a modified technique in neonates.[462]

Another interesting development was the use of pneumoperitoneum to prepare for massive hernia repair, as described by Moreno in 1947.[284] Furthermore, in 1971, Wagh and Read demonstrated an altered hydroxyproline/proline ratio in rectus sheaths of men with direct inguinal hernias.[440] In 1974, they indicated that direct inguinal hernias in men represent a disease of collagen.[442] This may also apply to incisional hernias. In 1991 the first laparoscopic incisional hernia repair was reported by Popp.[324] Finally, at the turn of the millennium, our group reported the first randomized clinical trial concerning incisional hernia, designed and analyzed conform CONSORT guidelines,[33] comparing suture and prosthetic incisional hernia repair.[256]

1.4 Outline of the incisional hernia problem; Incidence, complications, mortality, and recurrence.

Incisional herniation is a significant complication and one of the major elements of morbidity after abdominal surgery. In prospective studies with sufficient follow up evaluation, the incidence of primary incisional hernia ranges 11 to 19.5 percent of laparotomies (Table I)*. [Mudge 1985, Lewis 1989, Lord 1994, Sugerman 1996] Surprisingly, even higher rates are reported in some short-term evaluation studies, up to 24 percent. [Ellis 1984, Leese 1984, Wissing 1988, Pans 1998] Longer follow up would most likely further increase these rates.

In studying incisional hernia incidence, numerous factors may be of influence, like the patient population, used incision, technique, suture materials, and duration of follow up evaluation, which should all be taken into consideration. Most clinical trials, for instance, present a zero to ten percent incidence, but lack sufficient follow up evaluation, mostly up to 1 year (Table I). There is no doubt, however, that incisional hernias continue to become apparent many years after abdominal closure and incisional hernia repair. In long term follow up studies, several authors demonstrated that the incidence may be expected to almost double after the first year.[10, 12, 19a, 106, 155, 225, 239, 287, 333, 336, 367a, 388] Therefore, in studies focusing on incisional hernia rates, a sufficient follow-up evaluation and life-table analysis are mandatory (see paragraph 1.5.3).

Most incisional hernias are symptom-free and are discovered only upon routine physical examination. However, incisional hernias can be a significant source of morbidity, and delay in repair may have serious clinical consequences.[95] Fascial defects, especially the small ones, predispose to incarceration (6-14.6 percent)[259, 333] and strangulation (2.4 percent),[333] primarily of small bowel.[25, 95, 159, 287, 323, 356] If not promptly reduced, a strangulated small bowel may become ischemic, necrose, and ultimately perforate. The mortality rate of complicated incisional hernia repair in recent literature ranges from zero to 10.4 percent, whereas mortality rates of elective repairs range from zero to 5.3 percent (Table II). Naturally, these rates are less accurate in the smaller series.

Hernias may increase in size,[25, 95, 204, 287, 401, 449] with increasing difficulty of repair and higher recurrence rates.[225] Massive hernias may give rise to dystrophic ulceration of skin and subsequent evisceration, intertrigo, difficulty in bending over, chronic abdominal and back pain, and respiratory complications due to diaphragmatic dysfunction.[9, 74, 95, 154, 325, 356, 371, 401, 449] Occasionally, a gravid uterus in an incisional hernia has been described, with severe complications like abortion, premature deliveries, and intra-uterine and maternal death.[81, 82] Last but not least, patients may have complaints about the esthetic appearance of their incisional hernia, ranging from a disfiguring lump and difficulties with clothing to feelings of inferiority.[95]

Although many techniques of incisional hernia repair have been developed and described, the results are often disappointing. Following *primary* nonprosthetic repair, in recent literature recurrence rates range from zero to 54 percent (Table III). Prosthetic repairs with nonabsorbable meshes have better but still high recurrence rates, mostly less then 10 but up to 34 percent (see paragraph 1.6.2.3). Following *first-*

time recurrent incisional hernia repair, recurrence rates up to 49 percent have been described (Table IV). Performing surgeons usually highly underestimated these figures, an unawareness that contributes to the magnitude of the problem. In Germany, surgeons estimated their recurrence rate 5 to 9 percent following primary incisional hernia repair and 12 percent following recurrent repair, while most published series range 30 to 50 percent.[308]

Apart from the hazard to individual patient health, all the above has enormous economic consequences. With 500.000 laparotomies per year, an incisional hernia incidence of 15 percent, one out of three incisional hernia patients operated,[287] and overall costs of 5000 DM per patient, in Germany the total estimated costs of 1995 was 125 million DM.[110] Therefore, before all, preventing an incisional hernia is mandatory. Furthermore, more effectual techniques of hernia repair are needed to lower the incidence of recurrence.

* **Note**: Table I will as well be used to study the various possible risk factors. Some references in the text are given with name and year (superscript, e.g. [Luijendijk 2000]), to facilitate finding the information referred to in Table I.

Table I: The incidence of incisional hernia. Within parenthesis (%): percentage of wound failure, which is the combined rate of incisional hernia and wound dehiscence.

Author	year	n	follow-up	%	(%)	location	technique (L=layer)	p
Blomstedt	1972	115	8-24 m	13.9		midline	various suture, 1L	(1)
		80		3.8		oblique	various suture, 2L	
		30		9.5		transverse	various suture, 2L	
Goligher	1975	107		3.7	14.0	paramedian	chromic catgut, 3L	ns (2)
		104		3.8	4.8		c.g. + Nylon, 3L	
		108		0	0.9		stainless steel, 1L	
Irvin	1976	52	6 m	5.8	5.8	(para) median	Vicryl, 3L	ns
		52		3.8	9.6		Dexon, 3L	
		57		5.3	8.8		Prolene, 2L	
Kronborg	1976	163	3 m		7.4	various	Silk, 2L, interr	< 0.05
		163	3 m		0.6		Dexon, 2L, interr	(3)
Leaper	1977	121	6 m	8.0		various	Dexon, 1L	ns
		116		5.2			Nylon, 2L	
		120		5.1			stainless steel, 1L	
Stol	1978	255	6-9 m	4.8		median	Silk, 1L, interrupt	< 0.05
		271		9.4			Dexon, 1L, interr	(3)
Greenall	1980	235	≥ 6m	8.1		midline	various, 1L, cont	ns
		234	≥ 6m	6.4		transverse	various, 1L, cont	
Guillou	1980	82	≤ 1 yr	0	0	lat paramed	catg, prol, 2L, con	0.01
		67	≤ 1 yr	14.9	16.4	med paramed	catg, prol, 2L, con	I vs II, III
		58	≤ 1 yr	6.9	6.9	midline	catg, prol, 2L, con	(4)
Cameron	1980	180	≤ 6 m	6.1		various	Dexon	ns
		167	≤ 6 m	5.2			Prolene	
Bucknall	1981	104	8.5 m	11.5	12.5	(para) median	Dexon,1L, cont	0.04
		106	8.3 m	3.8	4.7		Nylon, 1L, cont	(5)
Lip	1981	60	1-3 yr	1.3		subcostal	Vicryl, 2L, interr	< 0.05
		63	1-3 yr	14.0		upper midline	Vicryl, 1L, interr	
Corman	1981	59	1 yr	0		midline	Vicryl, 1L, interr	ns
		53	1 yr	3.8		midline	Prolene, 1L, interr	
		49	1 yr	8.2		midline	Nylon, 1L, interr	
Bucknall	1982	1129	≤ 1 yr	7.4	9.1	various	various	
Donaldsn	1982	850	≤ 1 yr	0.4	0.4	lat paramed	various, 2L, cont	
Richards	1983	184	≤ 1 yr	0.5		various	Dexon, 1-2L, inter	ns
		201	≤ 1 yr	2.0		various	Prolene, 1-2L, con	
Askew	1983	42	≤ 6 m	9.5	11.9	various	Dexon, 1L, inter	< 0.05
		62	≤ 6 m	0	0	various	Nylon, 2L, con	
Knight	1983	1000	≤ 6 m	0.7	1.1	various	Prolene, 1L, con	

Table I: continued.

Author	year	n	follow-up	%	(%)	location	technique (L=layer)	p
Ellis	1984	46	≤ 1 yr	17.4		paramedian	Nylon, 1L, cont	ns
		50	≤ 1 yr	14.0		transverse	Nylon, 1L, cont	
Ellis	1984	40	≤ 1 yr	17.5		paramedian	Nylon, 1L, cont	ns
		39	≤ 1 yr	23.1		midline	Nylon, 1L, cont	
Leese	1984	50	≤ 1 yr	20.0		various	PDS	ns
		47	≤ 1 yr	8.5		various	Nylon	(6)
Ausobsky	1985	108	6m-4yr	15.7	16.7	various	Nylon, 1L, cont	< 0.01
		98	6m-4yr	4.1	6.1	various	Nyl/Dex, 2L cont	
Mudge	1985	337	9-10 y	11.0		various	catgut a/o Nylon	
McNeill	1986	51	18 m	9.8	9.8	upp midline	Dexon, 1L, cont	ns
		54	19 m	9.3	9.3	upp midline	Steel, 1L, interr	(7)
Cox	1986	213	1 yr	0.9	1.9	lat paramed	various, 2L, cont	< 0.001
		218	1 yr	9.2	9.2	midline	nylon, 1L, cont	
Sapala	1986	792	?	0.9		upper midline	Fascia Staple Gun	
Krukowski	1987	285	1 yr	7.7		midline	PDS, 1L, cont	ns
		295	1 yr	9.5		midline	Prolene, 1L, cont	(8)
Brennan	1987	105	≥ 1 yr	0	0	lat paramed	catgut, Prolene, 2L	< 0.02
		104	≥ 1 yr	2.9	2.9	ant sheath med		
		109	≥ 1 yr	3.7	4.6	pos sheath med		
Gilbert	1987	75	1m-2yr	0	0	lat paramed	nylon, 2L (periton)	ns
		77	1m-2yr	1.3	1.3	lat paramed	nylon, 1L	
Paes	1987	109	16 m	2.8		midline	nylon, 1L	
Wissing	1988	284	<1 yr	16.9		midline	Vicryl, interrupted	< 0.05
		292	<1 yr	20.5		midline	Vicryl, continuous	II vs IV
		280	<1 yr	13.2		midline	PDS, continuous	
		300	<1 yr	10.3		midline	Nylon, continuous	
Regnard	1988	1081	≤ 5 yr	13.0		various	various	(9)
Lamont	1988	699	6-12 m	6.4		various	Nylon, 1L, cont	
Schoetz	1988	172	1-12 m	2.9		midline	PDS, 1L, cont	ns
		28	1-12 m	3.6		transverse	PDS, 1L, cont	
Lewis	1989	103	≤ 5 yr	18.0		midline	Dexon, 1L, interr	< 0.05
		93	≤ 5 yr	9.0		midline	Prolene, 1L, cont	(10)
Cleveland	1989	82	?	6.1	6.1	upper midline	Vicryl, 1L, interr	ns
		62	?	6.5	8.1	upper midline	Vicryl, 1L, cont	(7)
Cleveland	1989	55	?	10.9	12.7	upper midline	PDS, 1L, cont	ns
		51	?	7.8	7.8	upper midline	Prolene, 1L, cont	(7)
Larsen	1989	73	41 m	2.7		various	Dexon, 1L, interr	ns
		69	41 m	4.3		various	Dexon, 1L, cont	
		70	41 m	2.9		various	Nylon, 1L, cont	
Gallup	1989	210	?	0.5		lower midline	polypro, 1L, cont	

Table I: continued.

Author	year	n	follow-up	%	(%)	location	technique (L=layer)	p
Gys	1989	65	1 yr	6.2	7.8	various	Maxon, 1L, cont	ns
		67	1 yr	6.0	9.4	various	Ethilon, 1L, cont	
Gallup	1990	285	6m-1yr	0.4	0.7	lower midline	Maxon, 1L, cont	
Deitel	1990	42	≥ 2 yr	0	0	upper midline	Dexon, 1L, cont	< 0.05
		42	≥ 2 yr	9.5	9.5	upper midline	Maxon, 1L, cont	(7)
Orr	1990	125	6m	3.9	3.9	lower midline	Maxon, 1L, interr	ns
		129	6m	2.4	2.4	lower midline	Maxon, 1L, cont	
Hugh	1990	87	6 m	1.1	1.1	midline	steel, 2L (periton)	ns
		98	6 m	1.0	2.0	midline	steel, 1L	(11)
Rubio	1991	1697	-13 yr	0.1		various	nylo/prole,1L,con	
Hoffman	1991	256	≤ 2 yr	5.5		lower midline	Vicryl, 1L, cont	
Kendall	1991	137	6m-2yr	0	0	lat paramed	PDS, 2L, cont	< 0.01
		104	6m-2yr	6.7	6.7	midline	PDS, 1L, cont	I vs II
		108	6m-2yr	3.7	6.5	midline	PDS, 2L, cont	I vs III
Trimbos	1992	122	1 yr	5.7		midline	Vicryl, 1L, interr	ns
		118	1 yr	4.3		midline	Maxon, 1L, cont	
Sahlin	1993	339	1 yr	6.2	7.1	various	Vicryl, 1L, interr	ns
		345	1 yr	8.1	9.3	various	Maxon, 1L, cont	
Israelsson	1994	325	1 yr	15.1		midline	PDS, 1L, cont	ns
		318	1 yr	15.7		midline	Nylon, 1L, cont	(12)
Lord	1994	126	1-6 yr	13.5		transverse	Nylon, 2L, cont	ns
		109		16.5		midline	Nylon, 1l, cont	(13)
Sivam	1995	358	?	3.9		midline	Nylon,1L,far&near	
Carlson	1995	80	2 yr	8.8		midline	Maxon, 1L, cont	ns
		91		4.4		midline	Nylon, 1L, cont	
Carlson	1995	1000	22 m	4.2	5.5	midline	Nylon, 1L, cont	(14)
Osther	1995	70	1 yr	15.7		various	Dexon, 1L, interr	ns
		67	1 yr	10.4		various	Maxon, 1L, interr	
Gislason	1995	164	<1 yr	4.3		various	Vicryl, 1-2L, inter	0.02
		163	<1 yr	5.5		various	Vicryl, 1L, cont	I, II vs III
		164	<1 yr	11.6		various	Maxon, 1L, cont	
Israelsson	1996	368	12 m	11.4	12.0	midline	monofilament, 1L	
Sugerman	1996	968	1m-5yr	19.5		upper midline	Dexon, 1L, cont	(7, 13)
Brolin	1996	120	30.4 m	9.2	9.2	upper midline	PDS, 1L, cont	< 0.01
		109	28.3 m	18.3	20.2	upper midline	Ethibond, 1L, inter	(7)
Colombo	1997	306	1.9 yr	14.7		midline	Dexon, 1L, interr	women,
		308	1.9 yr	10.4		midline	Maxon, 1L, cont	ns
Pans	1998	144	30.8 m	24.0		upper midline	Vicryl, 1L, interr	ns
		144	28.7 m	30.0		upper midline	Vicryl mesh + sut	(7, 15)

Table 1: continued.

(1) Significant difference between group I and II.
(2) Significant difference between group I and II, and between group I and III. Conclusion author: chromic catgut is unreliable.
(3) Conclusion author: Dexon is better than Silk.
(4) Conclusion author: The lateral paramedian incision is inherently strong, and therefore is suggested to be the incision of choice when a vertical incision is planned.
(5) Conclusion author: Closure of abdominal wounds with absorbable sutures (Dexon) does not appear to be justified.
(6) Conclusion author: Nylon remains the best material currently available for closure of the abdominal wall.
(7) All patients were morbidly obese.
(8) Conclusion author: PDS is the preferred suture material for closure of midline abdominal incisions.
(9) Of these 1081 patients, 94 (8.7 percent) had an incisional hernia at the time of follow-up. The lack of follow-up for several patients became obvious only after actuarial analysis. The actuarial rate of incisional hernia at 5 years was 13 percent.
(10) Life table analysis. In the Dexon group (11 incisional hernia appearances) and the prolene group (4 incisional hernia appearances), the 5-year cumulative recurrence rate was 18% and 9%, respectively ($p < 0.05$).
(11) Conclusion author: Closure of the peritoneal layer may be abandoned.
(12) Conclusion author: Suture of midline wounds is as safe with PDS as it is with nylon.
(13) Retrospective study.
(14) Chart review. No (essential) physical examination was performed.
(15) Conclusion author: Intraperitoneal Vicryl mesh following primary abdominal closure does not prevent incisional hernia. Life table analysis: 3-year cumulative recurrence rates non-mesh / mesh were 42 and 48 percent, respectively.

Table II: Mortality rate following incisional hernia repair (up to 1963 partly taken from Doeven).

Author	year	no. of pts.	Operation mortality (%)
Elective repairs			
Masson	1923	596	1.8
Branch	1934	300	1.3
Smith	1940	85	5.9
Pink	1947	31	0
Trace	1950	156	2.1
Obney	1957	176	0
Abel	1961	23	0
Mitchell-Heggs	1962	41	5.0
Akman	1962	500	0.4
Dick	1963	148	2.0
Doeven	1973	78	0
Ponka	1980	723	0.4
Langer	1985	154	0
Rives	1985	226	prosthetic repair: 3.5
Adloff	1987	130	prosthetic repair: 1.5
George	1986	81	0
Stoppa	1989	466	prosthetic repair: 1.8
			non-prost repair: 5.3
Heydorn	1990	2926	0.4
Liakakos	1994	49	prosthetic repair: 0
		53	non-prost repair: 0
Becouarn	1996	160	prosthetic repair: 1.2
Bang	1997	124	0
Gillion	1997	158	prosthetic repair: 0
McLanahan	1997	106	prosthetic repair: 0
Shukla	1998	50	0
Trupka	1998	33	prosthetic repair: 3.0
Mathonnet	1998	172	prosthetic repair: 1.2
Wantz	1999	206	prosthetic repair: 1.0
Arnaud	1999	250	prosthetic repair: 0.8
Complicated repairs			
Trace	1950	13	31.0
Stewardson	1978	8	0
Ponka	1980	71	2.8
Hjaltason	1981	11	0
Rives	1985	106	10.4
Heydorn	1990	181	1.1

Table III : The incidence of hernia *recurrence* following *primary* incisional hernia repair (suture techniques), taken from retrospective studies.

Author	year	n	follow-up	%	location	technique
Obney	1957	192	1-10 yr	12.5	various	overlapping, steel, 3L
Akman	1962	500	1-10 yr	1.6	various	overlapping, steel, 3L
Doeven	1973	35	> 1 yr	37.1	various	various, Mersilene
Doeven	1973	43	> 1 yr	25.6	various	Ton apparatus
Fischer	1974	151	3.5 yr	17.2	various	various suture repairs (1)
Maguire	1976	32	4-18 yr	18.8	upper midl	relieving incision
Pollock	1979	240	≥ 6 m	10.8	various	various sut repairs, cont
Jenkins	1980	50	?	8.0	various	SL:WL 4:1, Nylon
Langer	1985	154	4-10 yr	31.2	various	various suture repairs
George	1986	81	1m-13 yr	45.7	various	Nylon, 1-3L (2)
Lamont	1988	36	6-12 m	44.4	various	Nylon, 1L, cont
vdLinden	1988	151	1-8 yr	49.0	various	various suture repairs
Read	1989	169	1-8 yr	24.3	various	Prolene, 1L, cont (3)
Manninen	1991	172	4.5 yr	33.7	various	various suture repairs (4)
Naraynsingh	1993	85	71 m	1.2	midline	Nylon 1L, rectus repair
Shukla	1998	50	52 m	0	various	Prolene, Cardiff (5)
Paul	1998	114	5.7 yr	53.5	various	Mayo, Ethibond
Anthony	2000	48	45 m	54	midline	-

(1) Chart review, no physical examination performed.
(2) Keel repair and mass closure. Follow up 13.5 m, range 1m-13yr.
(3) 74 of 206 (primary + secondary repairs combined) without physical examination.
(4) Physical examination performed at patients complaining about repair (40%), only. Follow up 4.5 years, range 3m-12yr.
(5) Cardiff repair: interrupted far-and-near sutures, reinforcement sutures, +/- releasing incision.

Table IV: The incidence of hernia recurrence following *first-time recurrent* incisional hernia repair, taken from retrospective studies.

Author	year	n	follow-up	%	location	technique
Suture techniques						
Langer	1985	21	4-10 yr	42.9	various	sut, various
George	1986	12	1-13 yr	41.6	various	Nylon, 1-3L
vdLinden	1988	74	?	20.3	various	various
Read	1989	16	1-8 yr	43.8	various	Prolene, 1L, cont
Manninen	1991	35	3m-12yr	48.6	various	sut, various
Liakakos	1994	53	7.6 yr	24.5	various	Nylon
Mesh techniques						
Read	1989	20	1-8 yr	40.0	various	subcut. or intraperit.
Liakakos	1994	49	7.6 yr	8.2	various	intra or preperitoneal

1.5 Etiology, Risk factors

Numerous endogenous and exogenous factors are believed to play a role in the genesis of primary and recurrent incisional hernias. In the exceptional case, a single cause may exist, but more often the causes are numerous, complex, and interrelated.[219, 323, 437] The hernias presenting in the early postoperative period may have a different etiology than those presenting late. Hernias occurring during the first postoperative days should probably be largely attributed to technical failures, like loosening of knots, breaking of suture, or sutures cutting through the tissues, mostly brought about by high (intermittent) intraabdominal pressure. Here, in many ways the genesis of postoperative herniation is similar to that of wound disruption.[95, 129, 323] Late hernias are more likely to be due to complications of endogenous wound healing and constitution.[323]

For reasons of clarity, we grouped the possible risk factors in patient-related, operation-related, and hernia-related factors. These factors will be discussed, and evidence from the literature, if available, will be provided. Also, since abdominal closure (with hernia *appearance*) and incisional hernia repair (with hernia *recurrence*) are not the same (see paragraph 1.5.2.3), these entities are being separated.

1.5.1 Patient-related risk factors

Gender and abdominal closure. Careful prospective studies in recent years do identify male gender as a risk factor for incisional hernia appearance (Table Va). Regnard, Gislason, and Israelsson, however, did not find a significant difference between the sexes.[135, 182, 183, 336]

Table Va. Gender as a risk factor for incisional hernia following abdominal closure:

Author	year		No of patients	patients with hernia (%)	p
Pollock	1979	men	91	20.9	< 0.001
		women	149	4.7	
Greenall	1980	men	206	11.2	< 0.01
		women	263	4.2	
Bucknall	1982	men	510	12.2	< 0.0001
		women	619	3.6	
Krukowski	1987	men	302	13.6	< 0.01
		women	278	3.2	
Wissing	1988	men	650	17.2	< 0.05
		women	502	12.5	
Gislason	1995	men	219	7.3	ns
		women	237	8.0	

Gender and incisional hernia repair (Table Vb). In a retrospective study, Lamont did not but Koller did show a significant difference between the sexes with regard to incisional hernia recurrence.[216, 224]

Table Vb. Gender as a risk factor for incisional hernia recurrence following incisional hernia repair:

Author	year		No of patients	patients with hernia (%)	p
Koller	1997	men women	33 37	74 47	0.04

Age. With aging, a certain amount of atrophy occurs, with changes in connective and elastic tissues,[437] leading to a gradual weakening of the abdominal wall. Furthermore, the geriatric patient often suffers from certain conditions (e.g. pulmonary emphysema, prostatism) that may result in an increase in intraabdominal pressure. Also, conditions that impair wound healing (e.g. advanced malignancies, malnutrition) may coexist.

Age and abdominal closure. In prospective studies, age was determined as a risk factor for incisional hernia appearance by Blomstedt ($p < 0.001$), Stol ($p < 0.01$), Pollock ($p < 0.05$), Greenall ($p < 0.02$), Bucknall ($p < 0.001$), Krukowski ($p < 0.01$), Wissing ($p=0.009$), Gislason ($p=0.04$), and Israelsson ($p=0.02$).[41, 51, 135, 145, 146, 182, 183, 219, 320, 397, 457] Leaper, Ellis, Lamont, and Regnard did not show a significantly higher incisional hernia rate with higher age.[107, 224, 230, 336]

Age and incisional hernia repair. In a retrospective study, Lamont did not show a significantly higher recurrence rate with higher age.[224]

Diastasis recti (divarication). A diastasis of the rectus abdominis is a condition of unusual separation of the rectus abdominis muscles in which the attachment of the rectus muscle to the linea alba is widened and may sometimes balloon outwards.[174] It requires no treatment. A midline incision may be contraindicated in a patient with diastasis because of a high incisional hernia rate (personal experience Cahalane and Schumpelick, no evidence found in the literature).[55, 449]

The remaining patient-related risk factors can be divided in factors that cause an increased intraabdominal pressure and factors that impair wound healing, or both.

1.5.1.1 Intraabdominal pressure.

Introduction.

The abdomen has a dynamic muscular wall that can accommodate a wide variation in volume with little change in intraabdominal pressure. However, intraabdominal pressure may be influenced by changes in interabdominal volume or changes in abdominal wall compliance. For instance, massive incisional hernia repair increases intraabdominal volume, decreases abdominal wall compliance, and therefore produce a significant increase in intraabdominal pressure.[314]

Increased intraabdominal pressure places a distracting force upon the closed incision, which may result in wound disruption or incisional hernia. In general, with increased intraabdominal pressure, any point of weakness in the abdominal wall may permit a hernia to develop.

Several authors investigated the rise in intraabdominal pressure by different methods and in various incidents.[101, 203, 223, 243, 373] Normal pressures do not exceed 8 cm H_2O in the supine position. Walking produced a pressure of 18 cm H_2O, getting out of bed 29 cm H_2O. During vomiting, straining at stool, and coughing, the pressure reached from 80 to 150 cm H_2O. With these pressures cutting through of suture is more likely.

Possible risk factors with regard to raised intraabdominal pressure.

Obesity (Table VIa, VIb). Obesity increases intraabdominal pressure.[323, 373, 404] Furthermore, fatty infiltration decreases the quality of abdominal musculature. Technically, it is more difficult to approximate wound edges in a patient with a heavy pendulous abdomen. The thick layer of adipose tissue produces a distracting force to the wound edges, and preventing dead space is more difficult. Some authors even recommend excision of omentum to facilitate closure.[267, 375, 424] Also, the postoperative wound infection rate is higher in obese patients.[291] Therefore, several authors consider obesity as a relative contra-indication for operation, and postpone incisional hernia repair until the patient has lost weight.[95, 114, 259, 424, 451, 449] With regard to incisional hernia *detection* in an obese patient, it must be kept in mind that a protrusion may be hidden from palpation and sight by a heavy panniculus.[323, 343, 465]

Overweight is a risk factor for incisional hernia appearance (Table VIa) and recurrence (Table VIb). Israelsson showed in 1997, however, that this risk with regard to midline abdominal closure might be eliminated if patients are sutured with a suture length to wound length ratio of 4.0 to 4.9.[184]

Table VIa. Obesity as a risk factor for incisional hernia appearance:

Author	year		No of patients	patients with hernia (%)	p
Blomstedt	1972	no obesity	219	9.6	ns
		obesity	60	10.0	
Stol	1978	underweight	56	3.6	I-III, $p < 0.05$
		normal	356	5.9	II-III, $p < 0.1$
		overweight	109	12.8	
Bucknall	1982	no obesity	929	5.8	$p < 0.0001$
		obesity	200	15.0	
Wissing	1988	underweight	54	3.7	$p < 0.05$
		normal	743	13.1	
		overweight	339	21.2	
Regnard	1988	no obesity	927	7.0	$p < 0.0001$
		obesity	154	18.8	
Gislason	1995				ns
Israelsson	1996	normal	194	6.2	$p < 0.01$
		overweight (BMI ≥ 25)	174	17.3	

Table VIb. Obesity as a risk factor for incisional hernia recurrence:

Author	year		No of patients	patients with hernia (%)	p
Manninen	1991	no obesity	46	13.0	0.0015
		obesity	119	38.7	

Chronic cough (Table VIIa, VIIb). Pulmonary diseases also cause an increase in intraabdominal pressure. Coughing further aggravates the situation. [101, 203, 243, 323] In a randomized trial comparing various suture materials, Leaper did show a significantly higher incisional hernia rate in patients with a high postoperative 'respiratory score', which described 7 items.[230] Pollock, Greenall, Guillou, and Bucknall found similar figures. Wissing did not show a significantly higher incisional hernia rate with patients with a history of chronic obstructive pulmonary disease (COPD).

Table VIIa. Pulmonary disease as a risk factor for incisional hernia appearance:

Author	year		No of patients	patients with hernia (%)	p
Leaper	1977	score < 7	14	21.4	< 0.001
		score ≥ 7	280	3.2	
Pollock	1979	chest compl -	186	7.0	< 0.001
		chest compl +	54	24.1	
Greenall	1980	chest compl -	334	3.6	< 0.001
		chest compl +	135	16.3	
Guillou	1980	resp disease -	111	11.7	0.01
		resp disease +	14	42.9	
Bucknall	1982	chest infect -	934	5.6	< 0.0001
		chest infect +	195	16.4	
Wissing	1988	COPD no	1029	15.2	n.s.
		COPD yes	121	15.7	

Table VIIb. Pulmonary disease as a risk factor for incisional hernia recurrence:

Author	year		No of patients	patients with hernia (%)	p
- not found					

Prostatism. A patient with prostatism must strain to void, so intraabdominal pressure rises.[101, 323] No evidence was found in the literature, however, of prostatism being a risk factor for incisional herniation.

Constipation. If a patient strains at stool repeatedly, intraabdominal pressure rises.[101, 323] No evidence was found in the literature, however, of constipation being a risk factor for incisional herniation.

Postoperative abdominal distension. In a prospective study, Pollock and Bucknall demonstrated a significantly higher incisional hernia rate in patients having postoperative abdominal distension ($p < 0.0005$).[51, 320] Greenall, however, could not confirm these findings.[145, 146] With regard to distension being a risk factor for incisional hernia *recurrence*, no evidence was found.

Nasogastric decompression. Patients who do not receive nasogastric tube decompression do have increased rates of postoperative distention and vomiting.[302] In a randomized trial, however, this did not lead to a significantly increased incidence of incisional hernia ($p=0.09$), but questionnaires were used instead of physical examination to determine incisional herniation.[302]

Other conditions. Several other conditions may give rise to an increased intraabdominal pressure, like vomiting, hiccup,[260, 263] ascites, abdominal tumors,[373] ileus, pregnancy, trauma, and straining[243, 373] (e.g. during recovering from general anesthesia,[203] playing a wind-instrument, and straining at heavy lifting[243]). No evidence was found in the literature, however.

1.5.1.2 Impaired wound healing.

Introduction.

In regard to healing of abdominal wounds and occurrence of incisional hernias, particularly the healing of fascial and aponeurotic layers are of interest. The dynamic process of wound healing can be divided in three phases which are fundamentally the same for all tissues; the substrate, exudative or inflammatory phase (1st to 4th day), the fibroblastic or proliferative phase (5th to 20th day), and the remodeling or maturation phase (21st day up to years). However, the speed at which these phases develop depends on the potential for regeneration and repair of the tissue affected.[329] Skin and mucosa heal fast (complete in approximately 2 weeks), while aponeurosis takes considerably longer for repair (several months). The process of wound healing is complex, highly ordered, and controlled.[329, 458] For the purpose of this thesis, it will only be discussed briefly.

During the *exudative phase* (1st to 4th day), the abdominal wound has practically no holding strength. The wound simply falls apart if the sutures are removed. During this phase many changes occur in preparation of the proliferative phase, like removal of debris, bacteria, and devitalized tissue.[323, 329] It is dominated by vascular, cellular and enzymatic processes, preparing for the entrance and multiplication of the fibroblasts.[339] As regards the cellular reaction, the polymorphonuclear leukocytes are the first to take up position, and give the signal for the arrival of the main cell of this phase, the macrophage.[329]

During the *proliferative phase* (5th to 20th day), epithelialization, wound contraction and connective tissue repair take place.[339] The proliferating fibroblasts and macrophages are responsible for the formation of collagen, resulting in a rapid increase of tensile strength of the sutured wound. During this period the gain in strength is approximately 15 to 30 percent of the original tensile strength of the intact tissues. This phase may be delayed by infection and other factors, which may in fact reverse the process and turn back into the inflammatory stage.[329]

During the *remodeling phase* (21st day up to years), there is reorganization and rearrangement of the collagen fibers, stimulated by stress and strain, resulting in a steady gain of tensile strength up to approximately 80 percent of intact tissue. It depends on an equilibrium between the synthesis and lysis of collagen. Aponeurotic and fascial wounds heal more slowly than is generally recognized. Experimental studies suggest that at least 3 to 5 months are required to achieve substantial resistance against spreading of the cicatrix.[323, 329]

It has been shown that tensile strength of the wound continues increasing for a considerable period even though the collagen content of the wound is actually decreasing. This is due to 'cross-linking' of collagen fibers. This phenomenon is far more important for the ultimate tensile strength than the amount of collagen tissue present in the wound.[339]

Numerous animal experiments on fascial healing are reported.[98, 119, 207, 240, 400] In *rabbits*, Lichtenstein found that the strength of the wound at day one and after two months was similar when nonabsorbable sutures were left in place, the strength being 70 percent of intact tissues. When sutures were removed a regaining of 0 percent at day one to 41 percent at two months, was achieved.[240] He therefore advised the use of nonabsorbable sutures. Also in *rabbits*, Douglas found a tensile strength of 30 percent of the strength of normal tissues after 100 days with sutures removed. Fascial wounds reached maximal strength in 200-300 days, which was approximately 75 percent of intact tissues.[98] In *rats*, Foresman found a bursting strength of 80 percent of intact fascial tissues at 42 days, with or without sutures.[119]

The fact that the wound tensile strength never reaches that of the original tissue has been repeatedly demonstrated.[98, 454] Individual determinations of wound strength at a given interval may vary considerably, however, with an up to tenfold interindividual difference.[98] Also, there are differences of a quantitative nature in the healing wounds of different species. Thus, one must be cautious in transferring the results obtained in animals to the problems of wound healing in humans.[454]

Possible risk factors with regard to impaired wound healing.

Diabetes mellitus. The patient with diabetes is likely to be obese, which makes wound closure difficult. Furthermore, diabetics develop wound infection easily, particularly when the diabetes is difficult to control, and, once established, infection is more difficult to treat. The with medication treated well-controlled diabetic patient, however, may not have a higher incisional hernia rate. Stol and Regnard did not show a significantly higher incisional hernia rate, and Anthony no higher incisional hernia recurrence rate with diabetes mellitus.[19a, 336, 397] In a retrospective study, Sugerman did identify diabetes as a risk factor for incisional hernia appearance.[404]

Corticosteroids. In spite of a vast literature, it is not totally clear how corticosteroids inhibit wound healing.[175, 271, 278] Some mechanisms are known. For instance, steroids inhibit proliferation of fibroblasts and alter various aspects of the inflammatory

response. They reduce protocollagen and inhibit prolyl hydroxylase, with a reduction of collagen synthesis, although they do not necessarily prevent collagen deposition. In the practice of clinical surgery, patients on large doses of steroids often show impaired wound healing. Low doses may have the same effect in the presence of starvation or protein depletion.[95, 278, 323] In prospective studies, however, Stol, Bucknall, Wissing, as well as Regnard did not show a significantly higher incisional hernia rate with use of steroids.[51, 336, 397, 457]

Malnutrition. In patients with malnutrition, specific deficiencies including anemia, hypoproteinemia, and vitamin depletion may occur. Consequently, wound healing may be impaired, as demonstrated experimentally.[323, 329] Recent intake, however, is probably the most important. No food for a week seems worse than limited regular diet for a longer period.[175] In a prospective trial, Leaper did not show a significantly higher incisional hernia rate with preoperative nutritional state.[230]

Smoking. It is well known that smoking impairs wound healing. Smoking one cigarette lowers wound and tissue pO2 in normal volunteers by 30 percent for the better part of 1 hour.[175, 194] Also, a systemic effect of chronic cigarette smoking termed 'metastatic emphysema' has been described.[334] In a recent review, Read concludes that cigarette smoking has been shown repeatedly to damage connective tissue, thereby also causing attenuation of the transversalis fascia, leading to inguinal and incisional herniation.[334]

In abdominal closure. Leaper, Johnson, and Holland did not show a significantly higher incisional hernia rate with smoking.[164, 195, 230]

In incisional hernia repair. In a retrospective trial, Manninen did not show a significantly higher incisional hernia recurrence rate with smoking.[259] Leber, however, found the risk of developing a long term complication following prosthetic incisional hernia repair to be almost 2.5 times greater in smokers.[232]

Oncologic disease. Carcinoma may lead to malnutrition, hypoproteinemia, and anemia. Therefore, postoperative wound healing may be impaired, and herniation may occur.[95, 323, 457] For wound disruptions, this is illustrated by a series of Mendoza, who found as much as 7 percent (21/291) wound disruptions in patients with carcinoma, where most other series show an incidence of 0.4 to 2.7 percent.[281, 323] In a prospective trial, Leaper did not show a significantly higher incisional hernia rate with malignant disease.[230]

Obstructive jaundice. Jaundice impairs wound healing by interfering with fibroblastic activities. Armstrong studied patients undergoing surgery for obstructive jaundice and anicteric patients undergoing cholecystectomy.[21] Reduced wound healing manifested by a higher frequency of wound dehiscence (3.2 percent vs. 0.5 percent) and incisional hernia (10.3 percent vs. 1.8 percent) was seen in the jaundiced patients. This decreased wound healing, however, was not independently related to a raised bilirubin. The authors concluded that the reduced wound healing was due to the associated features of poor nutritional status, malignancy, and postoperative sepsis. Ellis and Lamont also identified jaundice as a risk factor for incisional hernia appearance.[105, 224]

Radiotherapy. Healing is impaired following radiotherapy to the abdomen. Tissues become atrophic and blood supply is decreased.[323] Regnard and Colombo did not find a significant difference in a prospective study.[75, 336] The amount of patients with radiotherapy was small, however.

Chemotherapy. Animal experiments show impaired wound healing with most cytostatic drugs.[95, 129] With regard to chemotherapy being a risk factor for incisional hernia, Colombo did not find a significant difference.[75]

Multiple laparotomies. Healing proceeds more slowly in heavily scarred tissue, with its impaired blood supply and loss of elastic fibers.[323] Ponka found that 25% (196/794) of patients that eventually developed an incisional hernia had had multiple operations. Israelsson, however, in a prospective trial, did not identify multiple laparotomies as a risk factor for incisional hernia.[182, 183]

1.5.1.3 Collagen, and the possibility of an inherent defect.
1.5.1.4 Aneurysmal disease

Collagen is not one molecule. Instead, there are multiple genetic types of collagen and each type appears to be associated with a specific function or type of tissue. For example, fascia, rigid tendon, and bone are composed mainly of Type I collagen. Skin, which is more elastic, is 80 percent Type I and 20 percent Type III. Pulsatile blood vessels are mainly composed of 80 percent Type III collagen with only 20 percent Type III.[271]

Tensile strength results from collagen crosslinking rather than collagen synthesis per se. In normal tissue repair, collagen synthesis and collagen degradation (by a variety of collagenases) are in a finely controlled state of equilibrium. Loss of this *dynamic equilibrium* results in abnormal tissue repair.

Collagen production requires the presence of vitamin C, Zn, Fe, Cu, and an adequate oxygen tension. Synthesis may be inhibited, for instance by deficiency of vitamin C leading to scurvy, in which *previously healed* wounds grow weaker until ultimately dehiscence occurs due to failure of normal fiber formation.[323, 454] Also, ingestion of seeds of Lathyrus odoratus, containing beta-aminoproprionitrile, is known to produce connective tissue lesions, inguinal hernias, dissecting aneurysms, and impaired wound healing in most mammals, due to inhibition of cross linkage of collagen.[323] Many other lathyrogenic agents have been identified. Also, other diseases with defects in collagen metabolism, like Ehlers-Danlos syndrome, Marfan's syndrome, and autosomal dominant polycystic kidney disease, have been associated with a greater incidence of abdominal wall hernia.[92, 285]

Should an inherent defect also be held (partially) responsible for incisional or inguinal herniation in apparently healthy patients? Boerema showed peroperatively, using a spring balance, that the aponeurotic tissues of the anterior abdominal wall disrupted at pulling forces varying from 1.5 to 12 kg.[42, 43] He concluded that there are 'tough and

not so tough' people. In 1970, Read identified attenuation of the rectus sheath in patients with inguinal hernia.[333, 334] In 1971, his group demonstrated decreased amounts of collagen in rectus sheaths of men with direct inguinal hernias, and they indicated that a biochemical explanation for this phenomenon could be the presence of a defect in hydroxylation of the collagen molecule.[440, 441] In 1974, they identified ultrastructural abnormalities and a deficiency in hydroxyproline content, and they indicated that direct inguinal hernias in men represent a *disease of collagen*.[442] Also, the Type I to Type III ratio is shown to be lower in patients with inguinal hernia, also suggesting some underlying disorder.[124]

Moreover, there is some indication that herniation and aneurysm formation are related, and it is suggested that they are caused by the same disorder. Cannon and Read found an increased frequency of direct and recurrent inguinal hernia in aneurysm patients.[59] In a retrospective study, Adye confirmed these findings.[8] Furthermore, Stevick, Hall, Holland, and Adye found an unexpectedly high frequency of incisional hernia in a small group of aortic aneurysm reconstruction patients (Table VIII).[8, 152, 164, 395] Johnson did not confirm these data in a retrospective review of a larger group of patients.[195] Also, Israelsson found a similar rate of incisional hernia in patients with abdominal aortic aneurysmal disease and others, when midline wounds were closed with a suture length to wound length ratio of at least four.[186]

Table VIII. Aortic aneurysm as a risk factor for incisional hernia appearance:

Author	year		No of patients	patients with hernia (%)	p
Stevick	1988	aneurysm	27	37.0	< 0.01
		occlusive	39	10.3	
Johnson	1995	aneurysm	231	6.1	
Hall	1995	aneurysm	128	10	< 0.05
		occlusive	65	3	
Holland	1996	aneurysm	34	38.2	0.04
		occlusive	30	20.0	
Adye	1998	aneurysm	58	31.0	0.03
		occlusive	42	11.9	
Israelsson	1999	aneurysm	71	15.5	ns
		others	737	14.5	

In conclusion, it remains a speculative issue whether an inherent defect in healing exists or co-exists in the patient with incisional or inguinal hernia and/or aortic aneurysmal disease. A variety of pathological mechanisms have been suggested to be accountable for this possible inherent defect, like defects in collagen and elastin cross-linkages,[53, 413] increased elastase activity with reduced elastin content, [58] and different relative proportions of collagen subtypes.[124, 280]

To this regard, smoking may also be a factor. In a recent review, Read concludes that cigarette smoking has been shown repeatedly to damage connective tissue, thereby also

causing attenuation of the transversalis fascia, leading to inguinal and incisional herniation.[334] This systemic effect of chronic cigarette smoking was termed 'metastatic emphysema'. In his view, this interference with collagen type I and III synthesis can also arise from genetic mutation (smokers as well as non-smokers), but in smokers herniation as well as aneurysm (aortic and intracerebral) has to be considered the result of a systemic protease-antiprotease imbalance due to smoking.[334]

Further evidence for the above mentioned correlation and its pathogenesis is needed.

1.5.1.5 Onset of herniation.

The late onset of some hernias suggests that immature collagen gradually stretches as a result of mechanical stress, so separating the aponeurotic layers and allowing the hernia to develop.[99] Others, however, conclude that the origins of incisional hernia can be traced back to events in the first month after operation, and that they are not the result of later weakening of a well-healed laparotomy incision. Forssell showed with radiographs of clips, attached during closure to the cut edges of the aponeurosis, that the mean distance between all the pairs of indicators continued to increase up to 15 *mm* in one year, mainly between 1.5 and 12 months.[120] In some cases, clinically undetectable separation of several *centimeters* within one month was responsible for subsequent late diagnosis of incisional hernia, which was later confirmed by Playforth and Pollock.[318, 319, 322] In only one patient a late hernia appeared without prior early fascial separation in their studies. These studies suggest that most incisional hernias do develop early, and that sutures cutting through during the early phases of wound healing may be largely responsible. Apart from technical failures, this may be due to weak tissues or high pressures. Inborn or acquired errors of metabolism may also be responsible.

1.5.2 Operation-related risk factors

Surgical technique. Wound failure is a function of the extrinsic strength, dependent on the material and technique used for closure, and the rate of recovery of intrinsic strength in the healing wound.[102, 219] The surgical technique is of special interest, since this is the factor that is most directly related to the work/art/skill of the surgeon, and therefore is directly controllable. Several influential factors concerning incisional hernia can be recognized and are summarized in Table IX. These and other possible operation-related risk factors will now be discussed.

Table IX: Some theoretical risk factors on incisional hernia (primary and recurrent) with respect to surgical technique.

1)	Selection of incision for laparotomy:
	- e.g. midline, paramedian, pararectus, transverse, McBurney, subcostal, Pfannenstiel
	- relation to prior incisions of the abdominal wall
	- length of incision
2)	Fascia quality:
	- use of non-healthy fascia for incisional hernia repair.
3)	Selection of suture material:
	- absorbable / non-absorbable
	- monofilament / multifilament
	- tensile strength / size
4)	Suture technique:
	- continuous or interrupted (e.g. figure-of-eight, running, festonnated)
	- mass or individual layer closure
	- suture length to wound length ratio
5)	Knot security:
	Various knots
	- flat knots: square knot, surgeon's knot, granny knot
	- sliding knots: identical, non-identical, parallel
	- half blood knot
	- chain stitch knot
	Various tying techniques
	- backhand, forehand
	- package knot, reversed package knot
6)	Closure technique:
	- approximating, overlapping, mesh, or other repair
	- use of relieving incisions
	- use of retention sutures
7)	Presence of tension:
	- Tissue-tension = tension used to put tissues together
	- Suture-tension = tension to tissues in between sutures due to tightness of suturing

To get to the best surgical technique, ideally, all these subfactors should be studied separately, favorably in randomized trials. Retrospective trials, however, can have a role in selecting factors that should be evaluated further by prospective means.

1.5.2.1 Incision.

The surgeon should be aware of the direction of Langer's lines if, after abdominal section, the incision is to heal with minimal scarring. Vertical incisions across the cleavage lines of the skin produce widely gaping wounds, and although they do heal, with the passage of time there is a tendency for widening of the cicatrix. Generally speaking, there is far less spreading of the wound edges when transverse or oblique incisions are made.[262, 323]

Any abdominal incision may be followed by subsequent herniation, but some incisions seem to be more susceptible. As mentioned before, most prospective studies lack sufficient duration of follow up, and therefore may not find a difference between midline, vertical, or transverse incisions (Table I). Greenall 1980, Ellis 1984 In trials randomizing for incisions, however, significant differences with regard to incisional hernia appearance are being demonstrated, despite the short follow-up. The *lateral paramedian* incision consistently has significantly lower rates of wound failure than medial paramedian or midline incisions (Table I). Guillou 1980, Cox 1986, Brennan 1987, Kendall 1991 Furthermore, subcostal incisions perform significantly better than upper midline incisions in two trials (Table I). Blomstedt 1972, Llp 1981 Although transverse incisions perform better than midline incisions in most trials, no significant difference is found (Table I). Blomstedt 1972, Greenall 1980, Schoetz 1988, Lord 1994

In the more early literature, the lower midline incision has a higher incidence of incisional hernia compared to the upper midline incision.[95] This, however, may be due to the fact that upper midline incisions were performed more often. Most prospective studies do not show a significantly higher incisional hernia rate comparing upper, lower, and complete midline incisions (short follow up). Stol 1978, Ellis 1984, Wissing 1988 Regnard, in a prospective non-randomized study with up to five years of follow up, did find a significant difference between infraumbilical (16.6 percent) and supraumbilical (7.2 percent) midline incisions ($p < 0.001$). [336] This may be due to lacking of the posterior rectus fascia in the lower midline incision.

Thus, the surgeon should carefully consider which incision will best serve his purpose without sacrificing the future welfare of his patient. Apart from the incisional hernia rate, other considerations may be of influence:

Transverse incisions. Since the combined line of force exerted by the transversus, internal oblique, and external oblique muscles is in a lateral direction, the tendency is for the wound edges to approximate each other when a transverse incision is made.[323] In the vertical incision, a substantial lateral distracting force is exerted upon it. The force required to approximate the edges of a vertical incision is fully 30 times greater than the force required to approximate a transverse incision.[84, 388, 414] The nerve supply to the anterior abdominal muscles arises from the lower six intercostal and first lumbar nerves. When these nerves reach the lateral border of the rectus sheath, they fan out transversely beneath the rectus muscle, being distributed to its deep surface. Therefore, the transverse incision is less disruptive of the nerve supply to the musculature than are the pararectus and long subcostal

incisions.[335, 414]

Subcostal incision. Unless confined solely to the rectus muscle, partial denervation of the abdominal wall ensues with permanent muscle weakness and numbness.[55]

McBurney incision. Following the McBurney incision for appendectomy, the incidence of incisional hernias is up to 2 percent.[64, 323]

Pfannenstiel incision. The literature on the Pfannenstiel incision, a combined transverse and longitudinal incision, suggests an incisional hernia rate of 0.0 to 0.5 percent.[39, 148, 313, 315] In these series, however, essential physical examination was not performed.

Pararectus incision. This incision results in destruction of blood supply as well as innervation, and therefore is not recommended.[95, 414]

Paramedian incision. The conventional (medial) paramedian incision is performed at a distance from the midline *not greater than one-third* the width of the rectus sheath, the lateral paramedian incision at *no less than two-thirds* the width of the rectus sheath from the midline. The rectus muscle is then dissected out and retracted laterally. Both sheaths and the peritoneum are incised in the same vertical plane.

The *lateral paramedian incision* is thought to be inherently strong, due to the splintage of the wound by the rectus abdominis muscle and the wide shutter mechanism that this provides.[96, 97] Furthermore, the proximity of healthy muscle tissue probably allows faster re-establishment of blood supply to the fascia.[55] It has been advocated as the strongest incision for abdominal surgery with regard to preventing incisional hernia appearance.[55, 79, 132, 149] Opening and closure, however, is more time-consuming (about 7-9 minutes longer than for a midline incision).[149, 201] Therefore, in case of emergency, the lateral paramedian incision is impractical. Furthermore, with re-entry, a second dissection of the rectus muscle may not be possible and the rectus either has to be split or a fresh incision made in unscarred tissue.[132] Others, however, do not share this experience.[55] A longer incision is needed to achieve equivalent exposure to the midline incision,[79] and some usually transient paraesthesia medial to the incision may occur.[55]

Vertical midline incision. Of the vertical incisions, the vertical midline incision results in minimal destruction of blood supply and innervation to the abdominal wall.[4, 95, 323] If healing is perfect, no muscular weakness or skin numbness will occur. In spite of its strong limitations with regard to wound failure, the midline vertical incision is extremely useful in certain situations when wide exposure or rapid entry is needed. It can be extended from xyphoid process to the symphysis pubis.

In attempting to offset the disadvantages of wound failure of the vertical incision greater care in closure becomes necessary. Using cadaver specimens, Tera noted that sutures placed lateral to the transition between linea alba and the rectus sheath were two-fold more resistant to pull-through than a suture passed through the linea

alba only.[408] Also, the 'suture length to wound length ratio' should be at least four (see paragraph 1.5.2.4).[190]

Median large incisional hernias constitute a disinsertion of the lateral belt muscles. Thus, lateral muscles retract and atrophy, as evidenced by histologic and electromyographic disorders.[401] Boerema showed peroperatively, using a spring balance, that the force needed to pull the edges of an aponeurosis together in large incisional hernias (breadth 12 cm) was 7-10 times greater than in simple primary laparotomies of comparable size (7-10 kg vs. 1 kg). This may explain the high frequency of recurrence following median incisional hernia repair.[43]

Relation to prior incisions. Numerous separate incisions weaken the abdominal wall.[323] For instance, subcostal plus upper midline incisions weaken the abdomen at the apex.

Length of incision. Longer incisions theoretically carry a greater risk of wound failure, because a larger area must heal. Sloan in 1932 studied his results and formulated the following (outdated) rule: The lateral pull upon the suture line following a vertical abdominal incision and the incidence of postoperative hernia are in proportion to the square of the length of the incision.[388] More recently, Pollock did identify incision length as a risk factor for incisional hernia appearance (Table X).

Table X. Length of incision as a risk factor for incisional hernia appearance:

Author	year	length	No of patients	patients with hernia (%)	p
Pollock	1979	< 18 cm ≥ 18 cm	214 26	8.4 30.8	< 0.001

1.5.2.2 Fascia quality.

Healing proceeds more slowly in heavily scarred tissue, with its impaired blood supply and loss of elastic fibers.[323] Furthermore, sutures in thin layers of fascia are more likely to tear out. Therefore, tissue of questionable viability should be excised and healthy fascia must be used for suture closure.[465]

With respect to the planning of an incisional hernia repair, some authors believe a postoperative interval of at least 6 months is needed, so stronger fascia will be available for repair.[465] To this regard, no evidence was found in the literature.

1.5.2.3 Suture material.

Selection of suture material. Important criteria for selection of suture material are ease of handling, knot security, absorbability, inflammatory response, refuge for organisms, and immediate and long-term strength.

Absorbable versus nonabsorbable suture material. The selection of sutures can be based, to some extent, on sound biologic principles. When two wound edges are coapted, there is a relatively prolonged period of increased collagen synthesis as well as degradation in the wound as compared with normal tissue. This is a *dynamic process.* Degradation of collagen is of equal importance as collagen production. Because of this dynamic and rapid remodeling, there is no suture material, either absorbable or nonabsorbable, that is able to provide strength to allow the tension-closed wound to heal without widening. Looking at skin healing, every experienced plastic surgeon has encountered the wide scar, which is revised by using permanent dermal sutures, only to discover that a wide scar returns, yet the permanent suture is intact and in place. Clearly, the biologic phenomenon of wound remodeling has occurred, allowing the remodeling scar to widen around the intact permanent suture.[271] This may also apply to fascial healing (no evidence found). So, on the long run, with respect to wound strength, it most likely makes no difference whether or not a suture is still in place.

To this respect, the width of the zone of increased collagenase activity may be of importance. Large tissue bites avoid the zone of increased collagenase activity that extends up to 5 mm from the wound margin.[238] This zone may increase, however, e.g. with the presence of infection.[329]

With respect to more early healing, theoretically, an acceptable suture for abdominal wound closure must retain its strength over many months (see animal experiments paragraph 1.5.1.2). Although the exact term of human fascial wound healing is not known, wounds of the abdomen certainly do not heal within 3 to 4 weeks. In a recent review, Rath states that the abdominal wall only regains its preoperative resistance and strength at the fourth postoperative month.[329] Full maturity and strength (approximately 80 percent) of the collagen scar is more likely to be completed after one year.[106, 208] However, the rate of healing is related not only to the structure involved but also to local and general factors. Even longer holding strength may be desirable when wound healing is delayed considerably, as with wound infection or certain medication.

Since World War II several synthetic absorbable and non-absorbable sutures have been developed, and new materials are being promoted regularly. The tensile strength along time and the duration of total resorption of these materials differ considerably (Table XI).

Table XI: Tensile strength along time (%) and duration of total resorption of various sutures.

	1 wk	2 wks	3 wks	4 wks	8 wks	1 year	2 year	total resorption
Silk						≈ 0		
Catgut plain	50	10						15 days
Catgut chromic	60	25		≈ 0				90 days
Dexon (1970)	80	20-50	10	≈ 0				120 days
Vicryl (1974)	80	50	20	≈ 0				60-90 days
Monocryl	55	25						90-120 days
PDS (1980)	90	75	60	41	14			180 days
Maxon (1984)	90	75	60					180 days
Nylon (1941)							75	-
Prolene								indefinite
polyethylene								indefinite

Numerous series on suture material are available (Table I). Again, most prospective studies lack sufficient duration of follow up, and therefore may not find a difference between the various suture materials. In trials randomizing for suture materials, however, despite the short follow up, significant differences with regard to wound dehiscence and incisional hernia appearance are being demonstrated.

Rapidly absorbable suture materials. The incidence of wound dehiscence and incisional hernia of chromic catgut, which loses its tensile strength after only 10 days, is unacceptably high, [Viljanto 1966, Horton 1969, Goligher 1975, Gajentaan 1978] and silk has a significantly higher incisional hernia rate than polyglycolic acid sutures (Dexon®). [Kronborg 1976, Stol 1978] It is assumed that the tensile strength of Dexon® and polyglactin 910 sutures (Vicryl®) is sufficient to prevent wound dehiscence, but the usual event-rate for dehiscence is so low that differences in suture performance may be undetected in the relatively small number of patients in some of these studies. [Hugh 1991] In fact, although others did not confirm these findings, [Irvin 1976, Leaper 1977, Cameron 1980, Corman 1981, Richards 1983, McNeill 1986, Larsen 1989] several studies have found that the incisional hernia rate is significantly higher for these relatively rapid absorbable sutures as compared to nonabsorbable materials. [Bucknall 1981, Askew 1983, Wissing 1988, Lewis 1989]

Slowly absorbable suture materials. Polydioxanone (PDS®), is a more slowly absorbable suture material. Up till now, no significant difference compared to nonabsorbable Nylon® [Leese 1984, Israelsson 1994] or Prolene® [Krukowski 1987, Cleveland 1989] has been demonstrated.
Polyglyconate (Maxon®), which is also a more slowly absorbable suture material, performed significantly worse compared to Dexon® in one trial, [Deltel 1990] but another found no difference. [Osther 1995] No significant difference was demonstrated compared to Vicryl® [Trimbos 1992, Sahlin 1993] or Nylon®. [Gys 1989, Carlson 1995]

In conclusion, the majority of known rapidly absorbable sutures actually retains only about 10-20 percent of their original tensile strength at 3 weeks and potentially place the abdominal wound at risk for complications such as hernia formation. With regard to incisional hernia appearance, chromic catgut, Dexon®, and Vicryl® undergo dissolution rapidly and, even though of adequate strength, should not be depended upon were long-term strength is needed.[300] The issue of *delayed* absorbable sutures versus nonabsorbable sutures is not settled yet, i.e. due to short follow up evaluation of most studies addressing this subject. For instance, a recent meta-analysis report clearly favors nonabsorbable suture, but no significant difference was found in the subgroup analysis between PDS and polypropylene.[161a] Also, other authors advocate the use of nonabsorbable sutures,[50, 108, 234] like polyamide (Nylon®, Dermalon®, Ethilon®), polyester (Dacron®, Mersilene®), polypropylene (Prolene®, Surgilene®, Deklene®), polyethylene (Ethibond®, Dermalene®), polybutester (Novafil®), and steel wire. Krukowski, however, preferred the use of PDS®, because of two reported cases in which multiple 'button hole' hernias appeared at the sites of penetration of the nonabsorbable polypropylene suture, many years following closure.[219, 220] He hypothesized that the sawing effect of the suture may be responsible. This hypothesis, however, seems in contrast with the biologic phenomenon of wound remodeling.

Another disadvantage of nonabsorbable sutures is its persistence as a potential source of occasionally reported suture sinus, or suture-related wound pain.[333, 456] Theoretically, such events should not occur with absorbable sutures. However, a recent large series did not show any difference in wound sinus and pain between suture types.[181] Nylon and polypropylene, however, tend to slip, and multiple throws must be placed. This may result in a persistent palpable knot, particularly in the asthenic patient.

Another consideration to this respect is the earlier mentioned studies with radiographs of clips (see paragraph 1.5.1.5), in which early fascial separation may be responsible for subsequent late diagnosis of incisional hernia.[120, 318, 319, 322] These authors conclude that the origins of incisional hernia can be traced back to events in the first month after operation, and that they are not the result of later weakening of a well-healed laparotomy incision. If this is true, loss of tensile strength by absorbable or nonabsorbable sutures may not be of major influence to incisional hernia appearance.

Note: Fresh laparotomy wounds and incisional hernias are not comparable (see paragraph 1.5.2.1, and 1.5.3).[42, 224] The above mentioned studies on suture material have all been performed in fresh incisions. Therefore, the mentioned suture materials may or may not be suitable for hernia repair (new points of view with regard to this issue will be provided in Chapter 5).

Monofilament or multifilament. Monofilament sutures are drawn and composed of one piece, have a smooth surface with a low coefficient of friction, and in general are stiff and have a memory for the shape in which they are bent. Multifilament sutures consist of several braided fibers, the surface is less smooth, and in general are more flexible and easier to tie. The higher coefficient of friction has consequences affecting knot properties and tissue drag.[339] Some of these properties can be improved by coating. The infection rate has been found higher when using multifilament material as compared to monofilament sutures, in most series.[301, 397, 457]

Tensile strength. Tensile strength is the strength per unit area, used to describe suture material or the healing of tissue. It is a constant, derived by dividing the force necessary to break a strand of material by the cross-sectional area of the material.[339] The immediate strength of suture material varies with its nature and diameter. The long-term strength varies with absorbability. Too little is known about the exact forces that a knotted suture thread must be able to resist in the human body. Leaper studied the forces necessary to tear out sutures in human cadavers (Table XII),[230] and Boerema demonstrated peroperatively that the aponeurotic tissues of the anterior abdominal wall disrupted at pulling forces varying from 1.5 to 12 kg.[42, 43] Results, however, were variable within the same person as well as between different people.

Table XII: Forces necessary to tear out sutures in human cadavers.

Tissue	force required (kg)	p (student's t test)
anterior rectus sheath alone	2.25	< 0.001
Full-thickness	3.93	
Full-thickness :		
0.5 cm from cut edge	3.93	< 0.001
1.0 cm from cut edge	7.16	
without linea alba	4.12	< 0.001
with linea alba	7.93	

Until more is known about the exact magnitude of forces of surgical sutures in vivo, it seems advisable to ensure that a knotted surgical suture is at least as strong as the tissue it surrounds, or even stronger when absorbable sutures are used.[339]

Size. In animal experiments, large diameter sutures do less frequently cut through tissues than small diameter sutures.[341] The difference in diameter, however, has important implications for the total amount of foreign body material in the wound. A 15 cm long, 0.45 mm diameter size 1 suture and a 0.35 mm diameter size 0 suture have a suture material volume of 0.023 ml and 0.014 ml, respectively, a difference of 65 percent.[420]

1.5.2.4 Suture technique

Continuous or interrupted suturing. In measuring the abdominal wound during distention, Jenkins found that the wound may increase in length as much as 30 percent.[190, 192] Only a continuous suture can accommodate to this lengthening by having an adequate reserve suture length in the wound. Consequently, the continuous suture distributes its tension across the suture line, limiting the forces on the tissues encircled by the sutures. A further advantage is the lessening of knot slippage (fewer knots), but the repair relies on a single suture.

Running and interrupted one layer closures of laparotomy wounds and incisional hernias do not show a difference in appearance and recurrence rates in most randomized series.[69, 75, 112, 135, 179, 300, 338, 399, 457] Therefore, running closures are advised because of the shorter operating and anesthesia time, less tissue damage, even distribution of tension across the suture line, less foreign body presence, and less costs.[75, 161a, 238, 277, 336, 341, 348, 394, 399, 405, 421, 439] The continuous loop closure is not superior to the simple running technique as far as wound rupture and wound infection is concerned, but may however enhance the risk of pulmonary complications and death.[295, 296]

Mass or individual layer closure. Dudley demonstrated that the mean force per unit area at the tissue-suture interface was reduced as the radius of the suture loop was increased, thereby preventing ischemic necrosis and suture cut-out.[102] Also, in mass closure, large tissue bites avoid the zone of increased collagenase activity that extends up to 5 mm from the wound margin.[238] In experimental and cadaveric studies it has been shown conclusively that wide bites of all layers of the abdominal wall (with exception of the skin), in midline incisions was up to three times more secure than the bites of layered closure (Table XII).[160, 230, 231, 320, 370, 408] Also, many random controlled clinical trials have evaluated the use of mass closure with an acceptably low incidence of wound dehiscence and incisional hernias (Table I). Goligher 1975, Leaper 1977, Cameron 1980, Gilbert 1987, Wissing 1988, Kendall 1991

Separate suture of the peritoneum is unnecessary, and may actually cause harm by increasing adhesions to the back of the wound.[132, 199]

Suture length to wound length ratio (SL:WL ratio).[180-186, 190-192, 250] Jenkins demonstrated that abdominal wounds may lengthen up to 30 percent during postoperative abdominal distension, due to raised intraabdominal pressure, and that the tissue bite in wound closure is related to the length of the suture. Therefore, to prevent for wound failure, the SL:WL should be at least 4:1. Anything less than 2.5:1 places wounds at risk. Tissue bites and stitch intervals of both 1 or 2 cm, using a continuous suture, result in a suture length to wound length ratio of approximately four.[439] Israelsson confirmed these findings, prospectively (Table XIII). In *midline* incisions, a SL:WL ratio less than four was identified as an independent risk factor for incisional hernia appearance. The integrity of the *lateral paramedian* incision, however, proved independent of the SL:WL ratio in a prospective study comparing midline and paramedian incisions.[201]

When too large amounts of suture material are inserted, complications may occur. In midline laparotomies, a stitch length (= suture length (cm) : number of stitches, which is (approximately) the length needed for one encirclement) of 5 cm or more was associated with an increase in the rate of wound infection ($p < 0.01$).[182, 183] A high ratio, therefore, should not be achieved by suturing with a stitch length of 5 cm or more.

Table XIII: Studies on suture length to wound length ratio.

Author	year	incision	SL:WL	No of patients	patients with hernia (%)	p
Kendall	1991	lat paramedian	2.6	137	0	< 0.01
		midline, mass	5.0	104	6.7	
		midline, layered	3.7	108	6.5	
Israelsson	1993	midline	< 4	241	23.7	0.001
		midline	≥ 4	122	9.0	
Israelsson	1996	midline	< 4	72	18.0	0.05
		midline	4-4.9	114	5.3	
Israelsson	1996	midline	< 4	326	21.5	< 0.01
		midline	≥ 4	351	8.8	

1.5.2.5 Knot security.

Knot security.[339, 407, 409, 418, 419] The strength of a knotted ligature depends on the tensile strength of the thread but, to a far greater extent, on the efficiency of the knot type in relation to the kind of material used. Knot slippage is partly a function of the suture material (e.g. size of the loop, suture type, coefficient of friction, suture diameter, memory of the suture material), and partly of the technique of forming the knot (e.g. type of knot, number of throws, changing of threads, length of the cut end, presence of moisture).[339, 410, 411] Each suture material has its own smallest secure knot. Knot security can be improved by tightly tying every individual throw, and increasing the size of the suture or the number of throws on the knot.[339, 419] Thicker suture material and more throws, however, loads the tissue with extra foreign body material, which may contribute to complications, such as impaired wound healing, infection, and palpable knots.

On the whole, monofilament sutures require more throws than multifilament sutures, and square knots are more reliable than sliding knots, but knot security highly depends on the amount of throws, the suture size, and the suture material used.[339, 418, 419] The knowledge of surgeons about knot properties in respect to the suture material has been proved insufficient, however.[339, 411] Therefore, ideally, this information should be supplied with each suture.[339]

With respect to abdominal wound closure, the first knot becomes unnecessary with a double stranded loop suture, simply by putting the needle through the loop after completing the first tissue bite.

1.5.2.6 Closure technique. See techniques of repair (see paragraph 1.6).

1.5.2.7 Tension.

Tissue-tension. Tension applied to put tissues together is thought to be of major influence to wound healing[44] and appearance and recurrence of incisional hernias.[106] Tension to the suture line may postoperatively be further aggravated by rising intraabdominal pressure (see paragraph 1.5.2.4).[190] It may lead to tearing and breaking of sutures, and untying of knots. Klein measured the tissue-tension during operation by using two tensiometers.[206] Up to 1.5 kPa (both sides) he used a Mayo or approximating repair, from 1.5 up to 3.5 kPa the defect was closed and a prosthetic repair performed, and above 3.5 kPa the defect was brought together with 3.5 kPa and the remaining defect left open but covered by a prosthetic mesh. In his series, when measurements were used, the recurrence rate following Mayo repair diminished from 44 to 22 percent and following prosthetic repair from 6.8 to 2.3 percent.[206]

Suture-tension. Tightly tied strangulating sutures may easily decrease pO2 levels to values that are incompatible with physiological wound healing.[339] They enhance the risk of wound necrosis and infection and decrease the tensile strength of the healing wound. Loosely approximated knots and wounds are significantly stronger and have much less sutures pulled through the tissue.[354, 355, 400]

1.5.2.8 Wound complications.

Wound hematoma. Hematomas may be detrimental to optimal wound healing, since they bring about high tissue tension, interfere with circulation, and predispose to infection.[323] Evidence to this respect was not found, however (Table XIV).

Table XIV: Postoperative wound hematoma following abdominal closure in patients that eventually developed an incisional hernia:

Author	hematoma	no of pts	pts with hernia (%)	incision	p
Regnard 1988	no yes	1071 10	8.6 20.0	various	ns

Wound infection. Among the postoperative complications, wound infection constitutes an undebatable risk factor for wound failure. Several authors consider wound infection to be the most important factor contributing to the development of incisional hernia.[25, 41, 50, 51, 63, 107, 118, 135, 145, 146, 182, 183, 204, 219, 220, 260, 263, 320, 336, 397, 449, 457] Bacteria may produce a variety of enzymes that destroy tissues and seriously interfere with wound healing. Necrotizing enzymes cause death of tissue. Collagenases decrease the production of or actually destroy collagen. Fibrinolysins or streptokinases interfere with healing by destruction of fibrin. Hemolysins cause hemolysis of red blood cells, thereby interfering with oxygen delivering to the wound. Also, suture material may get dissolved.[323]

Infection following abdominal closure. Although infection rates and definitions differ widely among the series, several authors have identified infection as a risk factor for incisional hernia (Table XV).

Table XV: Infection as a risk factor for incisional hernia following abdominal closure.

Author	year	incision	infection %	infection	no of pts	pts with hernia (%)	p
Blomstedt	1972	various	14.0	no	240	6.3	< 0.001
				yes	39	31.1	
Stol	1978	midline	7.2	no	488	4.9	< 0.001
				yes	38	34.2	
Pollock	1979	various	27.5	no	174	5.2	< 0.001
				yes	66	25.8	
Greenall	1980	various	26.4	no	345	3.2	< 0.001
				yes	124	18.5	
Bucknall	1982	various	15.9	no	950	4.5	< 0.00001
				yes	179	22.9	
Ellis	1984	various	17.8	no	143	25.9	< 0.01
				yes	31	64.5	
Krukowski	1987	midline	5.3	no	549	7.5	< 0.001
				yes	31	29.0	
Regnard	1988	various	11.5	no	957	6.5	< 0.0001
				yes	124	25.8	
Wissing	1988	midline	8.0	no	1060	12.7	< 0.05
				yes	92	43.5	
Gislason	1995	various	12.8	no	428	5.1	< 0.001
				yes	63	20.6	
Israelsson	1996	midline	12.2	no	323	9.3	< 0.01
				yes	45	27.0	

Infection following incisional hernia repair. George found that a significantly (p=0.0004) higher proportion of patients who had a postoperative wound complication (wound infection, hematoma, or seroma) developed a recurrent hernia.[130] Van der Linden did not find a significant difference with infection (Table XVI).[244]

Table XVI: Infection as a risk factor for incisional hernia following incisional hernia repair.

Author	year	incision	infection %	infection	no of pts	pts with hernia (%)	p
vdLinden	1988	various	15.9	no yes	127 24	47.3 58.3	ns

1.5.2.9 Other operation-related risk factors.

Antibiotics. The effectiveness of prophylactic broad spectrum antibiotics is well documented, also with regard to incisional hernia repair.[175, 438a] With regard to umbilical or incisional hernia, single dose cephalosporin prophylaxis administered 30 minutes before repair significantly reduced the wound infection rate in a randomized study (Table XVII).[5] Infection is considered to be a major risk factor for incisional herniation. Prophylactic antibiotics therefore may also prevent subsequent herniation.

Table XVII. Prophylactic antibiotics as a risk factor for infection in hernia surgery:

Author	year	incision	antibiotic	no of pts	pts with infection (%)	p
Abramov	1996	various	no yes	18 17	44.4 5.9	0.02

Wound contamination (fecal or purulent spill). Contamination may induce infection and subsequent herniation.

Drains. Delivery of drains *through the incision* is thought to be an important factor in eventual hernia formation.[10, 204, 323, 382, 388] On the other hand, drainage of the subcutaneous tissues through separate stab wounds may prevent hematoma formation, which in turn may lower the incidence of incisional hernias. With mesh repairs, combined data of the literature revealed seroma formation to be 30.4 percent in the single series in which suction drainage was not used and averaged 4.7 percent when drainage was applied.[286] Also, by negative suction, dead space is being avoided. The risk of an infection associated with drains, however, may outweigh their worth,[452] although collected fluid at the incision site may also predispose to infection.[379] To prevent introduction of microorganisms drainage should presumably be short term. No randomized trials are available.

Duration of operation. Longer operation times give rise to a higher postoperative wound infection rate.[291] Also, Pollock found the duration of operation to be a risk factor for incisional hernia appearance (Table XVIII).

Table XVIII. Duration of operation as a risk factor for incisional hernia appearance:

Author	year	length	No of patients	patients with hernia (%)	p
Pollock	1979	< 60 min ≥ 60 min	128 122	4.7 16.4	< 0.01

Blood transfusion and peroperative blood loss. Excessive blood loss may induce wound ischemia by directing blood away from muscle beds to more critical regional circulations. However, not the blood transfusions themselves but rather the circumstances necessitating transfusion may be the real determinants of prognosis with regard to postoperative infection and incisional herniation (analogue to Busch).[54] Pollock and Greenall did find blood transfusion as a risk factor for incisional hernia appearance (Table XIX).[145, 146, 320] Also, in a retrospective trial, Lord found that the intraoperative blood loss of patients with subsequent hernia averaged about 700 ml more than normally healed wounds (p = 0.009). Blood loss at operation exceeding 1000 ml increased the risk of an incisional hernia by a factor of 3.07.[248]

Table XIX: Blood transfusion as a risk factor for incisional hernia appearance:

Author	year	transfusion	No of patients	patients with hernia (%)	p
Pollock	1979	no	212	9.0	< 0.02
		yes	28	25.0	
Greenall	1980	no	410	6.3	< 0.05
		yes	59	13.6	

Anesthesia. General, spinal as well as local anesthesia[91] can be used for incisional hernia repair. Postoparative straining at awakening following general anesthesia, due to the presence of the intratracheal tube, does not occur with spinal and local anesthesia.

Postoperative mobilization. Immediate postoperative rest and immobility of the patient may seem important to successful early healing. A causative relation between early mobilization and wound failure has not been demonstrated, however.[95] In addition, appropriate stress and strain on the repairing wound stimulates realignment and remodeling activities, which is essential for gain in tensile strength.[20, 226, 339] Therefore, presumably, adapted early patient activity should be stimulated. Heavy lifting should most likely be avoided, however, and some authors restrict their patients for 6 months.[465] Elastic abdominal bandages have been recommended for the first 6 weeks.[465]

Emergency operations. Emergency operations have been identified as a risk factor for wound dehiscence.[135, 293] For incisional hernia appearance, this is not a constant finding (Table XX).

Table XX: Emergency operation as a risk factor for incisional hernia appearance:

Author	year	emergency operation	No of patients	patients with hernia (%)	p
Bucknall	1981	no	172	7.6	ns
		yes	38	7.9	
Krukowski	1987	no	423	9.2	ns
		yes	157	7.0	
Pollock	1989	no	82	1.2	0.001
		yes	67	23.9	
Gislason	1995	no	345	6.1	ns
		yes	146	9.6	
Israelsson	1996	no	273	9.9	ns
		yes	95	15.8	

Surgeon's experience (resident/surgeon (US), registrar/consultant (GB)). Technical skill is related to results in all parts of surgery. In a retrospective study, Lamont found that the seniority of the surgeon did not have a significant effect on the incisional hernia rate in either fresh incisions, relaparotomies or incisional hernias.[224] Irvin and Bucknall, however, did identify the surgeon's experience as a risk factor for hernia appearance.[51, 178] Others did not confirm this finding (Table XXI).

Table XXI: Surgeon's experience as a risk factor for incisional hernia appearance:

Author	year	surgeon	No of patients	patients with hernia (%)	p
Irvin	1976	consultant	93	4.3	$p < 0.05$
		registrar	68	13.2	
Stol	1978	yes	211	5.7	ns
		no	315	7.9	
Greenall	1980	consultant	186	4.8	ns
		registrar	283	8.8	
Bucknall	1982	consultant	424	4.2	$p < 0.005$
		senior registrar	471	10.0	
		registrar	207	9.2	

Dedication. Dedication to the problem is of utmost importance. Ponka emphasizes in his book: "Uniform success demands personal discipline, exquisite technical skill, precise and experienced judgment, extensive knowledge of recorded information, thorough appreciation of anatomy, basic comprehension of applied pathophysiology, careful preoperative management, conscientious postoperative care, and meticulous evaluation of results. Near-perfection is expected in the operative correction of hernias - a worthy standard for the evaluation of the results of all surgery." [323] Russell stated that many of the complications after surgery are operator dependent,[346] and Akman warned: "Careful technique and a good understanding of the anatomic character of the abdominal wall will contribute to a lower incidence of incisional hernia. After long and fatiguing major operations, rapid and careless wound closure will greatly increase the incidence of herniation." [10]

1.5.3 Hernia-related risk factors

Previous hernia repairs. Recurrent hernias seem to have higher recurrence rates (see Table III, IV).[130, 225, 259, 263, 333, 370] In one study, the risk of developing a long term complication following prosthetic incisional hernia repair was almost 4 times greater in patients with a preoperative diagnosis of a recurrent hernia.[232] This may be due to the fact that healing proceeds more slowly in heavily scarred tissue, with its impaired blood supply and loss of elastic fibers.[323]

Previous wound dehiscence. Patients with a history of resutured wound dehiscence are known for a high rate of incisional hernia appearance. Grace found 70 (49/70) percent incisional hernias in resutured wound dehiscences. Of 7 not repaired wound dehiscences, 6 developed an incisional hernia.[144] Gislason found 43 (23/53) percent incisional hernias in closed burst abdomen patients with at least one year of follow up.[135a]

Previous laparotomies. An increased risk of incisional hernia is present when laparotomy is performed through (relatively avascular) scar tissue (Table XXII).[224] Numerous separate incisions, however, weaken the abdominal wall.[323] Therefore, in spite of the higher incisional hernia rate, a previous incision may still be the preferred route of reentry.

Table XXII: Previous laparotomies as a risk factor for incisional hernia appearance:

Author	year		No of patients	patients with hernia (%)	p
Lamont	1988	fresh incision	699	6.4	
		relaparotomy	142	12.0	$p < 0.05$ (I vs II)
		incisional hernia repair	36	44.4	$p < 0.01$ (I vs III)

Size of the hernia. Larger fascial defects may have higher recurrence rates following suture repair, due to higher tension put to the tissues (Table XXIII). However, not the size of the defect but the available amount and laxity of adjacent tissue may be responsible for the surgical outcome.[7, 22a] Muscular changes are important. The lateral abdominal muscles retract, and become fatty and fibrous after their midline insertion to each other has been divided.[449] Advanced muscle retraction with resulting decreased laxity of the hernia surrounding tissues may be more important than the actual size of the fascial defect with respect to incisional hernia recurrence.

Table XXIII: Size of the hernia as a risk factor for incisional hernia recurrence:

Author	year	size	No of patients	pts with hernia (%)	p
Manninen	1991	< 5 cm ≥ 5 cm	82 86	27.0 38.0	ns (0.06)

Number of hernias. Higher number of incisional hernias may represent a bad fascia quality, may give rise to larger peroperative defects, and therefore may have higher recurrence rates following repair.

The hernia-free interval, statistical implications. Incisional hernias develop with time (paragraph 1.4). This observation is of major interest with regard to the selected form of statistical analysis in evaluation of incisional hernia rates and their risk factors. Because incisional hernias develop with time, and patients have variable lengths of follow up in most studies, life-table methods are essential for studying hernia recurrence rates. Failure to do so may lead to underestimation of recurrence rates and therefore may result in erroneous conclusions. However, with a few exceptions, [Regnard 1988, Lewis 1989] none of the series comprised in Table I made use of life-table analysis.

1.6 Techniques of repair

Many techniques of incisional hernia repair have been developed and described. Currently used repairs can be grouped in repairs with or without implantation of prosthetic material. Prosthetic repairs can be performed by laparotomy or laparoscopy.

1.6.1 Autologous repairs

1.6.1.1 Simple suture repairs

One-layered closure. The posterior and anterior rectus sheath is approximated "edge-to-edge" with one bite of suture, creating a mass-closure (paragraph 1.5.2.4). This closure is most frequently used in midline incisions.

Two-layered closure. The posterior and anterior rectus sheaths are closed separately in incisional hernias in which these sheaths can be identified. For instance, the lateral paramedian incision is closed in two layers. This principle can also be applied to other areas where both a peritoneal-transversalis fascia layer and a second layer can be identified.

Three-layered closure. This repair can be used in the lower abdominal quadrants, where three layers for closure can be identified: the peritoneum and transversalis fascia, the transversus abdominis and internal oblique, and the aponeurosis of the external oblique.[323]

Mayo repair. This refers to the technique of transverse closure, in which the upper layer is imbricated over the lower in a "vest-over-pants" manner.[113, 114, 263, 267-269, 309, 310] This technique can also be modified to a vertical repair with imbrication (*side-to-side overlap*). In 1995, this was the technique preferred by the majority of surgeons in Germany.[308, 309]

Relieving incisions. As an adjunct to one of the above mentioned techniques "relieving incisions" can be made vertically and bilaterally in the midportion anterior sheath of the rectus abdominis. This can be done by a long vertical incision[131] or by numerous smaller incisions.[70] Also, relieving incisions in the posterior rectus sheath have been described.[49, 323] By this relaxing incisions shifting of tissues is permitted and undue tension at the suture line might be avoided.[70, 131, 222, 258, 449]

Retention sutures. Retention sutures may be added to decrease the tension to the actual suture line. For this purpose, strong sutures are used in big bites and steps through the full thickness of the abdominal wall or through the fascial layers. A variety of retention sutures has been described.[116, 129, 323, 385] Most series, however, do not demonstrate prevention of wound dehiscence, and advise not to use retention sutures.[129, 135a]

1.6.1.2 Rectus sheath techniques

Advancing adjacent healthy tissue ranging from muscles to myofascial flaps by relaxing incisions or rotation maneuvers into the defects has been advocated.[380, 381] The many methods of repair illustrate the difficulty that many surgeons have had in obtaining a satisfactory cure rate. Some of these rectus sheath techniques will be discussed:

- Chaimoff freed the anterior sheath of the rectus abdominis from the subcutaneous tissues and made a long vertical lateral cut.[66] The two fascial flaps are than raised from the muscle and imbricated in the midline. Separation may be difficult, however, since the anterior rectus sheath is adherent to the rectus muscles, mainly at the tendinous inscriptions above the umbilicus.[326]

- In the 'Türflügelplastik' the posterior rectus sheath is freed from the muscle, approximated, and sutured. Furthermore, the anterior rectus sheath is raised as described by Chaimoff, but approximated instead of imbricated in the midline ('Brennersche Methode').[49, 114]

- Abrahamson described the 'shoelace repair' involving two suture lines.[3] The first involves the use of an undermined and reflected strip of the medial edge of each anterior rectus sheath to construct a new linea alba. The second passes to and fro between the remaining cut edges of the anterior rectus sheaths, substituting for the missing sheaths and lacing up the abdomen back to its normal contours. This repair resembles the technique described by Hunter.[176]

- Soliman described the 'triple layer anchorage' technique. At one side strips were fashioned of the hernial sac with its entire coverings of collagen scar. The strips are reversed through holes made in the superficial overlapping muscular layer and fixed back to the ipsilateral side.[392]

- Da Silva described the 'da Silva method',[167, 377, 378] a peritoneal-aponeurotic transposition. 1. The sac is cut in the middle. A longitudinal incision is made in the left posterior rectus sheath 3 cm from the medial margin from the muscle. The lateral edge produced by this incision is sutured to the right-sided cut edge of the sac. 2. A longitudinal incision is made in the right anterior rectus sheath 3 cm from the medial margin of the muscle. The medial edge produced by this incision is sutured to the medial edge in the left posterior sheath by reflecting each edge towards the midline. 3. The left-sided cut edge of the sac is sutured to the lateral edge of the cut, right anterior sheath.

- **Ramirez**, in his ***'components separation method'***, showed in a cadaver and clinical study that the rectus muscle with the overlying rectus sheath and its attached internal oblique-transversus muscles can be advanced about 5 cm in the epigastrium, 10 cm at the waistline, and 3 cm in the suprapubic region.[326] This represents a bilateral advancement of 10, 20, and 6 cm, respectively. This formidable advancement is possible after the external oblique is separated from the internal oblique muscle and the

rectus muscle is separated partially from the posterior rectus sheath. The external oblique muscle can be easily separated from the underlying internal oblique in a relatively avascular plane. Also, the rectus muscle can be easily separated from the posterior rectus sheath. To the contrary, the internal oblique is adherent to the transversus abdominis muscle, and its separation is difficult and suggestive of being bloody. Also, the segmental neurovascular bundle of the rectus muscle travels in the deep surface of the internal oblique muscles between this and the transversus muscle and penetrates into the rectus muscle at a variable distance (from 10 to 25 mm) from the lateral margin close to the axis formed by the deep superior and inferior arteries. In 1996, DiBello reported three recurrences out of 35 large recurrent ventral hernia repairs (8.6 percent), only using the above mentioned separation technique of the external oblique muscle.[94] In 2000, Shestak reported one recurrence of 22 massive midline abdominal wall defects using 'components separation'.[374a]

- Girotto stated that the ideal abdominal wall reconstruction must (1) prevent visceral eventration, (2) provide tension-free repair, and (3) provide dynamic muscle support.[134] Primary repair is far from tension-free, and mesh repair provides no dynamic contractile support. He therefore utilized ***Ramirez's technique in progressive steps*** depending on the extent of the defect. Step 1: elevating skin and subcutaneous tissue, Step 2: unilateral incision and separation of external oblique, Step 3: also contralateral external oblique, Step 4: separation of posterior rectus sheath. If mobilization was still insufficient, free tissue transfer or mesh repair was performed. He reported two recurrences out of 37 repairs (5.4 percent).

- Thomas utilized bilateral relaxing incisions in the external oblique and/or the transversus abdominis fascia with favorable results in 7 patients.[412] ***Ramirez*** did not agree on this modification of his technique. He pointed out that large defects require separation instead of incision of the external oblique fascia, and that partition of the transversus abdominis fascia entails unnecessary entering into the abdominal cavity.[327]

- Jacobsen utilized expanders for massive abdominal hernias (> 20 cm), placed in the lateral abdominal wall between the external oblique and the deeper complex of the internal oblique and transversalis fasciae.[188] Expansion was started after three weeks, and completed over 4 to 8 weeks. Than the expanders were deflated and suture hernia repair could be performed.

- Schmitz used an external fixator to stretch the abdominal wall over a period of three weeks, during which the fascial defect was markedly reduced.[364]

- Dioguardi ('cross-over flap') and later Sensoz ('overlap flap') described a technique with use of a dermal-fat flap, in which a deepithelialized lower flap is pulled up and sutured to the level of the costal margin and xyphoid. The upper flap is pulled down and sutured to the inguinal region. As a result, two cutis flaps are overlapped on each other over a sutured hernia repair.[93, 372]

- Bang described an abdominoplasty through a bikini crease incision.[26] After wide dissection in the supra-aponeurotic plane to the xyphoid and costal margins, the hernia was repaired using the lax surrounding tissues made available by the wide dissection.

- Lucas described a bilateral advancement technique for giant abdominal wall defects.[251] By freeing the skin and subcutaneous tissues up to the mid-axillary line and incising the external oblique fascia and muscle in the anterior axillary line he managed to close defects that previously measured 20 cm in width.

- Kuzbari in his 'sliding door technique' completely released the rectus abdominis muscles from the anterior and posterior rectus sheaths through an incision at their medial border. The released muscles are overlapped and sutured together. Also, the aponeurosis of the external oblique muscles is incised, and the released anterior rectus sheath is sutured.[222] Denervation with subsequent atrophy of the muscle may be expected, however.

1.6.1.3 Other autologous repairs

Cutis techniques. The use of skin with or without epidermal covering for incisional hernia repair was first described by Loewe in 1913. This skin is normally taken from the site of the redundant herniation sac. Nowadays, 'autodermal hernioplasty' is used infrequently, but reports do get published up to recently.[117, 217, 261, 292, 337, 360, 368, 450] Strips with[261] or without[217, 292] epidermal covering and larger segments of deepethelialized cutis are used as free transplants to reinforce a suture repair. Strips are used like a shoelace suture with full thickness fascia bites. Larger segments are positioned either ventral or dorsal to the repair, like a prosthetic repair.[217] Sinus formation, epidermoid cyst formation, and even carcinomatous degeneration have been described.[140]

Pedicled and free flaps. Difficult, large and complicated abdominal wall defects may request the use of pedicled or free flaps. For instance, for reconstruction of abdominal wall loss, the first procedure may be a mesh repair, followed by a full-thickness flap coverage after two weeks.[229, 398, 438] Or, for instance, a pedicled tensor fasciae latae flap can been used as a salvage procedure for infected mesh.[90] These techniques, however, imply extensive operations, leave one with functional deficits at the donor site and do not always produce a strong abdominal wall.[326, 380, 381] A transferred free muscle flap is usually denervated and will eventually become atrophic.[134, 326] Also, these procedures must be weighed against the results and the desirable features of prosthetic materials, like easy availability and reasonable costs. Some defects, however, are not amenable to primary repair or the use of synthetic mesh because of repeated recurrence or wound infection.

Various flaps have been designed, e.g. the pedicled myocutaneous extended latissimus dorsi flap,[171] the pedicled fasciomyocutaneous tensor fasciae latae flap,[90, 288, 446] and the myocutaneous rectus femoris flap.[272] A detailed description is beyond the scope of this thesis.

Pneumoperitoneum. This approach is particularly indicated in cases of very large ventral hernia in which the abdominal wall has become accustomed to a small intraabdominal volume, the so-called 'loss of right of domain'. Repositioning of the herniated viscera leads to an increase of intraabdominal pressure which impedes normal diaphragmatic action and decreases the venous return to the heart (which may have a deleterious effect on cardiac output),[314] the so called 'abdominal compartment syndrome'.[449] To cope with this problem, progressive preoperative or peroperative[455] pneumoperitoneum has been advocated.[31, 56, 72, 252, 284, 330, 331, 401, 403, 449] A detailed description is beyond the scope of this thesis.

Abdominal parietoscopy. The principle of parietoscopy is the creation of a subcutaneous plane of cleavage ventral to the aponeurosis by insufflation of CO_2 by suprapubic or umbilical access. Defects are repaired by standard endoparietal sutures or by percutaneous sutures using a Reverdin needle. The aim is repair of an abdominal wall defect without damaging the overlying skin, mainly for cosmetic reasons, especially in young woman. Obviously, with incisional hernia, this cosmetic reason is well-founded only with an almost invisible cutaneous scar.[67]

Electrostimulation. In an animal experiment, electrostimulation of healing incisional hernia repairs by low frequency, bipolar, symmetrical rectangular pulses accelerated the proliferation of connective tissue and scar healing as compared to the control group.[121] Pekarsky used an 'implantable electrical stimulator-alloprosthesis' in 28 patients with incisional hernias.[311] After two weeks the electrostimulator was removed under local anesthesia. Improved tissue growth and microcirculation in the suture area were claimed.

1.6.2 Prosthetic repairs

1.6.2.1 Materials

The use of synthetic mesh to reinforce a weakened abdominal wall or to repair especially large hernias has been a fairly recent development, mainly starting after World War II. Bursting pressure studies in animals with and without implants demonstrated the effectiveness of prosthetic materials in providing additional support to the operative area.[323] Prosthesis were developed to add strength and to avoid the excessive tension created when large defects are bridged together by approximating the patient's own tissues. Currently, several especially synthetic meshes are used (Table XXIV). They differ in strength, durability, absorbability, transparency, incorporation, tissue tolerance, porosity, flexibility, ease of handling, and tolerance in the presence of infection.

Table XXIV: Some of the most common employed synthetic meshes.

Meshes
Absorbable: Polyglactin 910 (Vicryl® mesh) Polyglycolic acid (Dexon® mesh) Non-absorbable: Polypropylene (Marlex® mesh, Prolene® mesh, Surgipro®, Trelex®, VYPRO®) Expanded polytetrafluoroethylene (ePTFE) sheet (GORE-TEX®, DualMesh®) Polyester (Dacron®, Mersilene®, Ticron®, Parietex®)

Polypropylene mesh. Polypropylene, a nonabsorbable monofilamentic mesh, is an effective material for hernia repair. It has been used liberally for four decades. It shows a mild reactivity, seems non-carcinogenic, and it retains its strength for indefinite periods of time. It is pliable, and gets well incorporated into adjacent tissues by connective tissue ingrow into the mesh's interstices. Experimental studies have shown that the mesh is well incorporated into the abdominal wall within 2 weeks of implantation.[286] Furthermore, it has a low infection potentiating ability and therefore performs well in the presence of infection. Incision and drainage of developed abscesses plus antibiotic therapy resulted in eventual healing in most series.[19, 187, 239, 242, 276, 363, 367, 424, 426, 427, 430, 445] Its propensity for inducing extensive visceral adhesions with occasional resulting ileus or intestinal fistulation, however, makes it unsuitable for direct contact with intestines.[89, 200, 232, 257, 299, 307, 367, 367a, 369, 398, 438] When a bowel fistula occurs, the mesh will have to be (partially) removed.[369, 380, 381] Since polypropylene meshes are difficult to remove when reoperations have to be performed, this caries a risk of (additional) iatrogenic bowel perforation.[37] Reoperation other than for mesh removal, however, can be performed easily by cutting through the mesh and the wound can be closed by suturing the mesh again.[229]

Another possible disadvantage of polypropylene mesh is that it might shrink, buckle, and curl as a consequence of physiological wound contracture.[210, 286, 367a, 449] Up to 40 percent shrinkage has been reported.[19, 367] This finding may have a role in the occurrence of complications, like erosion into the viscera and hernia recurrence, and may have consequences for the amount of overlap that should be used.

Occasionally, multilocular cystic masses at the site of a Prolene mesh reinforcement over a primary autogenous repair have been described. These masses did not respond to aspiration and needed surgical excision.[115]

Besides others, Marlex, Prolene, Atrium, and Surgipro brand of polypropylene mesh are used. Marlex is woven from single strands, Prolene from double strands, and Surgipro from multiple filaments of polypropylene.[286, 367a] Atrium (monofilament) has a 30 percent greater pore size (0.8 mm) then Marlex.[367] Marlex has a tighter knit than Prolene mesh,[89, 297] with Prolene being more pliable.[137, 404] Atrium is thinner, less rigid,

and the most pliable, with comparable strength.[137] Polypropylene meshes are currently the most widely used synthetic prosthesis.[137, 286]

Recently, a new lightweight macroporous (5 mm) vicryl-prolene composite mesh has been developed (VYPRO mesh, Ethicon).[207, 209, 212, 213, 367] The Vicryl is fully absorbed in about 56-70 days, leaving the permanent polypropylene mesh. This mesh is said to induce orderly ingrowth of a collagen-fiber network, thereby preventing for stiff and non-elastic scar plates that might result in loss of active and passive elasticity of the abdominal wall and foreign body feeling.[345, 367] Also, the inflammatory response may be reduced.[211] Further results have to be awaited.

Expanded polytetrafluoroethylene. Expanded PTFE is a microporous, flexible, woven biomaterial. The first clinical studies date from 1985.[153] With an ePTFE sheet there is absence of ingrowth of fibrocollagenous tissue into the patch and therefore direct contact with intestines does not result in extensive visceral adhesions. Occasionally, adhesion formation to the line of sutures with subsequent mechanical intestinal obstruction has been described, however.[34] The absence of ingrowth also results in insufficient anchorage of the patch to the adjacent fascia, resulting in herniations at the patch-fascia interface.[40] Also, the sheet is unsuitable for use in a contaminated or postoperatively infected environment. It then is extruded or falls apart in layers and has to be removed.[40, 91, 202, 380, 381] Furthermore, the costs of ePTFE are high, compared to polypropylene.

Recently, modifications to the ePTFE mesh have become available. The GORE-TEX DualMesh Biomaterial is promoted to have an adhesion-barrier surface on one side (pore size 3 micron) and a tissue-ingrowth-promoting surface on the other side (pore size 17 micron).[80, 390, 416] Long term results have to be awaited.

Polyester. Polyester fiber meshes are soft flexible prosthesis woven from braided polyester. Dacron consists of monofilaments, Mersilene of polyfilamented strands of polyethylene terephthalate. Parietex is made of multifilamented strands coated with purified type I collagen.[35] Adler found polyester to be an effective prosthetic material.[6] Only in France they are used in preference to other materials.[286] Leber reported a high incidence of enterocutaneous fistula with Mersilene (15.6 percent).[232]

Simmermacher, in his thesis, summarized that non-absorbable prosthetic materials like polyamide (Nylon®, Supramide®), polyester (Dacron®, Mersilene®, Ticron®), and polytetrafluoroethylene (Teflon®) proved to be unsatisfactory, due to an acute or chronic inflammatory reaction.[380, 381] In a recent extensive review of the animal and clinical studies, Morris-Stiff concluded that there is no clear evidence from the literature that supports a preference for the clinical use of one of the three main materials (polypropylene, polyester, ePTFE).[286] Leber, however, found in a retrospective study comparing Marlex, Prolene, ePTFE, and polyester (Mersilene®) that polyester mesh had a significantly higher mean number of complications per patient, a higher incidence of fistula formation, a greater number of infections, and more recurrent hernias than the other materials. The technique of placement had no

influence on the outcome. He concluded that polyester mesh should no longer be used for incisional hernia repair.[232] Wantz and Stoppa, who both performed hundreds of incisional hernia repairs with polyester, did not agree on this conclusion.[402, 448]

The ability of a mesh to minimize infection is due to the size of the pore or interstices.[137] The key number is 10 microns. Most bacteria are one micron and most macrophages and neutrophilic granulocytes are larger than 10 microns. Multifilament meshes (i.e. polyester (Mersilene), PTFE (Teflon), ePTFE, and polypropylene (Surgipro)) have interstices less than 10 microns. Bacteria can establish a nidus protected from macrophage elimination by the size of the space.[137]

In a recent pathological study, explanted meshes were studied after long term human implantation. A persisting inflammatory proliferative foreign body reaction with increased turnover in the recipient tissues was found in all meshes, but especially with polypropylene. Within the polypropylene group Atrium caused the least reaction. Mersilene and Goretex were relatively inert, but, respectively, degradation and lack of tissue integration were found.[213a]

Most surgeons have abandoned the use of absorbable prostheses in the repair of clean abdominal wall defects because the reherniation rate is reported up to 75 percent.[86, 305] This may be due to the fact that the prosthesis hampers the formation of properly orientated collagenous fibers by neutralizing the forces of the abdominal wall musculature, which are needed for the formation of collagenous fibers that are strong enough.[380, 381]

Experimental meshes.[14-19, 71, 193, 380, 381] Theoretically, the ideal prosthesis should be a functionally double layer prosthesis: macroporous and hydrophilic on the dermal side (firm adhesion formation), microporous and hydrophobic on the visceral side (no adhesion formation).[380, 381] Bendavid sutured a sheet of ePTFE and an on all sides one centimeter shorter sheet of polypropylene together, and used this composite mesh in an intraperitoneal position (n=30). No intestinal occlusion or fistula were found with follow up from 1-36 months.[37] Recently (1998), the Composix® mesh has become available, with one layer of ePTFE (visceral side) and two layers of polypropylene (dermal side).[352] Also, carbon fiber implants have been developed.[1, 147, 358] Long term results of these and other meshes have to be awaited.

1.6.2.2 Techniques of repair

Anatomic options for prosthetic hernia repairs. Various positions for mesh have been described with regard to repair of abdominal wall defects. Definitions in the literature sometimes are conflicting, inaccurate, and confusing. Usher was the first to describe the 'onlay' repair as being a mesh placed subcutaneously and external to the musculoaponeurotic layers.[426] Nowadays, various (onlay) repairs can be distinguished and they therefore need further specification. In this thesis, the fat printed terms are preferred. From inside to outside (with synonyms used in the literature) these are:

Intraabdominal placement	:	- in contact with intraabdominal contents
Intraperitoneal onlay	:	- dorsal to the peritoneum
Intraperitoneal inlay	:	- attached to the margins of the aponeurotic defect (patching, no overlap), peritoneum not closed.
Preperitoneal placement	:	- no contact with intraabdominal contents
Peritoneal onlay	:	- ***retromuscular, retrofascial, but preperitoneal*** - also termed: retrorectus (inaccurate)
Preperitoneal inlay	:	- attached to the margins of the aponeurotic defect (patching, no overlap), peritoneum closed.
Retromuscular prefascial	:	- ventral to the closed posterior rectus sheath - also termed: sublay (confusing) - also termed: underlay (inaccurate) - also termed: subaponeurotic placement - also termed: intraparietal placement
Premuscular prefascial	:	- reinforcement over a primary autogenous repair, mesh on top of the anterior rectus fascia - also termed: (supra) fascial onlay - also termed: subcutaneous placement

Combinations :

Fascial onlay/peritoneal onlay sandwich	: preperitoneal (sandwich = two layers)
Intraperitoneal/peritoneal onlay sandwich	: in contact with intraabdominal contents
Full-thickness replacement	: in contact with intraabdominal contents

Intraabdominal placement. Usher 1958, 1959, Jacobs 1965, McCarthy 1981, McDonalds 1984, Gillion 1997, Oussoultzoglou 1999 The prosthetic material is implanted deeply within the abdominal wall and deep to the peritoneum. After placement and suturing of the mesh, it is optional to bring the edges of the defect together over the mesh, with or without relieving incisions.[270, 447] Closed suction drainage also is optional, but seems desirable. Implants often get complicated by seroma formation.[95, 237, 449] Continuous negative suction to the operative site serves drainage of blood and plasma, but, more importantly, brings tissues and mesh together, which might facilitate wound healing. Some authors do not bother to protect the intestines or other intraabdominal organs from contact with the mesh.

Especially with polypropylene mesh, however, visceral adhesions, ileus, and intestinal fistulation have been described (paragraph 1.6.2.1). Therefore, the omentum, when available, can be positioned between the mesh and the other intraabdominal organs.[65] Adhesions now are permitted to form to the omentum, thereby preventing the often very firm adhesions that may form between the mesh and the intestines. So, feared for intestinal fistula might be prevented. Furthermore, should relaparotomy be performed for any reason, re-entry will be with less difficulty.

In rats, comparing various meshes, Vicryl mesh provided the best long-term protection to adhesions.[193] Therefore, when contact with viscera cannot be prohibited, interposition of Vicryl mesh may be of interest.[27, 83, 447] Intestinal fistulization has been described in rats and humans, however.[391]

Preperitoneal placement. Stoppa 1989, 1999, Wantz 1991, McLanahan 1997 The mesh is implanted deeply within the abdominal wall but superficial to the peritoneum, preferably with a large overlap of the mesh at the backside of the fascia. The aim is face-to-face adhesion of the prosthesis to the parietal layer, not edge-to-edge patching.[401]

When a 'giant prosthetic reinforcement of the visceral sac' with overlap of 8-10 cm is performed, this repair is also called the 'Stoppa procedure' or is attributed to Rives or both ('Stoppa-Rives method').[340, 401, 403, 447] Historically, however, for accuracy, Stoppa described the large retrofascial and preperitoneal placement (1973) and Rives the large retromuscular prefascial placement (1973).[403] The placement in this method is described 'preperitoneal' or 'retromuscular prefascial' with different locations (e.g. beneath or above the linea arcuata of Douglas, McBurney incisional hernia), at the level of the ribs the placement is intraabdominal.[447, 449]

Young described the 'starburst' mesh closure technique in which the mesh is fashioned with spokes 2 x 10 cm radiating from the central area. The spokes are brought through the fascia at approximately 7.5 cm from the edge. The central area is sutured to the edge of the defect. The spokes are sutured to the fascia at their exit points and then are again secured toward the center of the mesh.[463] Leber used a similar 'finger interdigitation technique' in which the mesh is cut in a starburst pattern and finger projections are brought through both layers of fascia and then sutured to the anterior rectus fascia.[232]

Matapurkar described the 'Marlex-peritoneal sandwich technique', in which the marlex mesh is sandwiched between two layers of peritoneum of the overstretched hernial sac (= variation of preperitoneal inlay).[406] The peritoneum preserves stem cells with pluripotent capacity. Recently, his group published the results of grafted peritoneum to a fascial defect in dogs.[265] This study suggests that a fully developed tissue, (pluripotent) peritoneum, is able to transform into another fully developed tissue, aponeurosis, a process known as metaplasia. In his hernia repair technique in humans, the hernial sac is incised in the middle, so the fascial defect can be bridged by two layers of peritoneal membrane. In their view, these layers need a 3-month period to regenerate into a tough aponeurosis. Therefore, (sandwiched) Marlex is used to assure the initial support.

Retromuscular prefascial placement. Rives 1985, Temudom 1996, Horeyseck 1997, Trupka 1998, Sakorafas 1998, Schumpelick 1996, 1999 The mesh lies beneath the belly of the rectus abdominis muscle and in front of the posterior rectus sheath, [340, 447] and can be extended if necessary in the plane beneath external and internal oblique muscles.[352] The space behind the rectus muscle is easily cleaved by blunt dissection to a point past where the intercostal nerves and vessel pierce the rectus muscle. In this position the mesh cannot become adherent to the intestines when the posterior sheath is closed,[423] and it is well incorporated into the abdominal wall at this depth.[323, 402] The anterior sheath of the rectus is closed.[423, 447]

Slim described a method in which the anterior rectus sheath of one side is incised laterally and retracted medially. The separation is continued around the medial edge and at the posterior surface of the muscle. The opposite posterior aponeurosis is then incised laterally and separated from the muscle. The overlapping anterior aponeurosis is now sutured to the lateral edge of the opposite posterior aponeurosis. The mesh is placed on top of this, under the muscles. Finally, the overlapping posterior aponeurosis is sutured to the lateral edge of the opposite anterior aponeurosis.[387]

Premuscular prefascial placement. Usher 1958, 1959, Larson 1978, Lewis 1984, Wagman 1985, Chevrel 1997, Balen 1998, Whiteley 1998 The mesh is positioned in the subcutaneous space, external to the musculoaponeurotic layers. Chevrel in addition fixes the polypropylene mesh to the abdominal wall by a spray of fibrin glue.[68, 449] Again, closing of the defect with[453] or without rectus fascia flaps, relieving incisions,[87] drainage, and antibiotics are optional.

Imbricating. Usher 1970, Rublo 1986 Usher devised a number of methods for implantation of Marlex mesh. He for example sutured two 5 cm strips of Marlex mesh as a cuff (anterior and posterior) over the opposing edges of the hernial ring. Then full thickness imbricating sutures were placed through the mesh, creating an overlap of the 'marlex-coated cuffs'. A second row of sutures was placed to complete the overlap. Usher reported to close large defects using this technique, even though under considerable tension. The imbricating sutures did not cut through.

Double layer. Two layers of mesh are used, one intraperitoneal and one fascial onlay. No approximation of tissues is performed. Usher 1960, Jacobs 1965

'Internal binder'. Lichtenstein proposed using Marlex as an internal binder, which is drawing tails of Marlex through the abdominal wall. Lichtenstein 1976

Laparoscopic incisional hernia repair. See paragraph 1.6.2.3 .

Suturing. Suturing can be performed interrupted, continuous or with staples. Articulating staplers allow the mesh to be stapled quickly and easily to the abdominal wall.[13, 266, 303] Flament reported, however, that he had to remove staples because of pain as a result of entrapped nerves.[449]

Fixation of the mesh may not always be necessary, however. In an experimental study, with preperitoneal placement, the authors found that mesh fixation was not mandatory. With respect to clinical practice, however, they concluded that fixation may still be necessary, but can be reduced to a minimum.[464]

In general, implantation of the prosthesis to the depths of the repair seems desirable. Tenderness may be somewhat greater when the implant is placed in the premuscular prefascial position,[323] and occasionally, erosion through the skin is described.[273] Also, an increased incidence of seroma formation has been reported,[452] although in a recent review the plane of placement of the mesh did not appear to affect the incidence of seroma formation.[286] Furthermore, when the mesh is inserted superficially the repair may become vulnerable to the increased intraabdominal pressure because of lack of external support and may therefore be associated with a higher incidence of recurrence.[14, 286, 401] Also, recently, two patients with mature fibrous cyst formation were described.[444] Others, however, show favorable results.[68, 228, 237, 426, 427, 443, 453] The issue of the best anatomic mesh position is not settled, yet, and most likely will vary with the mesh material and extent of the defect.

1.6.2.3 Results of prosthetic repair

Prosthetic repairs on the whole have better results than suture techniques, mostly less than 10 percent, but recurrence rates up to 34 percent have been reported.[232] The following Tables show some results of the literature on polypropylene, ePTFE, and polyester mesh repairs (Table XXV a, b, c, respectively). None of these studies are randomized.

Table XXVa: Results of incisional hernia repair with polypropylene mesh.

Author	year	no of pts	follow-up	recurr rate (%)	location	technique
Usher	1959	44	1-14 m	0	various	subcutaneous
		15	1-11 m	0	various	intraperitoneal
Usher	1961	10	4-8 m	0	various	double layer
Usher	1962	156	≥ 1 yr	10.3	various	subcutaneous, intraperit.
Usher	1970	48	6-36 m	0	various, large	imbricating
Drainer	1972	37	≥ 2 yr	0	various	subcutaneous, various
Lichtenstein	1976	39	-	0	various	internal binder
Larson	1978	9	± 3.5 yr	0	various	subcutaneous
		20	± 3.5 yr	20.0	various	preperitoneal
		24	± 3.5 yr	8.3	various	intraperitoneal
Deitel	1979	36	3.5 yr	0	various	subcutaneous, relieving inc
Ponka	1980	219	± 1 yr	3.2	various	various
McCarthy	1981	25	2.3 yr	8.0	various	intraperitoneal, fascia closed
Lewis	1984	50	2.6 yr	6.0	various, large	subcutaneous
McDonald	1984	50	-	6.0	various	intraperitoneal, fascia closed
Kjeldsen	1986	24	29 m	8.3	various, large	preperitoneal
Rubio	1986	11	-	0	various, large	imbricating mesh
Read	1989	37	1-8 yr	27.0	various, large	subcut. or intraperit.
Molloy	1991	50	45 m	8.0	various, large	subcutaneous
Matapurkar	1991	60	3-7 yr	0	various, large	preperitoneal 'sandwich'
Goonetilleke	1992	30	14 m	3.3	various, large	intraperitoneal inlay
Young	1994	7	6-48 m	0	various, large	preperitoneal 'starburst'
Liakakos	1994	49	7.6 yr	8.2	various, recurr.	intra or preperitoneal
Sugerman	1996	98	20 m	4.1	upper midline	subcutaneous
Schumpelick	1996	58	-	6.9	various	subaponeurotic
Temudom	1996	50	24 m	0	various	prefasc retromusc, Stoppa
Ohm	1997	37	17 m	8.1	various	subaponeurotic
McLanahan	1997	86	24 m	3.5	midline	subaponeurotic
Vestweber	1997	31	32 m	6.5	various, recurr.	subcutaneous
Chevrel	1997	133		9.0	various	subcutaneous
		103		1.0	various	subcutaneous + fibrin glue
Turkcapar	1998	45	36 m	2.2	midline	subcutaneous
Leber	1998	119	6.7 yr	13.9	various	various
Trupka	1998	33	9 m	0	various	subaponeurotic
Whiteley	1998	10	17 m	0	various	fascia flap + subcutaneous
Schumpelick	1999	81	22 m	4.9	various, > 4 cm	Marlex, subaponeurotic
		33	6 m	3.0	various, > 4 cm	Atrium, subaponeurotic
		32	4 m	0	various, > 4 cm	Vypro, subaponeurotic
Anthony	2000	29	45 m	29.0	midline	inlay

Table XXVb: Results of incisional hernia repair with ePTFE mesh.

Author	year	no of pts	follow-up	recurr rate (%)	location	technique
Bauer	1987	28	22.5 m	10.7	various	intraperitoneal inlay
van der Lei	1989	10	31.5 m	20.0	abd wall defects	intraperitoneal inlay
Monaghan	1991	12	15.5 m	8.3	various	intra- or pre-perit.
Deysine	1992	47	24 m	6.4	various	intra- or pre-perit.
Rubio	1994	18	-	0	various, large	intra + inlay (2L)
		60	37 m	6.7	various	intraperitoneal
Koller	1996	48	22 m	14.3*	various	intraperitoneal inlay
Koller	1997	26	26 m	13.1*	midline	intraperitoneal inlay
Gillion	1997	98	37 m	2.0	various	preperitoneal/sublay
Bellon	1997	38	48 m	7.9	various	various
Trupka	1997	26	-	19.2	various	subaponeurotic
Balen	1998	43	39 m	2.3	various	subcutaneous
Bauer	1999	98	6.2 yr	19.4	various	various
Gonzalez	1999	84	1-3 yr	2.4	various	intraperitoneal

*Kaplan-Meier estimate (24 m).

Table XXVc: Results of incisional hernia repair with polyester mesh.

Author	year	no of pts	follow up	recurr rate (%)	location	technique
Rives	1985	226	-	3.2	various	prefasc retromusc, Stoppa
Adloff	1987	130	11.6 m	4.5	various	intraperitoneal
Wantz	1991	30	-	0	various	prefasc retromusc, Stoppa
Becouarn	1996	160	3 yr	4.3	various	intraperitoneal
Mathonnet	1998	99	-	4.0	various	prefasc retromusc / preperit
		73	-	5.6	various	intraperitoneal
Leber	1998	32	6.7 yr	34.4	various	various
Stoppa	1998	751	2-12 yr	5.9	various	prefasc retromusc, Stoppa
Wantz	1999	206	-	1.5	various	prefasc retromusc, Stoppa
Flament[449]	1999	517	-	5.6	various	prefasc retromusc, Stoppa
Verhaeghe[449]	1999	816	-	5.9	various	prefasc retromusc, Stoppa
Arnaud	1999	250	8.1 yr	3.2	various	intraperitoneal

Complications. Combined data of the English literature (49 reports)[286] revealed seroma formation to be the most commonly reported complication, which was noted in 5.5 percent of both polypropylene (n=1281) and ePTFE (n=181) repairs but in only 0.8 percent with polyester (n=664). It was 30.4 percent in the single series in which suction drainage was not used and averaged 4.7 percent when drainage was applied. The plane of placement of the mesh did not appear to affect the incidence of seroma formation. Infection was the second most common complication. The overall incidence was 4.7 percent for polypropylene, 7.2 percent for ePTFE, and 8.3 percent for polyester, but a marked interseries difference from 0 to 29 percent was found. The incidence of sinus formation for all three materials was approximately 1.5 percent and enterocutaneous fistulation 0.3 percent. The authors conclude that on the basis of the current data cost probably should be the deciding factor.

Schumpelick, using ultrasonography, found a seroma rate of 100 percent.[449] These seromas mostly were not clinically apparent. Seromas over 10 ml were found in 35% with Marlex, 22% with Atrium, and 19% with Vypro, the difference with Marlex being significant ($p<0.05$).[367]

The incidence of enterocutaneous fistula is likely underestimated, because there are few long-term studies. The average time for fistulae to develop was 3.3 years in Leber's study (incidence 7/200, 3.5 percent).[232] Although not statistically significant, the excision of the hernial sac, lack of omental interposition, and the presence of a fascial gap all had a higher incidence of enterocutaneous fistula formation in his study.

Laparoscopic incisional hernia repair. In 1991, Popp reported the first incisional hernia repaired laparoscopically.[324] Several personal series have now been reported (Table XXVI), with various materials and results. Recently, Carbajo randomly assigned 60 patients with major eventrations, incisional hernias, or primary ventral hernias to either open or laparoscopic mesh repair.[60] Apart from the diversity of ventral hernias included, also different kinds of meshes and different fixation techniques (suture, endostapler) were used in both groups, and no survival analysis was performed. The authors report shorter operation time and hospital stay with the laparoscopic technique. Two recurrences were noted with the open technique compared to none with the laparoscopic technique (mean follow up 27 months). In a retrospective review, Ramshaw found 20.7 (36/174) percent recurrences in various open repairs and 2.5 (2/79) percent recurrences in ePTFE laparoscopic repair of ventral hernias (mean follow up 21 months).[328]

Theoretical benefits are less tissue trauma, reduced rates of seroma and infection because the skin and fascia directly overlying the prosthesis are not incised and dissected, a possibly better visual peroperative detection of (multiple) fascial defects, less postoperative pain and immobilization, a decreased hospital stay, quicker return to normal activities, decreased costs, and improved patient comfort.[60, 165, 233, 307, 328, 350, 351, 416] Operative time may or may not be longer.[60, 142, 328] Randomized trials, designed and analyzed conform CONSORT guidelines,[33] ensuring accurate and complete reporting, are needed.

Table XXVI: Results of laparoscopic incisional hernia repair.

Author	year	no of pts	follow up	recurr rate (%)	technique
Popp	1991	1			
LeBlanc	1993	5	2 m	0	ePTFE
Saiz	1996	10	10-17 m	0	Marlex
Barlehner	1996	53	8 m	7.5	polypropylene
Holzman	1997	21	20 m	9.5	Marlex, telephone interview
Park	1998	45	24 m	13.3	various, telephone interview
Franklin	1998	112	2.8 yr	1.8	Surgipro
Toy	1998	144	7 m	5.6	ePTFE
Costanza	1998	16	18 m	6.3	ePTFE
Sanders	1999	11	13 m	9.1	ePTFE

1.7 Study Objectives

The studies described in this thesis have been undertaken to determine the most effective way to repair and prevent incisional herniation and recurrence. To do so, at first the results of two widely used techniques of repair were studied in a retrospective fashion. The clinical results of the vertical "vest-over-pants" Mayo repair (Chapter 2) and the approximating "edge-to-edge" repair (Chapter 3) were evaluated, and the risk factors for incisional hernia recurrence were studied. Furthermore, the incisional hernia preventing properties of the "Pfannenstiel incision " was studied (Chapter 4). Subsequently, as a result of these studies, a prospective randomized multicenter trial was conducted, comparing suture closure with open prosthetic incisional hernia repair (Chapter 5). Then, combining our results and the literature, an effort was made to define the 'state of the art' incisional hernia repair (Chapter 6)

CHAPTER 2

Incisional Hernia Recurrence Following "Vest-Over-Pants" or Vertical Mayo Repair of Primary Hernias of the Midline

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2.1 Abstract

A series of 68 primary midline incisional hernias with a vertical Mayo repair was evaluated retrospectively. Patients without documented hernia recurrence following this repair were invited for physical examination. Life-table methods were used for statistical analysis. The 1-, 3-, 5- and 10-year cumulative recurrence rates were 35, 46, 48, and 54 percent, respectively. Also, generally accepted risk factors were studied. Multivariate analysis identified the size of the hernia ($p=0.02$) and the use of steroids ($p=0.04$) as the most important independent risk factors of first time recurrent incisional hernia. Considering the high recurrence rates found, the results of this study do strongly suggest that the vest-over-pants repair should no longer be used for closure of midline incisional hernias.

2.2 Introduction

Incisional hernias appear in at least 10 percent of patients with midline laparotomies.[55] Patients with an incisional hernia often complain of the aesthetic appearance or suffer from discomfort, pain or intestinal obstruction.[287] A variety of operative procedures for incisional hernia repair have been in use, but the results are often disappointing. Five-year cumulative recurrence rates as high as 41 percent have been reported.[157]

Mayo believed that a scar in one plane, from within out, was an important risk factor for developing a hernia.[267, 269] He therefore advocated an overlapping repair in which each line of sutures is protected by normal structures. These sutures hold the structures in apposition, and the intraabdominal tension itself prevents displacement.[269] Mayo's technique is considered to be a major step in the history of hernia repair. Formerly, surgeons attempted to unite extensively dissected rectus muscles vertically in the midline, with poor results.[269]

The present study was performed to evaluate the results of the vertical "vest-over-pants" Mayo repair. In addition, various potential risk factors for recurrent incisional hernia were analyzed.

2.3 Patients and Methods

The records of all patients with a vertical Mayo repair operated at the Department of Surgery of the Sint Franciscus Gasthuis Rotterdam between 1981 and 1990 were reviewed retrospectively. Because recurrent hernias are known to have higher recurrence rates[157, 225] and incisional hernias occur more often in the midline than in other vertical[55, 79, 107, 149] or transverse[25, 41, 107, 224, 229, 356] incisions, only patients with a primary hernia of the midline were selected for analysis. *Patient-related factors* of sex, age, obesity, chronic cough, prostatism, constipation, diabetes mellitus, history of oncologic disease, and use of steroids were noted. Obesity was measured using the Quetelet index. *Operation-related factors*, including surgical technique, suture materials, wound hematoma, wound infection, and the surgeon's experience (resident,

consultant), were also analyzed. *Hernia-related factors*, such as the hernia-free interval, type of incision, previous hernia repairs, and the size and number of the hernias, were evaluated as well. Midline hernias were divided into upper, lower, umbilical (≤ 3 cm proximal or distal from the umbilicus), or full length (> 3 cm proximal and distal from the umbilicus) hernias. Patients without documented hernia recurrence after the repair were invited for physical examination. In patients without recurrence, follow-up time was defined as the interval from hernia repair to present physical examination. In patients aware of a recurrence, the month of first detection was used as time to the event. In patients having a recurrence of which they were not aware, the time to the recurrence was estimated as the time halfway between the most recent control visit and the study examination. Whenever physical examination was not possible due to death or other reasons, the most recent documented physical examination was used to determine hernia recurrence and follow-up time.

For incisional hernia repair the vertical Mayo technique was used, being a modification from the classic transverse Mayo technique for umbilical hernia repair.[156, 267-269] This repair includes excision of the nonvital edges of the fascial defect and clearing of the rectal fascia over 3 to 5 cm. Mattress sutures (1-0 Vicryl®, polyglactin 910) are introduced approximately 2.5 cm from the margin of the aponeurosis on one side of the linea alba and 1 cm from the margin of the opposite side. When these sutures are tightened it draws one fascia beneath the other, creating a vertical fascial scar. The free margin of the overlapping flap is sutured to the surface of the opposite aponeurosis, creating a second suture line.[156, 267-269]

Life-table methods were used for statistical analysis. Cumulative percentages of patients having a recurrence along time were calculated and compared using Kaplan-Meier curves and log rank tests, the latter including the trend test version.[312] Multivariate analysis of various factors was done using Cox regression. The p values given are two-sided; $p = 0.05$ was considered the limit of significance.

2.4 Results

A series of 68 patients was analyzed. This group comprised 31 men and 37 women with a mean age of 65 years (range 20 - 82 years). Follow-up examination varied from 0.5 to 152 months (mean 35 months). For cases without recurrence ($n = 40$), mean follow-up was 50 months (range 1 - 152 months). The cumulative recurrence rates after 1, 3, 5 and 10 years were 35, 46, 48, and 54 percent, respectively (Table 1).

Table 1. Cumulative percentages of patients with recurrent incisional hernia following a primary vertical Mayo repair of the midline after 0-120 months of follow-up.

Months after operation	Patients in follow-up without hernia recurrence	Cumulative recurrence rate (%)	Standard error (%)
0.5	68	7	3
1*	63	13	4
6	40	29	5
12	33	35	6
24	30	39	6
36	26	46	6
48	21	46	6
60	15	48	7
120	5	54	8

* One month = 4 to 6 weeks

Of the 28 with a recurrence, 9 patients (32%) had a recurrence during the first month, 12 patients (43%) after one month and within one year, 2 patients (7%) during the second year, and 3 patients (11%) during the third year. Hence most of the recurrences (75%) occurred within the first postoperative year.

Univariate analysis of *patient-related risk factors* (Table 2) demonstrated that only the use of steroids was related ($p=0.05$) with recurrence (Fig. 1). Of the *hernia-related factors*, full length resulted in more recurrences than the combined group of median upper, median lower, or umbilical incisions ($p=0.01$), whereas there was no difference ($p=0.61$) between the latter three groups. Also the size of the hernia correlated with the risk of recurrence in cases with a single defect. Smaller defects generally had a lower risk of recurrence ($p=0.03$) (Fig. 2). Of the *operation-related factors*, none significantly correlated with recurrence. There was a trend, though, for a higher recurrence rate in patients who had had a wound infection ($p=0.09$).

Multivariate analysis demonstrated that the size of the hernia for patients with a single defect and use of steroids were the most important factors predicting a recurrence. A doubling of the size of the defect resulted in a 1.6-fold increased recurrence rate ($p=0.02$). The use of steroids led to a 2.9-fold increased recurrence rate ($p=0.04$). Full-length incisions generally had a higher recurrence rate when considered alone, but this factor was of no importance when adjusted for the size of the defect.

Table 2. Recurrence rates in relation to various risk factors in patients with a vertical Mayo repair of a primary incisional hernia of the midline.

Factors	No. of pts.[a]	No. of pts. with recurrence	5-Year cumulative recurrence rate (%)	p
Patient-related				
Sex				
Male	31	16	64	0.12
Female	37	12	36	
Age				
≤ 65 years	34	17	55	0.43
> 65 years	34	11	39	
Obesity (Q≥25)				
No	27	10	46	0.84
Yes	39	18	50	
Cough				
No	55	22	47	0.82
Yes	13	6	51	
Constipation				
No	64	26	47	0.97
Yes	4	2	66	
Prostatism				
No	31	16	64	-
Yes	0	0	-	
Diabetes				
No	65	27	49	0.95
Yes	3	1	33	
Oncology				
No	57	23	47	0.99
Yes	11	5	56	
Steroids				
No	59	22	44	0.05
Yes	9	6	≥72	

[a] Because of missing data, the numbers of patients do not always add up to 68.

Tabel 2. Continued.

Factors	No. of pts.[a]	No. of pts. with recurrence	5-Year cumulative recurrence rate (%)	p
Hernia-related				
Incision				
Full length	13	9	75	0.01[b]
Median upper	29	11	48	
Median lower	11	3	28	
Umbilical	14	4	45	
Size (cm)				
1.5-3.0	15[c]	4	31	0.03[d]
3.1-6.0	15[c]	7	44	
6.1-12.0	14[c]	8	73	
12.1-25.0	9[c]	5	≥78	
Multiple	14	4	42	
Operation-related				
Surgeon				
Resident	15	5	38	0.56
Consultant	45	21	56	
Both[e]	8	2	25	
Postop. infection				
No	60	23	45	0.09
Yes	8	5	75	
Hematoma				
No	61	24	47	0.55
Yes	7	4	≥57	

[a] Because of missing data, the numbers of patients do not always add up to 68.
[b] Full length compared to other median incisions combined (difference among the latter three groups: $p=0.61$)
[c] Single fascial defects
[d] Trend test
[e] Operation performed by resident under assisting supervision of consultant.

2.5 Discussion

With respect to "vest-over-pants" incisional hernia repairs, van der Linden et al.[244] reported 26 recurrences among 47 repairs, and Fischer and Turner[118] reported 11 recurrences for 57 repairs. A variety of incisions were included, however, and at that time life-table analysis was not yet performed. Because incisional hernias develop with time,[106] and patients have variable lengths of follow-up, life-table methods are essential for studying hernia recurrence rates. Failure to do so may lead to underestimation of recurrence rates and therefore may result in erroneous conclusions.

With respect to primary incisional hernia repair with various incisions and techniques but using life-table analysis, the literature reveals high cumulative recurrence rates (Langer et al.[225] reported a 10-year rate of 31% and Hesselink et al.[157] a 5-year rate of 41%). Seeking better results, we deliberately changed our technique in 1980 to the vertical Mayo repair, hoping the double breasted vest-over-pants technique would serve our needs. The outcome, a 10-year cumulative recurrence rate of 54%, is disappointing.

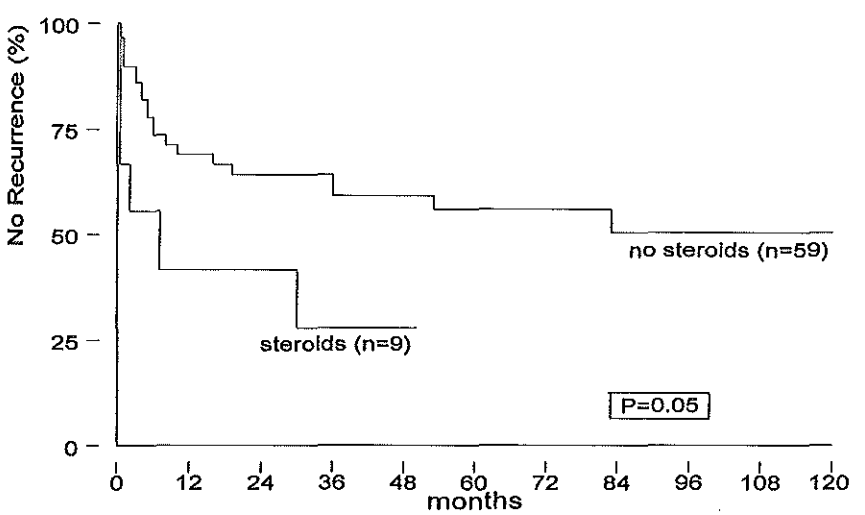

Fig. 1. Kaplan-Meier curves for recurrence of incisional hernia according to the use of steroids.

As with all suture techniques, the tension on the tissues might be responsible for these results, by increasing the risk of tissue ischemia and suture cut-out.[130, 425] Due to the nature of the Mayo repair, which creates an overlap, this risk might be even more pronounced. Second, the use of absorbable suture material might have an influence.[238, 456] Absorbable 1-0 Vicryl® sutures were used, which maintain their tensile strength for approximately 2 to 3 weeks. In this series, 32% recurred within the first postoperative month, suggesting that permanent suture material, by maintaining its tensile strength throughout the life of the wound, might be advantageous. However, Pollock and Evans[322] showed that early fascial separation may be responsible for subsequent incisional hernia as well. If so, early loss of tensile strength might *not* be a major influence. Prospective studies studying primary abdominal wall closure have not yet given a clear answer.[238, 456]

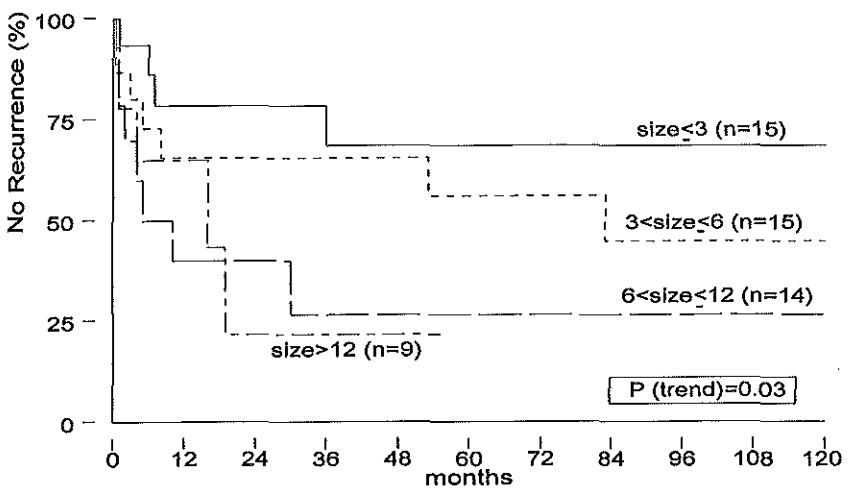

Fig. 2. Kaplan-Meier curves for recurrence of incisional hernia according to the size of the single lesion defect (< 3, 3-6, 6-12, and > 12 cm). Significantly fewer (p=0.03) recurrences were found in patients with small hernias. The 5-year cumulative recurrence rates of these groups were 31, 44, 73, and ≥78 percent, respectively.

With respect to risk factors *wound infection* is often considered to be the most important factor contributing to the development of incisional hernia.[25, 41, 50, 51, 107, 118, 130, 170, 229, 320] In the present study we observed a higher (though not significantly) recurrence rate after wound infection. This nonsignificant finding may be due to the small number of patients with infection ($n=8$) in this study. The *size of the hernia* was observed to be a significant factor for recurrence, confirming the findings of others. Hesselink et al.[157] demonstrated that hernias smaller than 4 cm had a significantly lower recurrence rate than larger ones. The lower tension associated with repair of small hernias may be responsible. Also, the use of *steroids* was identified as a risk factor, for small and large hernias, which may reflect the fact that steroids delay wound healing.[25]

At this time no consensus has been reached about whether, how, and when to operate on a patient with incisional hernia. Data from this and other series certainly are worrisome, making many surgeons hesitant to undertake a repair. Incisional hernia, however, is a significant source of morbidity, and delay in repair can have serious clinical consequences. Fascial defects, especially the small ones, predispose to incarceration or strangulation.[25, 356] The mortality rate of complicated incisional hernia repair is approximately 1 percent.[159] Second, nonoperated hernias might increase in size,[25] with increasing difficulty of repair and higher recurrence rates. Third, massive hernias may give rise to dystrophic ulceration of skin, chronic abdominal and back pain, and respiratory complications due to diaphragmatic dysfunction.[356, 401] Therefore, more efficacious techniques of hernia repair are needed.

Since the mid-1980s several series have shown low recurrence rates with use of prosthetic material,[228, 282, 401, 431, 435, 447] even in large defects, presumably due to the tension-free repair.[130] Although randomized trials are lacking, we now use prosthetic materials for repair of large defects (>6 cm). For smaller defects, an objective comparison between a one-layer approximating closure using nonabsorbable sutures and closure with intraperitoneal prosthetic material is currently being undertaken by means of a prospective randomized multicenter trial.

In conclusion, the size of the hernia and the use of steroids were identified as independent risk factors of first-time recurrent incisional hernias. The 5-year cumulative recurrence rates for hernias < 3 cm, 3 to 6 cm, 6 to 12 cm, and > 12 cm differed significantly: 31, 44, 73, and 78 percent, respectively. These high recurrence rates strongly indicate that the vest-over-pants repair should not be used for closure of midline incisional hernias.

CHAPTER 3

Incisional Hernia Recurrence Following "Edge-to-Edge" Fascial Closure of Primary Hernias of the Midline

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Submitted.

3.1 Abstract

A series of 131 primary incisional hernias with an "edge-to-edge" or approximating repair was evaluated retrospectively. Patients without documented hernia recurrence following the repair were invited for physical examination. Life table methods were used for statistical analysis. The 1-, 3-, 5- and 10-year cumulative recurrence rates were 20%, 37%, 43%, and 67%, respectively. Also, potential risk factors were studied. Multivariate analysis identified wound infection as the most important independent risk factor of first time recurrent incisional hernia ($p=0.003$), whereas Quetelet index tended to significance (p-trend=0.08). Considering the high recurrence rates found, the results of this study strongly suggest that the 'edge-to-edge' or approximating repair as described in this study should no longer be used for closure of midline incisional hernias.

3.2 Introduction

In studies with longer than one year follow up, incisional hernias do appear in 10 to 30 percent of midline laparotomies.[41, 47, 75, 88, 107, 181, 220, 238, 248, 277, 305, 404, 456] Patients with an incisional hernia often complain of the esthetic appearance or suffer from discomfort, pain, or intestinal obstruction. A variety of techniques of repair have been in use. Still, incisional hernia repair results are often disappointing. Five-year cumulative recurrence rates as high as 48 percent have been reported.[253]

In the Department of Surgery at the University Hospital Rotterdam Dijkzigt, mostly the "edge-to-edge" or approximating repair without the use of prosthetic material was used for hernia closure. The present study was performed to evaluate the long-term results of the approximating repair. In addition, various potential risk factors for recurrent incisional hernia were analyzed.

3.3 Patients and Methods

The records of patients with a history of an approximating incisional hernia repair between 1980 and 1989 at the University Hospital of Rotterdam, were reviewed retrospectively, and patients with a primary hernia repair of the midline were selected. *Patient-related factors* of sex, age, obesity, chronic cough, prostatism, constipation, diabetes mellitus, and the use of corticosteroids were analyzed. Obesity was measured using the Quetelet index (weight[kg]/length[m]^2). In addition, *operation-related factors* including the technique of surgery, suture materials, duration of operation, technique of anesthesia, wound complications (hematoma, infection), mortality, and length of hospital stay were analyzed. *Hernia-related factors* - the site of the incision and the size of the hernias - were also analyzed. Midline hernias were divided into upper, lower, or full-length hernias.

Patients with no documented hernia recurrence were asked to visit the outpatient department. On physical examination, hernia recurrences and complaints of discomfort and pain were scored. Patients not able to visit the outpatient department were examined by their general practitioner. In patients without recurrence, follow-up was defined as the interval from hernia repair to present physical examination. In patients aware of a recurrence, the time when it had first been noted was used. In patients not aware of an existing hernia recurrence, the time halfway the most recent and present physical examination was used. Whenever physical examination was not possible, due to death or other reasons, the most recent documented physical examination was used to determine hernia recurrence and follow up.

The approximating repair includes excision of fascial edges that, to the judgment of the surgeon, will not add to the strength of the reconstruction and freeing of the fascia over several centimeters. Then, closure is performed predominantly using Vicryl® (Polyglactin 910) sutures, either by interrupted or continuous one layer suturing.

Statistical analysis: Cumulative percentages of patients having a recurrence along time were calculated and compared using life-table methods (Kaplan-Meier curves; logrank tests). P values given are two-sided; 0.05 was considered the limit of significance.

3.4 Results

A series of 131 patients was analyzed. One patient died peroperatively. With no other patients dying within the first month, the operation mortality was 0.8 percent. The remaining group comprised 81 men (62 percent) and 49 women (38 percent) with a mean age of 56 (range 22-92) years. In 116 patients Vicryl sutures were used, in 14 the type of suture remained unknown. Follow up examination varied from 0.5 to 199 months, with a mean of 46 months. For cases without recurrence (n=71), mean follow-up was 57 (0.5-199) months. The size of the hernia varied from 1 to 30 cm, with a mean of 7.6 cm. The cumulative primary recurrences after 1, 3, 5 and 10 years were 20%, 37%, 43%, and 67%, respectively (Table 1).

Of the 59 with a recurrence, 24 patients (41%) had a recurrence within one year, 17 patients (29%) during the second and third year, and 5 patients (8%) during the fourth and fifth year. Wound complications (infection or hematoma) were seen in 18 patients (13.8%).

Table 1: Cumulative percentages of patients with recurrent incisional hernia following a primary approximating repair of the midline after 0-199 months of follow up.

Months after operation	Patients in follow-up without hernia recurrence	Cumulative recurrence rate (%)	Standard error (%)
1	130	-	-
6	126	13	3
12	100	20	4
24	89	28	4
36	74	37	5
48	61	40	5
60	45	43	5
72	39	50	5
84	31	54	5
96	26	56	6
108	18	61	6
120	14	67	7
132	10	67	7
144	8	67	7
156	8	67	7
168	6	74	8
199	4	74	8

Univariate analysis (Table 2) of *patient-related risk factors* demonstrated that the Quetelet index ($p=0.05$, Figure 1) and diabetes mellitus ($p=0.03$) were associated with recurrence. Of the *operation-related factors*, wound infection ($p=0.003$) was identified as a risk factor for recurrence (Figure 2). Of the *hernia-related factors*, median lower resulted in more recurrences than median upper hernia repairs ($p=0.05$). The size of the hernia did not associate with the risk of recurrence.

Multivariate analysis demonstrated that postoperative wound infection ($p=0.006$) was the most important factor predicting a recurrence, whereas Quetelet index tended to significance (p-trend=0.08). Diabetes was not found to be an independent risk factor in multivariate analysis, due to the correlation between Quetelet index and diabetes: diabetic patients generally had a higher Quetelet index ($p=0.02$ using X^2-test).

The median duration of operation was 60 (15-300) minutes, and the median hospital stay was 11 (2-62) days.

Table 2: Recurrence rates in relation to various risk factors in patients with a approximating repair of primary a incisional hernia of the midline.

Factors	No. of pts.[a]	No. of pts. with recurrence	5-Year cumulative recurrence rate (%)	p
Patient-related				
Sex				
Male	81	35	42	0.84
Female	49	24	44	
Age				
≤ 45 years	36	15	34	0.10
> 45 ≤ 65	61	29	42	
> 65 years	33	15	56	
Obesity (Q≥25)				
≤ 25	35	19	36	0.05[b]
> 25 ≤ 30	50	27	51	
> 30	9	6	70	
Cough				
No	93	43	42	0.88
Yes	36	16	48	
Constipation				
No	118	54	42	0.43
Yes	11	5	61	
Prostatism				
No	76	34	42	0.55
Yes	5	1	33	
Diabetes				
No	123	54	41	0.03
Yes	7	5	81	
Steroids				
No	119	55	45	0.44
Yes	11	4	20	

[a] Because of missing data, the numbers of patients do not always add up to 130.

[b] Trend test

Table 2. Continued.

Factors	No. of pts.[a]	No. of pts. with recurrence	5-Year cumulative recurrence rate (%)	p
Hernia-related				
Incision				
Full length	65	26	42	0.10[c]
Median upper	48	22	39	
Median lower	15	9	63	
Size (cm)				
1.5-3.0	37	16	36	0.16[b]
3.1-6.0	32	10	30	
6.1-12.0	21	12	66	
> 12	21	10	48	
Operation-related				
Anesthesia				
General	120	54	46	0.60
Epidural/spinal	5	3	20	
Technique				
Interrupted	99	47	41	0.82
Running	23	8	54	
Operation duration				
≤ 60 min	88	41	46	0.78
> 60 min	42	18	37	
Postop. infection				
No	121	51	41	0.003
Yes	9	8	67	
Hematoma				
No	121	54	42	0.14
Yes	9	5	54	

[a] Because of occasionally missing data, the numbers of patients do not always add up to 130.
[b] Trend test
[c] Median lower compared to median upper incisions p=0.05.

3.5 Discussion

In the current study most recurrences were seen after the first year, demonstrating the importance of the factor time in incisional hernia recurrence studies. Since incisional hernias develop with time,[106, 157] and patients have variable lengths of follow-up, life-table methods are essential for studying hernia recurrence rates. With respect to primary incisional hernia repair with various incisions and techniques, the literature reveals high cumulative (life-table) recurrence rates. Langer et al. reported a 10-year rate of 31%.[225] Our group reported a 5-year rate of 48% following the overlapping 'Mayo' repair.[253] The outcome of the present 'edge-to-edge' repairs, a 10-year cumulative recurrence rate of 67%, is even more disappointing. As with all suture techniques, the tension on the tissues might be responsible for these results, by increasing the risk of tissue ischemia and suture cut-out.[130, 425]

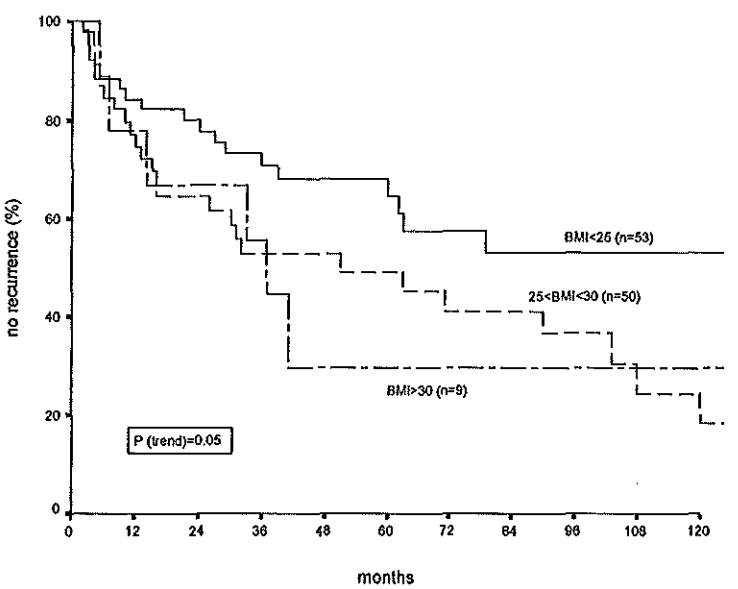

Figure 1. Kaplan-Meier curves for recurrence of primary incisional hernia according to the BMI = body mass index (Quetelet, kg/m^2).

The use of rapidly absorbable suture material may influence recurrence rates. Absorbable Vicryl sutures were used, which maintain their tensile strength for approximately 2 to 3 weeks. In fact, although others did not confirm these findings,[57, 77, 178, 227, 230, 277, 338] several studies have found that the incisional hernia rate following *fresh* abdominal closure is significantly higher for these relatively rapid absorbable sutures as compared to nonabsorbable materials.[5, 23, 238, 456] With incisional hernia suture repair, the tension put to the tissues may even be higher. To bring both edges together in defects of comparable size, Boerema needed 7-10 kg in an incisional hernia but only 1 kg in a first time laparotomy wound.[42] Also, comparing fresh incisions and incisional hernia repairs, Lamont et al. found a significant difference in incisional hernia appearance and recurrence.[224] Therefore, rapidly absorbable suture material may not be suitable for hernia repair. However, also with nonabsorbable sutures for incisional hernia suture repair, recurrence rates up to 54 percent have been reported.[310]

Apart from the suture material, the suture technique may be of influence. Jenkins demonstrated that abdominal wounds may lengthen up to 30 percent during postoperative abdominal distension, and that the tissue bite in wound closure is related to the length of the suture.[190] Therefore, to prevent for wound failure, the suture length to wound length (SL:WL) ratio should be at least 4:1. Anything less than 2.5:1 places wounds at risk. Tissue bites and stitch intervals of both 1 or 2 cm, using a continuous suture, result in a suture length to wound length ratio of approximately 4:1.[439] Israelsson et al. confirmed these findings prospectively for midline incisions.[180-186] In retrospective studies like the present study, the SL:WL ratios cannot be traced. Again, the above studies focus on fresh abdominal wounds, not on incisional hernia repair, making comparison difficult.

With regard to comparing upper, lower, and complete midline incisions, most prospective studies do not show a significant difference in incisional hernia rate.[107, 397, 456] Regnard et al., however, in a prospective non-randomized study with up to five years of follow up, did find a significant difference between fresh infraumbilical (16.6 percent) and supraumbilical (7.2 percent) midline incisions ($p < 0.001$).[336] In the current study, median lower *repairs* did result in more recurrences than median upper repairs, the 5-year cumulative recurrence rates being 63 and 39 percent, respectively ($p=0.05$). The lacking of the posterior rectus fascia below the linea arcuata of Douglas, which usually lies 3-5 cm below the umbilicus, may be responsible. On the contrary, however, in another study from our group, we observed less recurrences with lower midline as compared to upper midline repairs, the 5-year cumulative recurrence rates being 28 and 48 percent, respectively.[253] Also, Leber et al. recently found the risk of long-term complications to be over twice as likely with hernia repairs of the upper abdomen ($p=0.05$).[232]

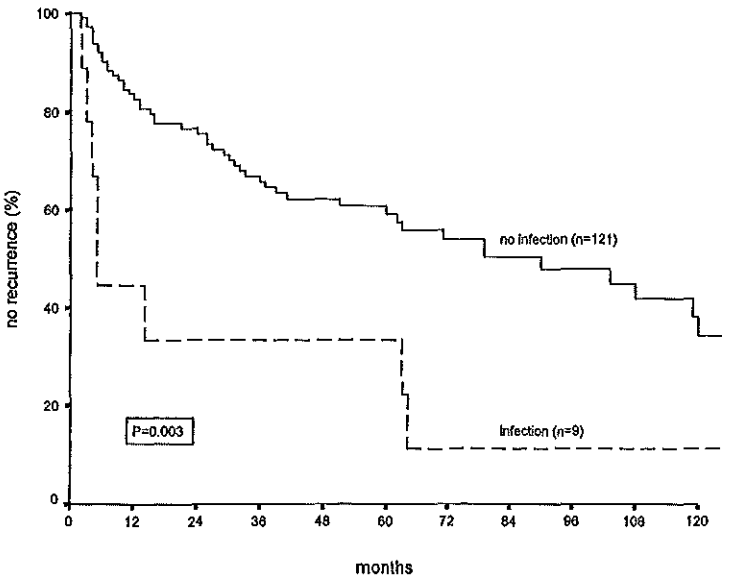

Figure 2. Kaplan-Meier curves for recurrence of primary incisional hernia according to wound infection.

Wound infection constitutes a well known risk factor for hernia occurrence and recurrence, and the results of this study do confirm the results of many others.[25, 41, 50, 51, 107, 118, 130, 135, 145, 146, 182, 220, 244, 320, 336, 397, 449, 456] Infection rates therefore should be minimized. In a randomized study, Abramov et al. showed that single dose cephalosporin prophylaxis administered 30 minutes before umbilical or incisional hernia repair significantly reduced the wound infection rate.[5] Prophylactic antibiotics may therefore also prevent subsequent herniation.

This and other studies do suggest that simple suture repairs of large incisional hernias should no longer be used. Other repairs, like mesh repairs or extensive rectus sheath techniques (e.g. Ramirez's components separation method)[326] need further attention. To define the indications for use of prosthetic materials in smaller hernias, an objective comparison between a one-layer approximating closure using nonabsorbable sutures and closure with retromuscular prosthetic material is currently being undertaken by our group by means of a prospective randomized multicenter trial.

In conclusion, wound infection was identified as an independent risk factor for first-time recurrent incisional hernia, whereas obesity tended to significance. The cumulative primary recurrence rates after 1, 3, 5 and 10 years were 20%, 37%, 43%, and 67%, respectively. These high recurrence rates strongly indicate that the approximating 'edge-to-edge' repair as described in this study should no longer be used for closure of midline incisional hernias.

CHAPTER 4

The low transverse "Pfannenstiel" incision and the prevalence of incisional hernia and nerve entrapment.

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4.1 Structured abstract

Objective. The authors determined the prevalence of incisional hernia and nerve entrapment in patients with a low transverse Pfannenstiel incision.

Summary Background Data. The literature on the Pfannenstiel incision suggests an incisional hernia rate of 0.0 to 0.5 percent. However, in these series, physical examination, which is essential in the authors' view, was not performed. To the authors' knowledge, the prevalence of nerve entrapment after the Pfannenstiel incision is not known or has never been published.

Patients and Methods. All adult women, operated on between 1986 and 1992 using a Pfannenstiel incision and not having had another lower abdominal incision other than for laparoscopy, were invited for follow-up at the outpatient department. All patients were interviewed and subjected to a physical examination, with special interest to the presence of incisional hernia or nerve entrapment.

Results. In patients having had a Pfannenstiel incision, no incisional hernias were found. In patients also having had a laparoscopy, the incisional hernia rate was 3.5 percent. Nerve entrapment was found in 3.7 percent. The length of the incision was identified as a risk factor ($p=0.02$).

Conclusions. Incisional hernia is a rare complication of the Pfannenstiel incision. Complications of nerve damage, however, are not uncommon and should be recognized. When possible, nerves should be identified and preserved, especially when extending the incision more laterally.

4.2 Introduction

Incisional hernias occur in at least ten percent of patients with midline laparotomies.[55] Patients with an incisional hernia often report an aesthetic appearance or suffer from discomfort, pain, or, occasionally, intestinal obstruction.[287] Moreover, after first incisional hernia repair, recurrence rates up to 53 percent have been described.[253] Therefore, preventing an incisional hernia is mandatory, and surgical methods should be developed and used to lower the incidence of incisional hernias.

In 1900, Hermann Johannes Pfannenstiel (1862-1909) described a low transverse abdominal incision to prevent incisional hernia.[103, 313] The incision that bears his name is the incision of choice for a variety of gynecological operations.[39, 73, 85, 158, 315] An aesthetically more pleasing "bikini-line" scar[39, 103, 315, 347, 414] and less postoperative complications[39, 73, 103, 109, 315] are mentioned as additional advantages of this technique. Nerve entrapment, however, can be a disadvantage.[151, 379, 383, 384, 393] In general surgery, a midline incision generally is used.

In this study, we evaluate the prevalence of incisional hernia and nerve entrapment after the Pfannenstiel incision in a large series.

4.3 Patients and methods

All adult women, operated on between 1986 and 1992 using a Pfannenstiel incision (Department of Gynecology, University Hospital Rotterdam) and not having had another lower abdominal incision other than for laparoscopy, were invited for follow-up at the outpatient department. The following data were noted: date of birth, date of operation, height, weight, presence of cough or constipation, incision length, postoperative complications (wound infection, hematoma), postoperative pregnancy, postoperative pain (localization, period, radiation, triggering, character), and numbness. Thereafter, the scar and the lower midline of the abdomen were examined for the presence of an incisional hernia, which was defined as any palpable fascial defect of the abdominal wall. Investigation included palpation of the area while the patient raised the extended legs in the supine position.

Furthermore, patients were asked about reports of pain, with special reference to signs of entrapment of the ilioinguinal (I-I) or iliohypogastric (I-H) nerve or both. These signs are an activity-induced sharp pain, felt around the incision site or a deeper abdominal region, which radiates to the labium or the medial parts of the thigh or both, later followed by a continuous burning pain in the same region. [151, 379, 383, 384, 393] In this study, entrapment was defined when such reports still were present more than five weeks after surgery or when reports started after a pain-free period. If pain was localized at the scar site and clearly was triggered by touch or pressure, the pain was attributed to a neuroma.

The Pfannenstiel incision was made 2 to 3 centimeters above the symphysis pubis at the border of the pubic hair. The incision, 8 to 12 centimeters long, extended through skin, subcutaneous fat, and rectus sheath and laterally through the fasciae of the internal and external oblique and transversus muscles. Thereafter, the anterior fascia and linea alba were separated from the underlying rectus and pyramidalis muscles, from symphysis to umbilicus. Then, the muscles were separated in the midline (dividing the fascia transversalis, and, cranially from the arcuate line, the posterior rectus fascia), and finally also the peritoneum was divided. The incision was closed in layers (Vicryl®, polyglactin 910, Ethicon, Somerville, NJ), the peritoneum with a continuous suture, the rectus muscles, when appropriate, with one to three interrupted approximating sutures. The transversely incised fascia was closed with one continuous suture. The technique of closure of the skin varied with the surgeons' preference.

For statistical analysis, comparison of percentages was done with Fisher's exact test. Medians were compared with the Mann-Whitney U test. A p value (two-sided) of 0.05 was considered the limit of significance.

4.4 Results

A total of 346 patients were invited to participate, of whom 300 (87%) were willing to visit the outpatient clinic. Reasons not to participate were having to go to work ($n=15$), not having any reported problems about the scar ($n=10$), distance to the hospital ($n=10$), reported problems about waiting times ($n=8$), and simple lack of interest ($n=3$). Another 28 patients, initially willing to participate, did not show up without explanation. Of the 272 patients examined, 29 patients did not meet inclusion criteria, leaving 243 patients for evaluation.

The mean age was 35 years (range, 16 to 57 years). The mean postoperative follow-up was 60 months (range, 19 to 94 months). Five patients (2.1%) had an incisional hernia. In all cases, a palpable fascial defect of approximately 1 cm^2 was located in the midline, just caudal to the umbilicus. For none of these patients had the hernia been the cause of any reported problems. In one patient, a bulge on the abdomen was visible on examination. The Quetelet-index (weight[kg]/length[m]^2), cough, constipation, postoperative infection, hematoma, and pregnancy could not be identified as risk factors.

Of the women who were examined, 146 (146/235=62%, 8 missing data) had had a laparoscopic procedure performed through an extraumbilical incision. All patients presenting with an incisional hernia had a history of laparoscopy. Consequently, 5 of 146 (3.5 percent) of the women with a previous laparoscopy were found to have an incisional hernia, whereas no incisional hernias were found in women without previous laparoscopic investigation ($p=0.08$).

Long-term reported problems of pain were experienced by 57 of 243 (23 percent) of the patients. In 9 patients (9/243=3.7%), these reported problems could be attributed to entrapment of the I-I or I-H nerve or both, and in 5 patients (5/243=2.1%), these reported problems could be attributed to a neuroma. In 61 patients (61/243=25.1%), reported problems of numbness were present. Two patients had reported a neuroma as well as numbness. Four patients had reported nerve entrapment as well as numbness. The length of the incision could be identified as a risk factor for nerve entrapment ($p=0.02$), but did not correlate with neuroma ($p=0.99$) or numbness ($p=0.60$).

4.5 Discussion

Incisional hernia. In this series, the Pfannenstiel laparotomy (in patients with or without laparoscopy) has an incisional hernia rate of 2.1 percent. Compared to midline laparotomy hernia percentages reported in literature, of up to 46 percent,[55, 157, 253] this rate is low. Obviously, in the current study, the distribution of age, gender, and disease is quite different from most studies on midline incisions. Therefore, conclusions from this study must be interpreted with care. With respect to incisional hernia, however, we believe the difference is striking. Other series on the Pfannenstiel incision also suggest a low prevalence, with incisional hernia rates from 0.0 to 0.5 percent,[39, 148, 313, 315] but in these series, no physical examination was performed.

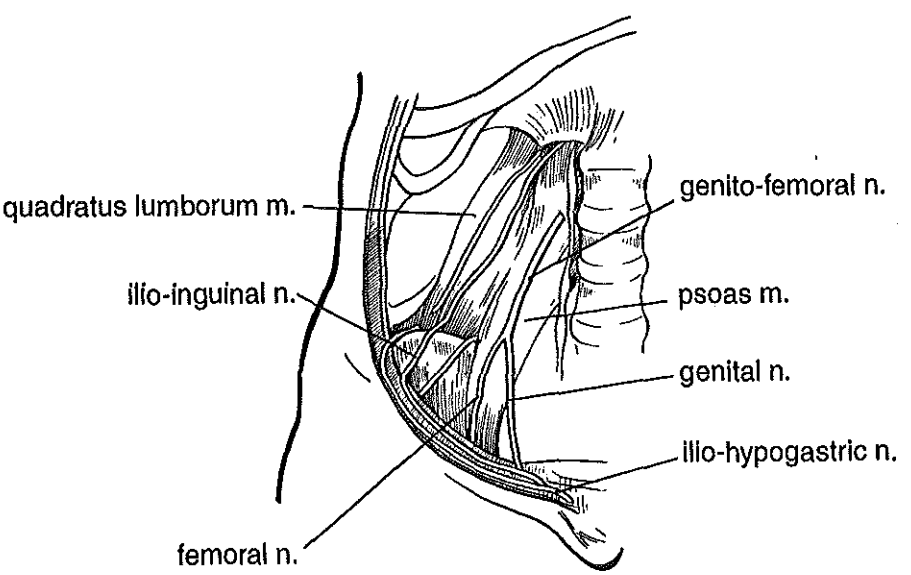
All incisional hernias were found just caudal to the umbilicus. In the Pfannenstiel incision, the anterior rectus fascia and linea alba are separated from the underlying muscles up to the umbilicus, and so the rectus fascia may be damaged at the umbilical level. However, because all the patients with an incisional hernia also had had laparoscopy, whereas no hernias were found in 169 patients with no laparoscopy, the hernias may very well be the result of laparoscopy. When an incision of approximately 1.5 cm is made for laparoscopy and only the skin is sutured, the chances of developing an incisional hernia increase significantly.[197] Still, without suturing the fascia, incisional hernia is a rare complication in literature (0.01 to 0.17%).[163, 197, 359] In our series, in patients having had a Pfannenstiel incision as well as laparoscopy, the hernia rate is 3.5 percent. Because several cases of incarceration of incisional hernias have been reported as a complication of laparoscopy,[163, 221, 359, 362] we subscribe to the advice to close the fascia.

Various factors may contribute to the fact that the Pfannenstiel incision performs better with respect to occurrence of incisional hernias. First and most obvious, in the Pfannenstiel incision, the skin, subcutaneous tissue, and fascial defect are remote from the muscle defect, which is covered by healthy nonincised tissue, whereas in the low midline incision, all layers are incised in one plane, making, for instance, contamination more easy. Second, the linea alba, into which the oblique muscles insert, is not incised with the Pfannenstiel incision. Strong contractions of these muscles are necessary during coughing, vomiting, and defecation.[414] Moreover, the linea alba has the poorest blood supply of any area in the abdominal wall, and this may contribute to deficient healing.[414] Third, use of the Pfannenstiel incision obeys all principles regarding atraumatic surgery without tension. The skin incision is along Langer's lines, resulting in reduced traction at the skin edges. The division of the external oblique aponeurosis is parallel to its fibers, along the lines of tension.[84, 103] The force required to approximate the edges of a vertical incision is approximately 30 times greater than the force required to approximate a transverse incision.[84, 414] Fourth, damage to nerve supply and venous and lymphatic drainage may differ and may thereby also influence wound healing.[414]

Therefore, to prevent incisional hernias, we might have to consider the use of a transverse skin and anterior fascia incision combined with a vertical muscle incision in other parts of the abdomen as well.

Nerve entrapment. The essential nerves of the groin are the I-H, I-I, and genitofemoral (G-F) nerves (Fig. 1). Communication between their branches and overlap in sensory innervation is common.[393] The I-H and the I-I nerve run a inferomedial course within the internal and external oblique muscles and travel through the inguinal canal.[383] The medially running I-H nerve supplies the skin of the overlying pubis (Fig. 2).[383, 393] The laterally running I-I nerve innervates the inguinal region, labium, and upper inner thigh. This area also is innervated by the genital branch of the G-F nerve. The femoral G-F branch passes under the inguinal ligament and supplies the anterior proximal aspect of the thigh.[383, 393] Entrapment of the G-F nerve is rare.[383] Injury to the I-H and I-I nerves by the Pfannenstiel incision is more likely to occur because of the nerves' superficial course.[151, 379, 383]

Figure 1: The essential nerves of the groin.



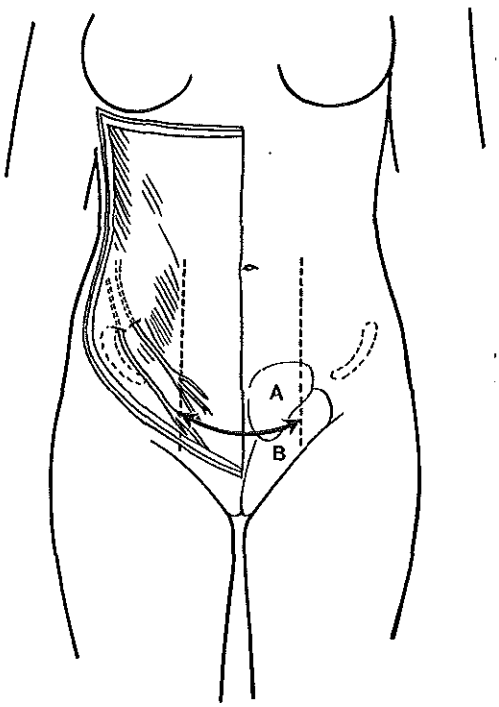


Figure 2: Nerve entrapment significantly is seen more often when the incision is extended more laterally. (A) Area innervated by iliohypogastric nerve. (B) Area innervated by ilioinguinal and genital branch of genitofemoral nerve. Communication between branches and overlap in sensory innervation is common.

In this series, 9 (3.7 percent) patients had symptoms of nerve entrapment. Nerve entrapment significantly was seen more often when the incision was extended laterally, beyond the lateral edge of the rectus sheath, confirming the observation of others (Fig. 2).[384] Nerve entrapment can result from incision of the nerve followed by neuroma formation, incorporation of the nerve by a suture in the closure of the fascia, or the tethering or constriction of the nerve in the surrounding scar tissue.[197, 384] The symptoms may begin early or commence many years after surgery.[151, 383, 384, 393] Surgeons not familiar with this entrapment neuralgia may not recognize the syndrome and judge reported problems to be psychosomatic.[151, 317, 383, 393]

Other complications of nerve damage due to the Pfannenstiel incision are neuroma formation (2.1 percent) and numbness (25.1% percent). As a conclusion, ideally, when using the Pfannenstiel incision, and extending laterally, the nerves should be identified and spared.[246]

The Pfannenstiel incision for general surgery. Although some authors think that access is obtained more easily[287, 414] and less time consuming[103] by a low midline incision, many others claim sufficient access to the operating area[39, 84, 109, 158, 347, 414] and do not find a significant difference in operating time.[2, 39, 158] Experience might be of influence. Appendicectomies,[39, 109, 347] prostatectomies,[2, 148] inguinal hernia repairs,[2, 148] and sigmoid resections for colocolponeopoesis[123] have been described using the Pfannenstiel incision. Advantages of this incision are a lower incisional hernia rate (none in this series, in patients without a history of laparoscopy), less wound infection,[39, 73, 109] hematoma formation,[39, 73] and direct postoperative pain,[73, 109] and the better aesthetic appearance.[39, 103, 109, 315, 347, 414] A disadvantage, however, is the possibility of nerve complications.[317, 384] Furthermore, in patients with ovarian or other tumors, its use might be contraindicated because proper exploration of the upper abdomen for tumor expansion is not adequate.[274]

In conclusion, wherever feasible, we recommend the use of the Pfannenstiel incision in lower abdominal surgery, because incisional hernia is a rare complication, and the incision allows for excellent cosmetic results. Complications of nerve damage, however, are not uncommon, and should be recognized. When possible, nerves should be identified and preserved, especially when extending the incision more laterally. Depending on the operation to be performed, however, the advantages may counterbalance the disadvantages.

CHAPTER 5

Comparison of Suture Closure and Mesh Repair for Incisional Hernia.

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The incidence of incisional hernia is sufficiently frequent to render it a serious complication of abdominal surgery.
Charles D. Branch, N Engl J Med 1934[45]

5.1 Abstract

Background. Incisional hernia is a major health care problem. Several uncontrolled or non-randomized studies of suture and prosthetic repairs have been reported, but no consensus has been reached regarding the optimal method for repair.

Methods. We performed a randomized, multicenter trial between March 1992 and February 1998 during which all adult patients scheduled for repair of primary or first-time recurrent incisional hernias of a vertical midline incision less than 6 x 6 centimeters were randomized to suture or prosthetic repair. The patients were followed up by physical examination at one, six, 12, 18, 24, and 36 months. Also, potential risk factors for recurrent incisional hernia were analyzed, using life-table methods.

Results. Among the evaluated 154 primary and 27 first-time recurrent incisional hernia patients there were 56 recurrences. The average follow-up for patients without recurrence was 26 months. The 3-year cumulative recurrence rates of the suture and mesh repairs were 43 and 24 percent ($p=0.02$) for primary repairs (95% CI for this 19% difference: 3% to 35%), and 58 and 20 percent ($p=0.10$) for first-time recurrent repairs (95% CI for the difference: -1% to 78%). When both hernia groups were combined, the significance increased ($p=0.005$), with a difference of 23 percent (95% CI: 8% to 38%). Multivariate analysis identified technique of repair, infection, prostatism, and operated aortic aneurysm as independent risk factors, but not defect-size.

Conclusions. A retrofascial preperitoneal prosthetic repair is superior to suture repair with regard to hernia recurrence, irrespective of fascial defect size.

5.2 Introduction

Incisional hernia is a major health care problem. It is one of the most frequent long-term complications of abdominal surgery. In prospective studies with sufficient follow-up, the incidence of primary incisional hernia ranges from 11 to 20 percent of laparotomies.[238, 287, 404] They can be a source of serious morbidity, like incarceration (6-14.6 percent)[259, 333] and strangulation (2.4 percent).[333] If not promptly reduced, a strangulated small bowel may become ischemic, necrose, and ultimately perforate. The mortality rate of complicated incisional hernia repair in recent literature ranges up to 10.4 percent,[340] and for elective repairs up to 5.3 percent.[401] Although many techniques of repair have been described, the results are often disappointing. Following primary non-prosthetic repair, recurrence rates range from 24 to 54 percent.[310, 333] Prosthetic repairs seem to have better but still high recurrence rates, up to 34 percent.[232] Following recurrent incisional hernia repairs, recurrence rates up to 48 percent have been described.[259] These series of suture and prosthetic repairs, however, are either

uncontrolled or non-randomized and it remains uncertain whether or not, and when prosthetic repairs are superior to suture techniques. To define the indications for use of prosthetic materials, a randomized multicenter trial was conducted.

5.3 Patients and Methods

Adult patients scheduled for repair of a primary or first-time recurrent incisional hernia of a vertical midline incision were randomized to suture or prosthetic repair. The preoperative length or width of the fascial defect was not to exceed six centimeters. Patients could only be enrolled once. Exclusion criteria were multiple preoperative hernias, signs of infection, prior repair with prosthesis, and hernia repair planned as part of another intraabdominal procedure. Patients were specifically asked to give consent for randomization after a physician informed them about the trial. Randomization, stratified by hospital and primary or first-time recurrent hernia, was achieved by calling an independent randomization center.

Patient-related factors of gender, age, obesity, cough, constipation, prostatism, diabetes, steroid medication, smoking, and the abdominal surgical history were noted. Obesity was defined as a body mass index (weight[kg]/length[m]^2) of ≥ 30. *Operation-related factors*, including the surgical technique, hematoma, dehiscence, and infection were also analyzed. Wound infection was defined as the discharge of pus from the wound, scored up to the one-month visit. *Hernia-related factors*, like primary or first-time recurrent hernia, the pre- and per-operative size, and the exact location in the midline were scored.

At the onset of anesthesia intravenous cephalosporins were administered. With the *suture technique*, the two fascia edges were approximated in the midline with a continuous polypropylene (Prolene® no.1) suture, with tissue bites and intervals of approximately one centimeter. The *retrofascial preperitoneal mesh repair* was performed by freeing the backside of the fascia over at least four centimeters. The polypropylene (Marlex® or Prolene®) prosthesis was tailored to the defect with at least 2 to 4 centimeters overlap and sutured to the back of the abdominal wall at 2 to 4 centimeters from the edge with a continuous Prolene® no.1 suture. To prohibit prosthetic contact with the underlying organs, a peritoneal defect was closed or the omentum was sutured in between. Whenever this was unrealizable, a completely covering polyglactin 910 (Vicryl®) mesh was fixed in between. The fascial edges were not closed over the prosthesis, unless a completely tension free repair could be performed. Drainage and closure of the (sub-) cutis was optional. The duration of surgery and hospital stay were noted.

The patients were followed up at intervals of one, six, 12, 18, 24, and 36 months. Patient-awareness of hernia recurrence and complaints about the scar were noted. Thereafter, the scar was examined for recurrence, which was defined as any palpable or ultrasound detected fascial defect located within seven centimeters of the hernia repair. Investigation included palpation while the patient raised the extended legs in the supine position. A staff surgeon evaluated resident findings. Ultrasound examinations were performed only when physical examinations were not definitive.

Statistical analysis: Percentages and continuous variables were compared using Fisher's exact test and Mann-Whitney's test, respectively. Cumulative percentages of patients with recurrences over time were calculated and compared using Kaplan-Meier curves and log rank tests, the latter including the trend test version in case of ordered groups. Multivariate analysis of various factors was done using Cox regression. Whether the effect of treatment group depended on size of the repaired hernia was investigated by appropriate interaction terms. The p values given are two-sided; $p=0.05$ was considered the limit of significance. The primary analysis was by intention-to-treat, i.e. patients remained in their allocated groups even if the surgeon judged the patient intraoperatively to not be suitable for the technique assigned. A per-protocol analysis, excluding patients with major protocol violations, was also performed.

The Ethical Committees of the participating hospitals approved the protocol.

5.4 Results

Between March 1992 and February 1998, 200 patients were enrolled, 171 with a primary and 29 with a first-time recurrent incisional hernia. Seventeen primary and two first-time recurrent randomizations were not eligible: either no incisional hernia was demonstrated intraoperatively (9), the operation was canceled (5), no follow-up was obtained (3), hernia repair was part of another procedure (1), or herniation was too close to an enterostoma (1). At base-line, patients were slightly younger and there were relatively more patients with an operated aortic aneurysm in the prosthetic group, while there were relatively more patients with prostatism in the suture group (Table 1). In multivariate analysis, adjustments were made for these factors.

Table 2 shows the recurrence rates for the randomized groups according to the stratification factor (primary hernia, first-time recurrent hernia). The ***primary hernia group*** comprises 80 suture repairs and 74 prosthetic repairs (eight with an additional Vicryl® mesh). Mean duration of follow-up was 26 (range 1-36) months for patients without recurrence, similar for both treatment groups. Thirty-two patients were lost to follow-up, 16 in each group: Seven patients died (none within one month), five were reoperated through the repair, one moved abroad, and 19 (mean follow up still 10 months) did not appear at their next appointment for various reasons (e.g. work, immobile). These patients were included in the analysis with their follow up censored at the time of last contact or reoperation.

Table 1: Base-Line Characteristics of Patients with Incisional Hernia Assigned to Suture Repair or Prosthetic Repair.*

Variable	Suture (n=97)	Prosthetic (n=84)
Gender (M:F)	1.0 : 1	1.5 : 1
Age (years)	63 (25-82)	57 (23-85)
BMI (kg/m^2)**	26.0 (20-41.5)	26.2 (19.7-41.5)
Prostatism (males)	6/47	1/49
Smoking	27/92	32/82
Infection	2/92	3/82
Hematoma	8/96	9/83
Size (cm^2)	20 (1-225)	24 (1-160)
Major reasons for laparotomies prior to repair***;		
Gastro-intestinal operation	48	38
Gynecological operation	16	15
Cholecystectomy	9	5
Aortic aneurysm	6	12
Other (not listed above)	28	30

* Figures are median (range) or numbers of patients.

** BMI = Body mass index (Quetelet)

*** Some patients had more than one previous laparotomy.

Five prosthetic repairs and seven suture repairs were converted to the other repair technique (one of each developed recurrence). In all converted prosthetic repairs, the surgeon judged that the resulting (>36 cm^2) peroperative defect was too large for repair without a strength adding prosthesis. In the converted suture repairs, two were protocol violations (see per-protocol analysis) and in two the surgeon did not perform a prosthetic repair in a 1 x 1 centimeter defect. In one, the risk of mesh infection was judged too high due to an inadvertent enterotomy.

The 3-year cumulative recurrence rates of the suture and mesh repair were 43 and 24 percent, respectively, which is a statistically significant ($p=0.02$) and clinically important difference (Table 2).

Table 2. Recurrence rates in the randomized groups, subdivided according to whether the repaired hernia was a primary or a first-time recurrent hernia.

	Repair	Number of patients	Number of recurrences	3-year cumulative recurrence rate (%)	P-value	Risk Difference (95% CI)
Primary Hernia Group						
	Suture	80	30	43	0.02	19 (3 to 35)
	Mesh	74	15	24		
	Total	154	45			
First-time Recurrent Hernia Group						
	Suture	17	9	58	0.10	38 (-1 to 78)
	Mesh	10	2	20		
	Total	27	11			
Hernia Groups Combined						
	Suture	97	39	46	0.005*	23 (8 to 38)
	Mesh	84	17	23		
	Total	181	56			

* Stratified logrank test

The *first-time recurrent hernia group* comprises 17 suture repairs and 10 mesh repairs. Two suture repairs were converted because the surgeon judged that the peroperative (>36 cm^2) defect was too large for repair without a prosthesis (one recurred). Mean duration of follow-up was 30 (range 1-36) months for patients without recurrence, similar for both treatment groups. The 3-year cumulative recurrence rates of the suture and mesh repair were 58 and 20 percent, respectively (Table 2). This difference of 38 percent is not significant (p=0.10), which may be due to the relatively small number of patients in this subgroup.

Primary and first-time recurrent hernias (n=181):
When both hernia groups were combined, mean duration of follow-up was 26 (range 1 to 36) months for patients without recurrence, similar for both treatment groups. An increased significance (p=0.005) was found (Table 2, Figure 1). The 3-year cumulative recurrence rates were 46 (suture repair) and 23 (mesh repair) percent, respectively.

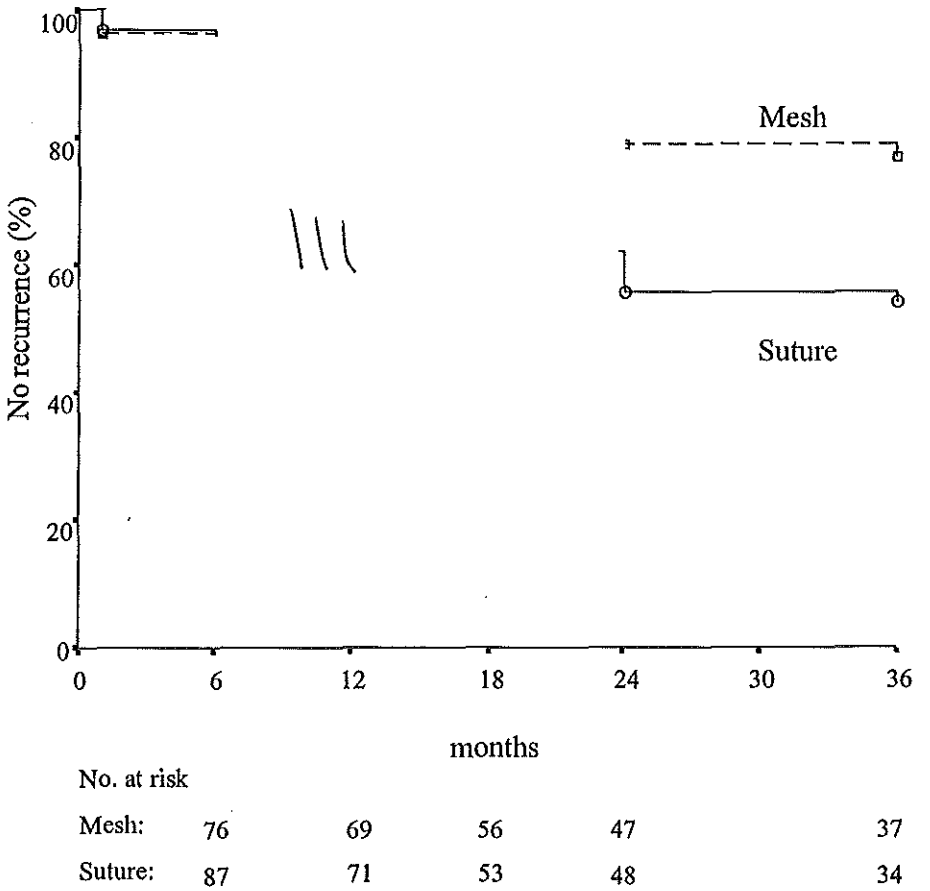

Figure 1. Kaplan-Meier curves for recurrence following repair of a primary or first-time recurrent incisional hernia according to suture repair (n=97) or prosthetic repair (n=84). Significantly fewer (p=0.005) recurrences were found in patients operated with the prosthetic repair.

Per-protocol analysis. Of the total group (n=181), five patients were marked as major trial violations. In one, the most proximal of four intraoperatively found hernias was repaired using a prosthesis, the others with Vicryl sutures. In another, the fascial defect was sutured under a subcutaneous prosthetic repair. In the third, several peroperatively discovered weak spots were not covered by an onlay prosthesis for unknown reasons, making recurrence inevitable. The last two were converted despite the fact that a prosthetic repair could have been performed with ease according to the operative notes (one recurred). With these five removed, the 3-year cumulative recurrence rates of the suture (n=95) and mesh (n=81) repair were similar to the intention-to-treat analysis, namely 46 and 23 percent, respectively (p=0.005).

Analysis of prognostic factors. In univariate analysis prostatism (males), operated abdominal aortic aneurysm, and infection were identified as significant risk factors for recurrence (data not shown). Table 3 shows the results of the multivariate analysis of these factors together with treatment group, age, size, and hernia group. In this analysis, treatment group, infection, prostatism (males), and operated aortic aneurysm were all identified as independent risk factors. Adjusted for the other factors, mesh repair resulted in a 57 percent reduced recurrence rate (p=0.009; 95% CI: 19%-77%) as compared to suture repair. Age did not show to be of importance. The same applies to hernia group (primary, first-time recurrent). The 95% CI for the effect of this factor is wide, however. No significant prognostic value, neither in univariate nor multivariate analysis, was found for the other investigated parameters, including size. Also the difference in recurrence rates between suture and mesh repair was not significantly affected by hernia size.

Analyzing the subgroup of small hernias ($\leq$ 10 cm^2), suture repair (n=30) resulted in a 3-year cumulative recurrence rate of 44 percent. The recurrence rate in the mesh repair group (n=20) was 6 percent (p=0.01).

For patients with or without an operated aneurysm the percentage of smokers was 56% (9/16) and 32% (50/157), respectively (p=0.06). Within either group, however, the recurrence rates did not significantly differ between smokers and non-smokers (p=0.35 and p=0.46, respectively).

Table 3: Multivariate analysis of various factors regarding recurrence rates.

Factor		No. of pts.	Recurrence[A] rate (3 yrs)	Relative risk (RR)	P-value[B] RR	95% CI RR
Repair	Suture	97	46 %	1		
	Mesh	84	23 %	0.43	0.009	0.23 - 0.81
Hernia group	Primary	154	34 %	1		
	Recurrent	27	43 %	1.72	0.14	0.84 - 3.51
Aneurysm	No	162	32 %	1		
	Yes	18	67 %	3.79	0.001	1.68 - 8.54
Infection	No	169	34 %	1		
	Yes	5	≥ 80 %	4.32	0.007	1.48 - 12.59
Prostatism	No	89	35 %	1		
	Yes	7	49 %	6.27	0.006	1.68 - 23.35
	Na[C]	82	35 %	1.01	0.98	0.56 - 1.82
Age ≥ 65	No	117	32 %	1		
	Yes	64	42 %	1.01	0.97	0.56 - 1.84
Size > 10 cm^2	No	50	31 %	1		
	Yes	128	38 %	1.45	0.30	0.72 - 2.92

A univariate analysis

B compared to the reference category (RR=1)

C not applicable (females)

Median operation duration was 45 (range 15-135) minutes for suture repair and 58 (range 15-150) minutes for mesh repair (p=0.09). Median hospital stay was 6.0 (range 1-37) days for suture repair and 5.0 (range 1-15) days for mesh repairs (p=0.44).

Complications.

Suture repair (n=97). In one patient, a complete wound dehiscence occurred following marked distension due to an ileus (fifth day).

Prosthetic repair (n=84). In one patient a recurrence revealed itself due to an intestinal strangulation, 18 months postoperatively. In another, contact with the intestines was not adequately prevented for. One month later, at relaparotomy due to a persisting ileus, two loops of small intestines appeared to be intimately fixed to the mesh in adhesions, prohibiting fecal flow. Complications did not occur in the polypropylene with additional Vicryl mesh repairs (8), other than two recurrences. Infection (3) did not lead to mesh removal. Bulging was seen in five patients (6 percent). One patient suffered from postoperative bleeding.

An attempt was made to trace the reasons for recurrences. Possible explanations were; The mesh was attached with ≤ 2 cm overlap (5), interrupted sutures were placed 2 cm apart (1), marked distention occurred during the first week (1), steroids were used (1), a large hematoma became infected (1), and a probably inadequate repair was performed during a painful procedure due to insufficient epidural anesthesia (1). In seven recurrent mesh repairs, a probable explanation was not found.

Combined treatment-groups (n=181). Postoperative pain was evenly distributed (19 percent: suture group n=19, mesh group n=15), and generally disappeared after the first month. Seven of these could be attributed to hematomas, five to recurrence. Postoperative serosanguineous leakage occurred following three suture and four mesh repairs (two recurred). An inadvertent enterotomy occurred in 4 patients (2 percent), without later complications. Also, suture thread sinus (1), pneumonia (4), urinary tract infection (3), and myocardial infarction (1) were documented.

Awareness. All patients were asked *before* each follow up physical examination whether they had noticed a recurrence. Of those that believed they did not have recurrences (*n*=139), physical examination revealed fourteen (10 percent) recurrences. All patients that believed they had recurrences (*n*=42) indeed had them on examination. Counting only these self-reported recurrences, the 3-year cumulative recurrence rate was 35 and 17 percent for the suture and mesh group, respectively (p=0.02).

5.5 Discussion

The technique of closure of incisional hernias has tended to develop as a practical, experiential matter. Several authors reported favorable results with mesh repair,[37, 232, 239, 242, 286, 340, 401, 403, 404, 431, 449] but to date this technique has never been investigated in a proper randomized fashion. We now report a prospective randomized multicenter trial comparing suture closure to mesh repair.

Incisional hernia repairs using suture techniques bring the defect edges together, which may lead to excessive tension and subsequent wound failure, due to tissue ischemia and sutures cutting through the tissues.[130] Prosthetic mesh allows defects of any size to be repaired without tension. In addition, polypropylene mesh, by inducing an inflammatory response, sets up a scaffolding that, in turn, induces collagen synthesis. The current study now proves the superiority of mesh repair over suture repair with regard to hernia recurrence. It is worthwhile noting that the data suggest that this superiority also applies to small hernias (defects ≤ 10 cm^2, $p=0.01$).

In the present study no measures were taken to blind the clinicians and patients in evaluating recurrences, which might be considered a limitation of the study. Identical inquiry forms not stating the performed repair were used, but in 17 percent of cases the surgeon who performed the operation also exclusively evaluated that patient at follow-up. Furthermore, with thorough examination the performed technique sometimes may be suspected, because of the fact that following mesh repair a fascial rim can be palpated in the non-obese patient with a large fascial defect. Therefore, the attending physicians may have known which technique was performed, and bias on their part may have affected the outcome. However, the recurrence rate following suture repair was similar to that predicted on the basis of our previous work.[157, 253, 255] Also, when only the self-reported recurrences, which are likely to be less susceptible to biased ascertainment, were counted, the difference remained significant ($p=0.02$). It is unlikely, therefore, also because the differences found are so large, that the results are due to observer bias.

Hernia-size was an independent risk factor in two retrospective studies of our group, evaluating 'approximating'[255] and 'overlapping' (Mayo) repairs.[253] Another study failed to find significance ($p=0.06$).[259] In retrospective studies, however, defect-size is seldom sufficiently described and analysis is therefore less reliable. Also, the extent of decrease of laxity of the hernia surrounding tissues, influenced by muscle retraction and scarification, may be more important than the actual size of the fascial defect. In this prospective study, defect-size did not prove a risk factor for recurrence in either repair.

Patients operated for an abdominal aortic aneurysm prior to incisional hernia repair had significantly higher recurrence rates compared to patients without this history. An increased frequency of (recurrent) inguinal[8, 59] and incisional hernia[8, 152, 164, 395] in aneurysm patients has been previously reported in several retrospective studies. Others, however, did not confirm these results.[186, 195] A speculative issue is whether an inherent defect in healing exists in the patient with aortic aneurysmal and/or hernial disease. A

variety of pathological mechanisms have been suggested to be accountable, like defects in collagen and elastin cross-linkages,[413] increased elastase activity with reduced elastin content,[58] and different relative proportions of collagen subtypes.[124, 212a, 280] Smoking may also be a factor,[334] but was not of influence in this study. Altered collagen metabolism may play an important role in predisposing an individual to hernia formation.[124] Further evidence for this correlation and its pathogenesis is needed.

Infection did not lead to polypropylene mesh removal in this and most other series,[239, 286, 401, 431] but was a risk factor for recurrence. Therefore, including broad spectrum antibiotics at the induction of anesthesia is recommended. This reduces infection rates,[5] and recurrence rates.[438a]

From our results we recommend adhesion of the prosthesis to the backside of the defect with as large as possible overlap. Suturing of the mesh should probably be best with a stitch interval of no more than 1-2 cm, either continuous or interrupted, with monofilament sutures placed in healthy fascia. Stapling may [13] or may not [449] be an alternative. Bulging must be prevented but the mesh should not be implanted under tension. Contact of polypropylene mesh with viscera must be avoided because of the risk of adhesions and fistula formation.[286] When peritoneum or omentum is not available, Vicryl mesh interposition may be performed to protect the viscera,[83, 249, 403] but experimental and clinical studies are not conclusive regarding the efficacy of Vicryl interposition preventing these complications.[83, 391] Therefore, Vicryl interposition, 'premuscular prefascial' or 'retromuscular prefascial' mesh placement,[340, 403, 449] use of mechanical adhesion barriers,[166, 289] or prosthesis with an adhesive as well as a nonadhesive layer need further attention.[37, 380, 391]

In conclusion, this first randomized study shows that a retrofascial preperitoneal polypropylene mesh repair is superior to suture repair with regard to hernia recurrence. Operative time, hospital stay, and complications like postoperative pain and leakage were similar in both repairs. Our study indicates that prosthetic repair is the method of choice for all non-emergency incisional hernia repairs, irrespective of size, and should encourage surgeons to use prosthesis even in repair of small incisional hernia defects.

CHAPTER 6

Discussion, general recommendations, and conclusion.

Old ideas die hard.
Thomas B. Hugh, 1991

Combining our research results and knowledge from the literature, the following summarizing statements and recommendations about risk factors and technique are made:

6.1 Risk factors

Evidence based risk factors, as discussed in the 'Introduction', can be appreciated from the following. It is emphasized, however, that most of these risk factors are not a constant finding, and that they are derived from studies of different quality (e.g. retrospective vs. prospective studies, uni- or multivariate analysis, follow up, survival- or non-survival analyses, number of patients, physical examination).

Abdominal closure. Evidence based risk factors with regard to incisional hernia 'the novo' following abdominal closure are patient-related and operation-related. Patient-related risk factors found in the literature are male gender, age, obesity, diabetes, pulmonary disease, postoperative abdominal distention, jaundice, multiple previous laparotomies, and a history of operated aortic aneurysmal disease. Operation-related risk factors are incision site, incision length, suture material, suture length to wound length ratio, duration of operation, wound infection, emergency operation, blood transfusion, and the surgeon's expertise.

Incisional hernia repair. With regard to incisional hernia recurrence following repair, the evidence based risk factors are slightly different and supplemented with hernia-related risk factors. Patient-related risk factors are male gender, obesity, prostatism, smoking, use of steroids, and a history of operated aortic aneurysmal disease. Operation-related risk factors are suture repair, and wound infection. Hernia-related risk factors are previous hernia repairs, previous wound dehiscence, and the size of the hernia.

No evidence was found in the literature regarding diastasis recti, constipation, malnutrition, oncologic disease, radiotherapy, chemotherapy, fascia quality, different kinds of anesthesia, and wound hematoma.

The above mentioned risk factors are derived from studies with various incisional hernia repairs, and therefore may not apply to the now recommended incisional hernia repair with the use of a prosthesis. In our randomized study, only infection and aortic aneurysmal disease were identified as risk factors for mesh repair (prostatism was identified as a risk factor in univariate analysis of the suture repairs and remained significant in multivariate analysis of the combined repairs).

6.2 Technique recommendations

Controversy over laparotomy technique, suture material, and incisional hernia repair will continue and will not get resolved with this thesis. However, with the scientific knowledge now available, the following is recommended:

6.2.1 Fresh laparotomy, state of the art.

Incision. Many factors influence the surgeon's choice when making an abdominal incision. Some will be overriding, such as inadequate access through alternative incisions, or previous surgery which makes it illogical to open the abdomen via an entirely separate incision.[107] However, there are many occasions when either a vertical or transverse incision would be appropriate. Careful consideration which incision will best serve the surgeon's purpose without sacrificing the future welfare of his patient in stead of personal preference or convention should select the route of final choice. With regard to this, apart from other factors, the incisional hernia rate has to be taken into consideration.

Any abdominal incision may be followed by subsequent herniation, but some incisions seem to be more susceptible. In trials randomizing for incisions, significant differences with regard to incisional hernia appearance are being demonstrated, despite the often short follow up. The *lateral* paramedian incision consistently has significantly lower rates of wound failure than medial paramedian or midline incisions.[46, 79, 149, 201] Furthermore, subcostal incisions perform significantly better than upper midline incisions in two trials.[41, 245] The morbidity of the hernia and of reoperation far exceeds the saving in time which makes the midline incision so popular. The midline incision should therefore be replaced as the main opening into the abdomen.[55] The lateral paramedian incision should probably supersede the midline incision in elective operations. As discussed in Chapter 4, for lower abdominal surgery, the use of the Pfannenstiel incision may be a good alternative, with incisional hernia being a rare complication, and the incision allowing for excellent cosmetic results. More cranially located transverse incisions with vertical partial splitting of the linea alba deserve further attention. In spite of its limitations with regard to wound failure, however, the midline vertical incision is very useful in certain situations when wide exposure or rapid entry is needed.

Closure. Secure wound closure is essential for an uncomplicated and appropriate recovery after abdominal surgery. The most serious wound complications are wound dehiscence, incisional hernia, and infection. These complications are closely related to the condition of the patient, type of incision, suturing technique, and material used for closure.[348] In the repair of fresh abdominal wounds, certain principles must be followed. The following is recommended:

Lateral paramedian incision (planned operations): Closure is performed in two layers. The closure of a lateral paramedian incision proved to be independent of the SL:WL ratio.[201] With regard to the suture material, it seems that nonabsorbable

(Prolene)[46] as well as slowly absorbable sutures (PDS)[201] can be used, in a continuous fashion (no comparative studies available).[161a]

Midline incision (emergency operations): Good results should not be sacrificed for speed. The abdominal wall is sutured in one layer, excluding the skin and the peritoneum ('mass closure'). Separate suturing of the peritoneum is unnecessary, and may actually cause harm by increasing adhesions to the back of the wound.[105, 132, 199] The preferred suture material is a long monofilament suture, with a double stranded loop. The issue of delayed absorbable sutures or nonabsorbable sutures is not yet settled, i.e. due to short follow up evaluation of most studies addressing this subject.[161a] Slowly absorbable suture materials may however put the abdominal wound at risk when wound healing is delayed (e.g. wound infection, steroid medication). Continuous running suturing is performed in a loosely approximating way, preventing strangulation of the encircled tissue. Tension sutures are not helpful and should be abandoned.[174] In midline closures the length of the suture must be at least 4 times the length of the wound and the stitch length must be less than 5 cm. This is achieved with tissue bites and stitch intervals of for instance both 1 cm or both 2 cm. Knotting depends on the suture material used. With a double stranded loop suture, the first knot becomes unnecessary, simply by putting the needle through the loop after completion of the first bilateral tissue bite.

6.2.2 Incisional hernia repair, state of the art.

There is an important association between wound infection and failure of both suture and mesh incisional hernia repair. The effectiveness of prophylactic broad spectrum antibiotics in reducing infection rates is well documented, also with regard to incisional hernia repair.[5] Prophylactic antibiotics also reduce incisional hernia recurrence rates,[438a] and therefore should be administered 30 minutes before repair.

The old scar is excised. The hernial sac may be found just beneath the skin. The margins of the defect must be clearly identified, as must the peritoneal layer or posterior rectus sheath. Some authors therefore advice to always completely expose the entire previous incision.[204, 449] Tissue not contributing to the reinforcement of the repair must be identified and not used for suturing. This tissue may be useful for covering of mesh, however.

Retromuscular retrofascial preperitoneal polypropylene mesh repair is superior to suture repair. There is no subgroup identified, yet, that performs equal to or better without mesh. Current infection is a contraindication for whatever repair. Inadvertent enterotomie, however, may make implantation of a foreign body less desirable.[299] Contact of polypropylene mesh with viscera must be avoided, e.g. by closure of peritoneum or positioning of omentum between the mesh and intraabdominal organs. Vicryl interposition,[83, 449] other anatomic mesh positions,[133, 361] use of mechanical barriers (e.g. Interceed®, Seprafilm®),[11, 166, 266, 289] or prosthesis with an adhesive and a nonadhesive layer (e.g. Composix®) needs further attention.[37, 380] The aim is face-to-face adhesion of the prosthesis to the abdominal wall, not edge-to-edge patching,[401] so

sufficient overlap should be created. The amount of overlap of the mesh should probably extend at least 3-4 cm beyond the margins of the defect, but this issue needs further attention. Suturing of the overlapping mesh can be performed to the back of the abdominal wall or to the edge of the hernial ring. Stapling may or may not be an alternative.[13, 449] Wrinkles, folds, and bulging should be avoided, although some laxity of the mesh at operation is likely to be corrected by eventual shrinkage of the mesh.[19]

Closure of the defect over or under the mesh repair is optional. Some authors cover the mesh with a musculoaponeurotic layer, but not when this objective would result in excessive tension.[206, 323] To quantify tissue tension objectively, intraoperative tensiometry measurements by tensiometers may be an option.[206] Others believe that reattaching the tendons of the retracted lateral abdominal muscles is an important objective in reconstruction, to accomplish a normal anatomic and physiologic abdominal wall, especially with regard to large fascial defects.[323] Relaxing incisions or rectus sheath techniques may often be necessary. Contact of the mesh with the skin should be avoided to prevent erosion of the mesh through the skin.[273]

Closed suction drainage may be essential to prevent hematomas and seromas in the space containing mesh, especially with large repairs.[286, 449] When a seroma occurs it can be treated by aspiration under aseptic conditions when the collection is large and troublesome. Smaller collections disappear in a few weeks.[323] Hematomas obviously result from imperfect hemostasis. Small hematomas need not to be disturbed, but larger hematomas require evacuation and meticulous hemostasis in the operating room.[323]

When suppuration occurs, drainage of the wound is essential. When a mesh repair is performed, the implanted material might become infected. Depending on the circumstances and the used material, the mesh can be left in place or should be removed. Many early infections will respond to drainage, irrigations, compresses, and antibiotic therapy.[323]

With regard to the indication for rectus sheath techniques, laparoscopic techniques, the best anatomic mesh position, and the best prosthetic material for incisional hernia repair, further randomized trials have to be awaited.

6.3 Does every incisional hernia need repair?

Indication for operation. Complicated incisional hernias, giving rise to for instance ileus or strangulation, need immediate repair. Other hernias can be operated in an elective setting. At this time, however, no consensus has been reached about whether, and when to operate on a patient with an incisional hernia. It is generally agreed that a hernia should be repaired to avoid the complication of incarceration and its attendant risk of strangulation.[138] Indications for operation are not evidence based, however, since no precise figures from large studies are available with respect to complications like ileus, strangulation, mortality, and getting larger with time of nonoperated incisional hernias. Moreover, incisional hernia repair is not without complications. The mortality rate varies from zero to 5.3 percent in elective repairs (figures may be less accurate in the smaller series). Furthermore, ileus, infections, hematomas, etc. may occur, sometimes making relaparotomy necessary. Also, hernia recurrence rates can be high, dependent on the repair technique used and the associated risk factors.

In practice, patients with physical or esthetical complaints of their incisional hernias usually do get operated (approximately one out of three patients),[110, 287] unless there are cardiopulmonal or conditional contra-indications for operation. Also, obesity and old age may the surgeon make decide not to operate.[376]

As mentioned above, incisional hernias do occasionally result in incarceration and strangulation of intraabdominal structures, primarily the small bowel. If not promptly reduced, a strangulated small bowel may become ischemic, necrose, and ultimately perforate. Patients choosing to leave their incisional hernia unrepaired need to be told to watch for the development of a painful, irreducible lump at the site. The patient must be advised to seek immediate care should this occur. The early (within four to six hours) reduced lump or emergency operation will forestall development of gangrene, and is therefore most likely to have a favorable outcome compared to late interference.[104, 138, 161, 323, 374] In a study on a series of 132 patients with incarceration and emergency operation of a miscellaneous group of abdominal wall hernias (inguinal, femoral, umbilical, incisional, and ventral), there were 6 postoperative deaths (4.5 percent).[138] Patients who died had an average of 8.2 days of symptoms prior to surgical intervention, and five out of six were not operated on in the first 24 hours after admission.

No studies have been done that compare well-warned non-operated incisional hernia patients with patients that do get their incisional hernia repaired. To define the exact indications for incisional hernia repair to this respect, a randomized trial is needed.

6.4 Questions left to be answered

In the process of preparation of this thesis some unsolved problems became visible which do need further evaluation. Hopefully, these items will get resolved by researchers around the world in the near future. The following matters should be considered:

What are the exact indications for incisional hernia repair? An objective comparison between no repair and mesh repair is needed by means of a randomized trial.

Do all incisional hernias spontaneously get larger with time, with increasing difficulty of repair and higher recurrence rates? This assumption[25, 225, 449] has not been adequately studied, and should be one of the parameters studied in the above-mentioned randomized trial.

What is the time required for human fascial healing? For how long should a suture material keep its tensile strength following abdominal closure with regard to fascial healing time? Are delayed absorbable sutures sufficient (even in the presence of infection or other causes of delayed wound healing), or should nonabsorbable suture material be used for abdominal closure? This may also differ with the various incisions used for entry. Randomized studies and long follow up evaluation are needed.

What is the best mesh repair, and what is the amount of overlap needed? The various anatomic positions and techniques of open and laparoscopic mesh repairs need further attention, in a randomized fashion.

What are the long-term complications with mesh (e.g. more difficult re-entry, mesh shrinkage, mesh migration, incidence of intestinal fistula), and which prosthetic material does best serve our needs?

Do obese patients with an incisional hernia have to loose weight before mesh repair? The notion expressed that only those who have dieted successfully should be considered denies the realities of the clinical situation.

Should one always plan to open the entire previous incision even if the preoperatively detected hernia is not large, since multiple hernias are often present in the incision?[229, 449, 465] Failure of doing so may leave additional hernias unrepaired and 'recurrence' inevitable. On the other hand, large dissections may have a higher complication rate and, because of the larger area that now must heal, may have a higher recurrence rate.

To avoid contact of polypropylene mesh with viscera when peritoneum or omentum is not available, Vicryl mesh interposition, subcutaneous or subaponeurotic mesh placement, use of mechanical adhesion barriers, or prosthesis with an adhesive as well as a nonadhesive layer need further attention.

Will certain rectus sheath techniques or laparoscopic repairs prove to be better than open mesh repair, and for which patients and incisional hernias? Especially Ramirez's

'components separation method' technique in progressive steps should be analyzed further for large and massive incisional hernias. Also, laparoscopic repairs may have certain advantages. Randomized trials are needed.

Is a disturbed collagen mechanism or other chemical aberration/ genetic disorder an etiologic factor for incisional hernia (and aneurysmal disease) and, if so, can this be corrected?

6.5 Conclusions

If we are to decrease the incidence of incisional hernias, we must become aware of every factor that could be important in their production. It is clear that the surgeon, through choice of incision and closure material, careful surgical technique, adequate control of infection, and sound preoperative preparation of the patient, has the necessary knowledge and information to minimize the incidence of incisional hernias. Once an incisional hernia has occurred, and repair is undertaken, mesh repair is superior to suture repair with regard to incisional hernia recurrence. Until additional randomized trials prove differently, retrofascial preperitoneal polypropylene mesh repair is the method of choice for all non-emergency incisional hernia repairs, including those with small fascial defects.

CHAPTER 7

Summary

In this thesis, the research performed by our group and the available literature were combined to define the incisional hernia problem. Incidence, morbidity, mortality rates, possible etiologies, risk factors, prevention, and techniques of repair were scrutinized. Incisional hernia appears to be a major health care problem.

Chapter 1 reviews the literature and describes the outline of the problem. From currently available data the following conclusions are conducted:

In prospective studies with sufficient follow up evaluation, the incidence of primary incisional hernia ranges 11 to 19.5 percent of laparotomies. Surprisingly, even higher rates are reported in some short-term evaluation studies, up to 24 percent (Table I). Longer follow up would very likely further increase these rates. In long term follow up studies, several authors demonstrated that the incidence may be expected to almost double after the first year. Therefore, because incisional hernias develop with time, and patients have variable lengths of follow up, life-table methods are essential for studying hernia appearance and recurrence rates. Failure to do so may lead to underestimation and erroneous conclusions. So, focusing on hernia appearance and recurrence rates, at least several years of follow up evaluation and life-table analysis are recommended.

Most incisional hernias are symptom-free and are discovered only upon physical examination. However, incisional hernias can be a significant source of morbidity, and delay of repair may have serious clinical consequences, like incarceration (6-14.6 percent) and strangulation (2.4 percent). If not promptly reduced, a strangulated small bowel may become ischemic, necrose, and ultimately perforate. The mortality rate of complicated incisional hernia repair in recent literature ranges zero to 10.4 percent, whereas elective repairs have rates ranging zero to 5.3 percent (Table II). Massive hernias may give rise to dystrophic ulceration of skin and subsequent evisceration, chronic abdominal and back pain, and respiratory complications due to diaphragmatic dysfunction. Furthermore, patients may have complaints about the esthetic appearance of their incisional hernia, ranging from a disfiguring lump and difficulties with clothing to feelings of inferiority.

Physical examination is essential in determining the presence of hernia recurrence and studies that score hernia presence by questionnaire are of limited value. In recent literature recurrence rates up to 54 percent following primary nonprosthetic repair have been reported (Table III). Prosthetic repairs have better but still high recurrence rates, mostly less then 10 percent but up to 34 percent (Table XXV). Following recurrent incisional hernia repair, recurrence rates up to 49 percent have been described (Table IV).

Several series of suture and prosthetic incisional hernia repairs have been reported, but these are either uncontrolled or non-randomized trials. At this time no consensus has been reached about whether, how, and when to operate on a patient with an incisional hernia.

In *Chapter 2* a series of 68 patients with a primary midline incisional hernia, repaired between 1981 and 1990 using a vertical overlapping Mayo repair, was evaluated, retrospectively. Patients without documented hernia recurrence were invited for physical examination. The mean follow up was 35 months, for cases without recurrence 50 months. Life-table methods were used for statistical analysis. The 1-, 3-, 5-, and 10-year cumulative recurrence rates were 35, 46, 48, and 54 percent, respectively. Also, generally accepted risk factors were studied. Multivariate analysis identified the size of the hernia ($p=0.02$) and the use of steroids ($p=0.04$) as independent risk factors for recurrence. Considering the high recurrence rates found, the results do strongly suggest that the vest-over-pants repair as described in this study should no longer be used for closure of midline incisional hernias.

These figures and conclusions were recently confirmed by Paul et al.[308-310] In this German study the recurrence rate after the Mayo duplication repair was 54 percent (no survival analysis) during a follow up time of 5.7 years with a follow up rate of 84 percent. Nonabsorbable sutures were used (Ethibond®). At follow up physical examination and ultrasound was used. In another recent German study, Trupka found a recurrence rate of 38 percent with a mean follow up of 44 months following Mayo repair, also supporting our conclusions.[422]

In *Chapter 3* a series of 130 patients with a primary midline incisional hernia, repaired between 1980 and 1989 using an approximating repair, was evaluated retrospectively. Patients without documented hernia recurrence were invited for physical examination. The mean follow up was 46 months, for cases without recurrence 57 months. Life-table methods were used for statistical analysis. The 1-, 3-, 5-, and 10-year cumulative recurrence rates were 20, 37, 43, and 67 percent, respectively. Also, generally accepted risk factors were studied. Multivariate analysis identified wound infection ($p=0.006$) as independent risk factor of first time recurrent incisional hernia, whereas obesity tended to significance (p-trend$=0.08$). Considering the high recurrence rates found, the results do strongly suggest that the approximating repair as described in this study should no longer be used for closure of midline incisional hernias.

In *Chapter 4*, seeking for an incision that prevents for incisional hernia appearance, the prevalence of incisional hernia and nerve entrapment in patients operated upon by means of a Pfannenstiel incision was evaluated. The Pfannenstiel incision is a transverse skin and transverse anterior rectus sheath incision combined with a longitudinal partial thickness dorsal linea alba incision. All adult women, operated on between 1986 and 1992 through a Pfannenstiel incision and not having had another lower abdominal incision other than for laparoscopy, were invited for physical examination, with special interest to the presence of incisional hernia or nerve entrapment. In patients having had a Pfannenstiel incision, no incisional hernias were found. In patients also having had a laparoscopy, the incisional hernia rate was 3.5 percent. In all these incisional hernias, the defect was located at the site of the previous trocar stab wound, just caudal to the umbilicus. Nerve entrapment was found in 3.7 percent. The length of the incision was identified as a risk factor ($p=0.02$). In conclusion, wherever feasible, the use of the Pfannenstiel incision in lower abdominal

surgery is recommended, because incisional hernia is a rare complication, and the incision allows for excellent cosmetic results. Complications of nerve damage, however, are not uncommon and should be recognized. Nerves should be identified and preserved, especially when extending the incision more laterally. Depending on the operation to be performed, the advantages mentioned above may counterbalance the disadvantages.

In *Chapter 5*, to define the indications for use of prosthetic materials in incisional hernia repair, a prospective randomized multicenter trial was conducted. Between March 1992 and February 1998, 200 adult patients scheduled for repair of a primary or first-time recurrent incisional hernia of a vertical midline incision, the preoperative defect not exceeding 6 x 6 centimeters, were randomized to suture or retromuscular, retrofascial, preperitoneal prosthetic repair. The patients were followed up at one, six, 12, 18, 24, and 36 months, for physical examination. In addition, potential risk factors for recurrent incisional hernia were analyzed, using life-table methods. A total of 19 patients were found not eligible. Among the evaluated 154 primary and 27 first-time recurrent incisional hernia patients there were 56 recurrences. The average follow up for patients without recurrence was 26 months. The 3-year cumulative recurrence rates of the suture and mesh repair were 43 and 24 percent ($p=0.02$) for primary repairs (95% CI for this 19% difference: 3% to 35%) and 58 and 20 percent ($p=0.10$) for first-time recurrent repairs (95% CI for the difference: -1% to 78%). When both hernia groups were combined, the significance increased ($p=0.005$), with a difference of 23 percent (95% CI: 8% to 38%). Multivariate analysis identified suture repair, infection, prostatism, and operated aortic aneurysm as independent risk factors, but not defect-size. Analyzing the subgroup of small hernias (≤ 10 cm^2), suture repair ($n=30$) resulted in a 3-year cumulative recurrence rate of 44 percent. The recurrence rate in the mesh repair group ($n=20$) was 6 percent ($p=0.01$). In conclusion, this first randomized study regarding the specialty of incisional hernia repair shows that a retromuscular, retrofascial, preperitoneal prosthetic repair is superior to suture repair with regard to hernia recurrence, irrespective of fascial defect size. Postoperative pain, leakage, duration of operation, and hospital stay were similar in both repairs. This study indicates that prosthetic repair is the method of choice for all non-emergency incisional hernia repairs and should encourage surgeons to use prosthesis even in repair of small incisional hernia defects.

In *Chapter 6*, combining our studies and the knowledge from the literature, the evidence based risk factors for abdominal closure and incisional hernia repair are summarized. Also, the unsolved problems regarding the 'science of incisional hernia' are discussed. Furthermore, the *state of the art* closure of fresh laparotomy wounds and incisional hernias is defined. It is concluded that, once an incisional hernia has occurred and repair is undertaken, mesh repair is superior to suture repair with regard to incisional hernia recurrence. Until additional randomized trials prove differently, prosthetic repair is the method of choice for all non-emergency incisional hernia repairs, irrespective of fascial defect size.

CHAPTER 8

Samenvatting

In dit proefschrift worden de bevindingen uit eigen onderzoek gecombineerd met de gegevens uit de literatuur, zodat eerst de omvang van het probleem dat veroorzaakt wordt door littekenbreuken kan worden bepaald. De incidentie, de morbiditeit, de operatiesterfte, de mogelijke oorzaken en risicofactoren, hoe littekenbreuken kunnen worden voorkomen en de verschillende chirurgische technieken worden uitvoerig belicht. Daaruit komt duidelijk naar voren dat littekenbreuken een groot probleem in de huidige gezondheidszorg vertegenwoordigen.

Hoofdstuk 1 geeft een overzicht van de literatuur op het gebied van littekenbreuken. De geschiedenis wordt belicht en de littekenbreuk gedefinieerd. Uit de ons nu bekende literatuurgegevens worden de volgende conclusies getrokken:

Uit prospectieve studies met een lange follow-up blijkt dat littekenbreuken na 11 tot 19,5 procent van alle buikoperaties voorkomen. Opvallend genoeg worden in sommige studies met een korte follow-up zelfs nog hogere percentages genoemd, tot 24 procent (Tabel I). Als de follow-up van deze studies zou worden verlengd zou het percentage zeer waarschijnlijk nog hoger worden, omdat uit verschillende studies met lange follow-up gebleken is dat de incidentie vrijwel verdubbelt na het eerste jaar. Omdat littekenbreuken zich kunnen ontwikkelen gedurende een lange tijd en patiënten vaak een variabele follow-up hebben is overlevingsstatistiek een voorwaarde voor het bepalen van de incidentie en recidiefpercentages van littekenbreuken. Als dit wordt nagelaten kunnen deze getallen te laag worden berekend, hetgeen tot verkeerde conclusies kan leiden.

De meeste littekenbreuken veroorzaken geen klachten en worden pas bij lichamelijk onderzoek ontdekt. Andere littekenbreuken vormen echter een belangrijke bron van morbiditeit. Incarceratie wordt beschreven in 6 tot 14.6 procent en strangulatie in 2.4 procent van de gevallen. Als een gestranguleerde darm niet direct wordt bevrijd, al dan niet operatief, dan zal deze ischemisch en necrotisch worden en uiteindelijk perforeren. Het percentage patiënten dat overlijdt na een operatie van zo'n gecompliceerde littekenbreuk varieert in de literatuur van nul tot 10.4 procent en na een electieve ingreep van nul tot 5.3 procent (Tabel II). Zeer grote littekenbreuken kunnen verder de reden zijn van ulceraties van de huid (met soms zelfs een 'gebarsten buik' tot gevolg), chronische buik- en rugklachten en problemen met het ademhalingsapparaat ten gevolge van een gestoorde functie van het diafragma. Niet in de laatste plaats worden littekenbreuken vaak als lelijk ervaren door de patiënt. Dit varieert van klachten over een ontsierende zwelling en problemen met de kleding tot gevoelens van minderwaardigheid.

Het lichamelijk onderzoek is essentieel bij het bepalen van de aanwezigheid van een (recidief) littekenbreuk. Studies die gebruik maken van vragenlijsten zonder dat lichamelijk onderzoek wordt verricht zijn van weinig waarde. Uit de recente literatuur blijkt dat indien een littekenbreuk voor de eerste keer wordt gerepareerd met behulp van hechtingen, de littekenbreuk variërend van nul tot 54 procent van de gevallen terugkomt (Tabel III). Indien deze littekenbreuken worden gerepareerd met behulp van een onoplosbaar matje van prothetisch materiaal, dan zijn deze recidiefgetallen lager, meestal onder de tien procent, maar soms oplopend tot 34 procent (Tabel XXV). Indien

een littekenbreuk voor de tweede keer of vaker gerepareerd wordt, dan worden recidiefpercentages tot 49 procent beschreven (Tabel IV).

Er zijn veel studies gepubliceerd over reparaties van littekenbreuken met en zonder prothetisch materiaal, maar deze studies zijn allemaal zonder controlegroep of niet gerandomiseerd uitgevoerd. Er is daarom heden ten dage nog geen consensus bereikt over hoe en wanneer een patiënt met een littekenbreuk geopereerd moet worden.

In ***Hoofdstuk 2*** wordt een retrospectieve studie beschreven naar de resultaten van de verticale overlappende 'Mayo- plastiek' die verricht werd voor de reparatie van primaire littekenbreuken van de middellijn van de buik. In totaal werden 68 patiënten onderzocht die tussen 1981 en 1990 in het Sint Franciscus Ziekenhuis Rotterdam waren geopereerd. Alle patiënten werden lichamelijk onderzocht op de polikliniek, tenzij een recidief littekenbreuk al vast stond. Voor de statistische analyse werd onder andere overlevingsstatistiek gebruikt. De gemiddelde follow-up bedroeg 35 maanden, voor patiënten zonder recidief 50 maanden. De 1-, 3-, 5- en 10-jaar cumulatieve recidiefpercentages waren respectievelijk 35, 46, 48, en 54 procent. Ook de algemeen aanvaardde risicofactoren werden onderzocht. Met behulp van multivariate analyse werden de grootte van de poort van de littekenbreuk ($p=0.02$) en het gebruik van medicatie met corticosteroïden ($p=0.04$) als onafhankelijke risicofactoren voor het ontstaan van een recidief littekenbreuk geïdentificeerd. Op basis van de hoge recidiefpercentages die in deze studie aan het licht kwamen werd geconcludeerd dat de 'Mayo-plastiek' zoals beschreven in deze studie niet langer gebruikt moet worden voor de reparatie van primaire littekenbreuken van de middellijn.

In ***Hoofdstuk 3*** wordt een retrospectieve studie beschreven naar de resultaten van de approximerende plastiek die verricht werd voor de reparatie van primaire littekenbreuken van de middellijn van de buik. In totaal werden 130 patiënten onderzocht die tussen 1980 en 1989 in het Academisch Ziekenhuis Rotterdam -Dijkzigt waren geopereerd. Alle patiënten werden lichamelijk onderzocht op de polikliniek, tenzij een recidief littekenbreuk al vast stond. Voor de statistische analyse werd onder andere overlevingsstatistiek gebruikt. De gemiddelde follow-up bedroeg 46 maanden, voor patiënten zonder recidief 57 maanden. De 1-, 3-, 5- en 10-jaar cumulatieve recidiefpercentages waren respectievelijk 20, 37, 43, en 67 procent. Ook de algemeen aanvaardde risicofactoren werden onderzocht. Met behulp van multivariate analyse werd het optreden van een wondinfectie ($p=0.006$) als onafhankelijke risicofactor voor het ontstaan van een recidief littekenbreuk geïdentificeerd, terwijl obesitas naar significantie neigde (p-trend$=0.08$). Op basis van de hoge recidiefpercentages die in deze studie aan het licht kwamen werd geconcludeerd dat de approximerende plastiek zoals beschreven in deze studie niet langer gebruikt moet worden voor de reparatie van primaire littekenbreuken van de middellijn.

In ***Hoofdstuk 4*** wordt, op zoek naar een chirurgische incisie die littekenbreuken kan voorkomen, de prevalentie van littekenbreuken en zenuwbeklemming in patiënten met een Pfannenstiel-incisie geëvalueerd. Bij de Pfannenstiel-incisie wordt de huid boven het schaambeen en de voorste rectusschede transversaal en de linea alba (alleen dorsaal) longitudinaal geïncideerd. Alle volwassen vrouwen die tussen 1986 en 1992 op de afdeling Gynaecologie van het Academisch Ziekenhuis Rotterdam -Dijkzigt werden geopereerd met behulp van een Pfannenstiel-incisie en die daarnaast met uitzondering van een laparoscopie niet waren geopereerd door een andere onderbuikincisie, werden uitgenodigd voor een bezoek aan de polikliniek. Alle patiënten werden lichamelijk onderzocht naar de aanwezigheid van een littekenbreuk en tekenen van een zenuwbeklemming. In patiënten met alleen een Pfannenstiel-incisie werden geen littekenbreuken aangetroffen. In de patiënten die daarnaast ook een laparoscopie hadden ondergaan was het littekenbreukpercentage 3,5 procent. Al de gevonden littekenbreuken bevonden zich nabij de navel, op de plaats van het litteken van de vroegere trocar-insteekopening. Zenuwbeklemming werd gevonden in 3,7 procent van de patiënten. De lengte van de Pfannenstiel-incisie kon worden geïdentificeerd als een risicofactor ($p=0.02$) voor het optreden van een zenuwbeklemming. Op basis van de resultaten van deze studie werd geadviseerd, indien de te verrichten operatie dat toestaat, de Pfannenstiel-incisie te gebruiken, omdat littekenbreuken zeldzaam zijn en het litteken dat zich in de grens van de pubisbeharing bevindt een mooi cosmetisch resultaat heeft. Een zenuwbeschadiging is echter een complicatie die de aandacht verdient. De zenuwen moeten geïdentificeerd en gespaard worden, met name als de Pfannenstiel-incisie verder naar lateraal wordt verlengd.

In ***Hoofdstuk 5*** wordt de eerste in de wereld verrichtte gerandomiseerde studie op het gebied van littekenbreuken gepresenteerd. Het betreft een multicentrum-studie (elf ziekenhuizen), geleid vanuit het Academisch Ziekenhuis Rotterdam -Dijkzigt. Het huidige artikel beschrijft de eerste resultaten. Omdat de resultaten van onze studies naar de resultaten van de 'Mayo-plastiek' (Hoofdstuk 2) en de approximerende techniek (Hoofdstuk 3) zo slecht waren werd besloten de indicaties voor het gebruik van prothetisch materiaal voor de reparatie van littekenbreuken te bepalen. Daartoe werden tussen 1992 en 1998 tweehonderd volwassen patiënten die op de opnamelijst stonden voor het verrichten van een primaire of eerste recidief littekenbreukcorrectie van de middellijn en waarvan de preoperatief bepaalde breukpoort niet groter was dan 6 bij 6 centimeter gerandomiseerd voor een van twee technieken. De ene techniek bestond uit het sluiten van de littekenbreuk met behulp van een onoplosbare polypropylene hechting (Prolene® no.1). De andere techniek bestond uit het sluiten van de breukpoort met behulp van een onoplosbaar polypropylene matje (Marlex® of Prolene®), geplaatst dorsaal van de rectus abdominis spier en zijn fascie, maar indien mogelijk ventraal van het peritoneum. Daarbij moest een overlap van het matje gecreëerd worden van ten minste 2 tot 4 centimeter. De patiënten werden na de operatie op de polikliniek teruggezien na 1, 6, 12, 18, 24 en 36 maanden, tijdens welk bezoek onder andere een lichamelijk onderzoek van het litteken werd verricht. Ook de algemeen aanvaardde risicofactoren werden geanalyseerd. Voor de statistische analyse werd onder andere overlevingsstatistiek gebruikt. Van de 200 patiënten kwamen er om verschillende redenen 19 niet in aanmerking voor analyse. Van de geëvalueerde 154 patiënten met een primaire littekenbreuk en de 27 patiënten met een eerste recidief littekenbreuk werd

na de operatie bij 56 patiënten een recidief littekenbreuk gevonden. Voor patiënten zonder recidief littekenbreuk was de gemiddelde follow-up 26 maanden. De 3-jaar cumulatieve recidiefpercentages van de correctie met de hechting en het matje waren 43 en 24 procent (p=0.02) voor primaire littekenbreukcorrecties (95% betrouwbaarheidsinterval voor dit 19% verschil: 3% tot 35%) en 58 en 20 procent (p=0.10) voor eerste recidief littekenbreukcorrecties (95% betrouwbaarheidsinterval voor dit verschil: -1% tot 78%). Als de beide littekenbreukcorrectie-groepen werden samengevoegd dan werd een grotere significantie bereikt (p=0.005), met een verschil van 23 procent (95% CI: 8% tot 38%). Met behulp van multivariate analyse werden de correctie met een hechting, wondinfectie, prostatisme (mannen) en een voorheen geopereerd aneurysma van de buikaorta als onafhankelijke risicofactoren voor het ontstaan van een recidief littekenbreuk geïdentificeerd. De peroperatief gemeten grootte van de breukpoort was geen risicofactor, hetgeen betekent dat bij grotere breuken geen hogere recidiefpercentages gevonden werden. Voorts werd ook voor kleine breuken ($\leq$ 10 cm^2) aangetoond dat de reparatie met prothetisch materiaal beter was dan die met een hechting (p=0.01). Concluderend blijkt uit dit gerandomiseerde onderzoek dat een littekenbreukcorrectie met een matje, zoals beschreven in deze studie, met betrekking tot het recidiefpercentage superieur is aan een littekenbreukcorrectie met een hechting, onafhankelijk van de grootte van de breukpoort. De hoeveelheid postoperatieve pijn en wondlekkage alsmede de duur van de operatie en de opname waren overeenkomstig voor beide technieken. Deze studie toont aan dat de beschreven littekenbreukcorrectie met behulp van een onoplosbaar matje de te verkiezen methode is voor de electieve reparatie van alle littekenbreuken, ook voor littekenbreuken met een kleine breukpoort.

In ***Hoofdstuk 6*** worden de resultaten van bovenstaande studies en de resultaten uit de literatuur met elkaar gecombineerd en worden de 'evidence-based' risicofactoren voor het ontstaan van littekenbreuken na het sluiten van een nieuwe buikincisie en na het sluiten van een littekenbreuk samengevat. Ook worden de nog onopgehelderde problemen met betrekking tot littekenbreuken besproken. Vervolgens wordt de 'state of the art' met betrekking tot het sluiten van nieuwe buikwonden en littekenbreuken bepaald. Er wordt geconcludeerd dat, als er eenmaal een littekenbreuk is ontstaan en een reparatie wordt gepland, een reparatie met behulp van prothetisch materiaal moet worden ondernomen. Totdat aanvullende gerandomiseerde studies mogelijk anders zullen bewijzen is de reparatie met behulp van een matje zoals beschreven in Hoofdstuk 5 de te verkiezen methode voor de electieve reparatie van alle littekenbreuken, onafhankelijk van de grootte van de breukpoort.

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Curriculum vitae

Roland Walter Luijendijk, son of Alexander Philip Luijendijk and Emma Wilhelmina Juliana Luijendijk-van Dijkhuizen, was born on June 9th, 1964, in Hazerswoude-dorp, the Netherlands. After graduating in 1982 from Secondary School (Samenwerkingsschool Waddinxveen), he started Medical School at the University of Leiden. During his study, he spent one year (1987-1988) as a research fellow in the United States of America, at the Departments of Anesthesiology and Plastic and Reconstructive Surgery of the University of Utah, Salt Lake City. In April 1988, he was a member of an American Interplast team to Santiago and Temuco in Chili. After he graduated in 1990 (MD), he spent 6 months as a plastic surgery resident at the Academic Hospital Leiden (*Prof. dr. D.E. Tolhurst, A.N. Posma, and R. Zeeman*). He then started as a research fellow at the Academic Hospital Rotterdam - Dijkzigt (*Prof. dr. J. Jeekel, and Dr. J.N.M. IJzermans*), worked two years as a surgery resident at the same hospital, and was accepted into general surgery training. In 1995, he started training at the Department of General Surgery, Sint Franciscus Gasthuis Rotterdam (*Dr. J.C.J. Wereldsma*). Later that year he got the opportunity to return to the field of plastic surgery, and decided to follow his heart. After being a plastic surgery resident at the Free University Hospital Amsterdam (*Prof. dr. J.W. Mulder, F.H. de Graaf, Dr. J.J. Hage, and H.A.H. Winters*), he was accepted into plastic surgery training. From 1996 until 1999 he trained at the Department of General Surgery, Leyenburg Hospital, The Hague (*Dr. C.M.A. Bruijninckx, Dr. J.C. Sier, Dr. B. Knippenberg, Dr. W.H. Steup, and P.V.M. Pahlplatz*). In November 1996, he was a member of a German-American Interplast team to Kibosho in Tansania (*Prof. dr. G. Lemperle, and Dr. Prakash Chhajlani*). In 1998 he married with Madeleine Jacobine Josefien Roeland, and their son Coen Walter Luijendijk was born. In January 1999, he returned to the Free University Hospital Amsterdam to continue his plastic surgery training.

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