

## European Hernia Society guidelines on the closure of abdominal wall incisions

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### Abstract

**Background** The material and the surgical technique used to close an abdominal wall incision are important determinants of the risk of developing an incisional hernia. Optimising closure of abdominal wall incisions holds a potential to prevent patients suffering from incisional hernias and for important costs savings in health care.

**Methods** The European Hernia Society formed a Guidelines Development Group to provide guidelines for all surgical specialists who perform abdominal incisions in adult patients on the materials and methods used to close the abdominal wall. The guidelines were developed using the Grading of Recommendations Assessment, Develop-

ment and Evaluation (GRADE) approach and methodological guidance was taken from Scottish Intercollegiate Guidelines Network (SIGN). The literature search included publications up to April 2014. The guidelines were written using the AGREE II instrument. An update of these guidelines is planned for 2017.

**Results** For many of the Key Questions that were studied no high quality data was detected. Therefore, some strong recommendations could be made but, for many Key Questions only weak recommendations or no recommendation could be made due to lack of sufficient evidence.

**Recommendations** To decrease the incidence of incisional hernias it is strongly recommended to utilise a non-midline approach to a laparotomy whenever possible. For elective midline incisions, it is strongly recommended to perform a continuous suturing technique and to avoid the use of rapidly absorbable sutures. It is suggested using a slowly absorbable monofilament suture in a single layer aponeurotic closure technique without separate closure of the peritoneum. A small bites technique with a suture to wound length (SL/WL) ratio at least 4/1 is the current recommended

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Meeting presentation: The EHS guidelines on the closure of abdominal wall incisions were presented during the 36th Annual Congress of the European Hernia Society in Edinburgh on May 31st 2014.

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method of fascial closure. Currently, no recommendations can be given on the optimal technique to close emergency laparotomy incisions. Prophylactic mesh augmentation appears effective and safe and can be suggested in high-risk patients, like aortic aneurysm surgery and obese patients. For laparoscopic surgery, it is suggested using the smallest trocar size adequate for the procedure and closure of the fascial defect if trocars larger or equal to 10 mm are used. For single incision laparoscopic surgery, we suggest meticulous closure of the fascial incision to avoid an increased risk of incisional hernias.

**Keywords** Guidelines · Abdominal wall closure · Laparotomy · Laparoscopy · Prophylactic mesh · Prevention · Incisional hernia

## Introduction

### Background

Incisional hernias are a frequent complication of abdominal wall incisions, but a wide range of incisional hernia rates are reported [1–6]. The weighted mean incisional hernia rate at 23.8 months was 12.8 % in a systematic review and meta-regression study [7], but incidence rates up to 69 % have been reported in high-risk patients with prospective long-term follow-up [8]. The reported incidence is determined by several factors: the patient population studied, the type of

abdominal wall incision, the length of follow-up and the method of incisional hernia diagnosis. Risk factors for incisional hernias include postoperative surgical site infection, obesity and abdominal aortic aneurysm [9–11]. Nevertheless, it seems that the suture material and the surgical technique used to close an abdominal wall incision, are the most important determinants of the risk of developing an incisional hernia [1, 12]. The development of an incisional hernia has an important impact on the patients' quality of life and body image [13]. Furthermore, the repair of incisional hernias still has a high failure rate with long term recurrence rates above 30 %, even when mesh repair is performed [14–16]. Optimising the surgical technique to close abdominal wall incisions using evidence based principles, holds a potential to prevent patients suffering from incisional hernias and the potential sequelae of incisional hernia repairs [17]. The mean direct and indirect costs for the repair of an average incisional hernia in an average patient in France in 2011 was € 7,089 [18]. Thus, reducing the incisional hernia rate by optimising the closure of abdominal wall incisions holds a great potential for costs savings in the use of health care facilities and in reducing postoperative disability.

The European Hernia Society (EHS) originated from the “Groupe de la recherche de la paroi abdominal” (GREPA), which was founded in 1979 with the aim: “The promotion of abdominal wall surgery, the study of anatomic, physiologic and therapeutic problems related to the pathology of the abdominal wall, the creation of associated groups which will promote research and teaching in this field, and the

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development of interdisciplinary relations”. During the autumn board meeting of the EHS in September 2013 in Italy it was decided to extend our mission to actively promote the prevention of incisional hernias by the Sperlonga statement: “Maybe we should first learn and teach how to prevent incisional hernias, rather than how to treat them?”

### Objective

The objective is to provide guidelines for all surgical specialists who perform abdominal incisions in adult patients on the optimal materials and methods used to close the abdominal wall. The goal is to decrease the occurrence of both burst abdomen and incisional hernia. The guidelines refer to patients undergoing any kind of abdominal wall incision, including visceral surgery, gynaecological surgery, aortic vascular surgery, urological surgery or orthopaedic surgery. Both open and laparoscopic surgeries are included in these guidelines.

### Methods

As EHS secretary of Quality, Filip Muysoms, under the auspices of the European Hernia Society board, proposed the Guidelines Development Group. The project was presented to the EHS board and accepted during the board meeting in Sperlonga, Italy, on September 28th 2013. The members of the Guidelines Development Group were chosen to recruit key opinion leaders and researchers on the subject from Europe. A geographical distribution across European countries was attempted and some younger surgeons having performed research on the subject were included in the Guidelines Development Group. Many of the members have contributed previously in producing guidelines on a national and international level. The Guidelines Development Group included abdominal wall surgeons, upper gastro-intestinal surgeons, hepato-biliary surgeons, colorectal surgeons and a vascular surgeon.

During a Kick Off meeting of the Guidelines Development Group in the Bonham Hotel in Edinburgh on October 28th 2013, the members attended a seminar on the meth-

odological aspect of developing guidelines by Robin T Harbour, the Lead Methodologist of the Scottish Intercollegiate Guidelines Network (SIGN) [19]. The AGREE II instrument was used from the start of the project to guide our methodology and structure of producing the guidelines [20]. AGREE II gives as definition for the Quality of a guideline: “The confidence that the potential biases of guideline development have been addressed adequately and that the recommendations are both internally and externally valid, and are feasible for practice.” During this first meeting Key Questions were formulated and translated into 24 patients-intervention-comparison-outcome (PICO) formats. For each Key Question at least three Guidelines Development Group members were assigned as investigators and specific search terms were formulated. The Key Questions with their PICO’s and assigned authors are listed in addendum 1.

On November 11th 2013, a meeting in Glasgow at the SIGN headquarters was held with the steering committee of the Guidelines Development Group to discuss the search strategy. A clinical librarian working for SIGN performed the primary literature research for all Key Questions. This involved a search for systematic reviews and/or meta-analyses on the Key Questions in Medline, Embase, NIHR CRD, NICE and The Cochrane library. The PRISMA flow diagram is shown in Fig. 1 and the search terms used are in addendum 2. The Guidelines Development Group members evaluated the systematic reviews for their relevance to the Key Questions and a qualitative assessment was done using the SIGN checklist No 1 for systematic reviews and meta-analyses [19]. Only systematic reviews of High Quality were used as basis for the guidelines development. A second search (no filters) on the Key Questions was performed for relevant RCT’s published after the end of the search performed for the systematic reviews involved. If no High Quality systematic review was identified for a Key Question, the working group members performed a separate systematic review using the PRISMA statement methodology [21]. To avoid lengthening of this guidelines manuscript, the results of these systematic reviews will be submitted as a separate manuscript on behalf of “The Bonham Group”, which are the members of the Guidelines Development Group. The members working together on a Key Question provided a Summary of Findings table from the results of the literature search, which were presented and discussed during the second group meeting.

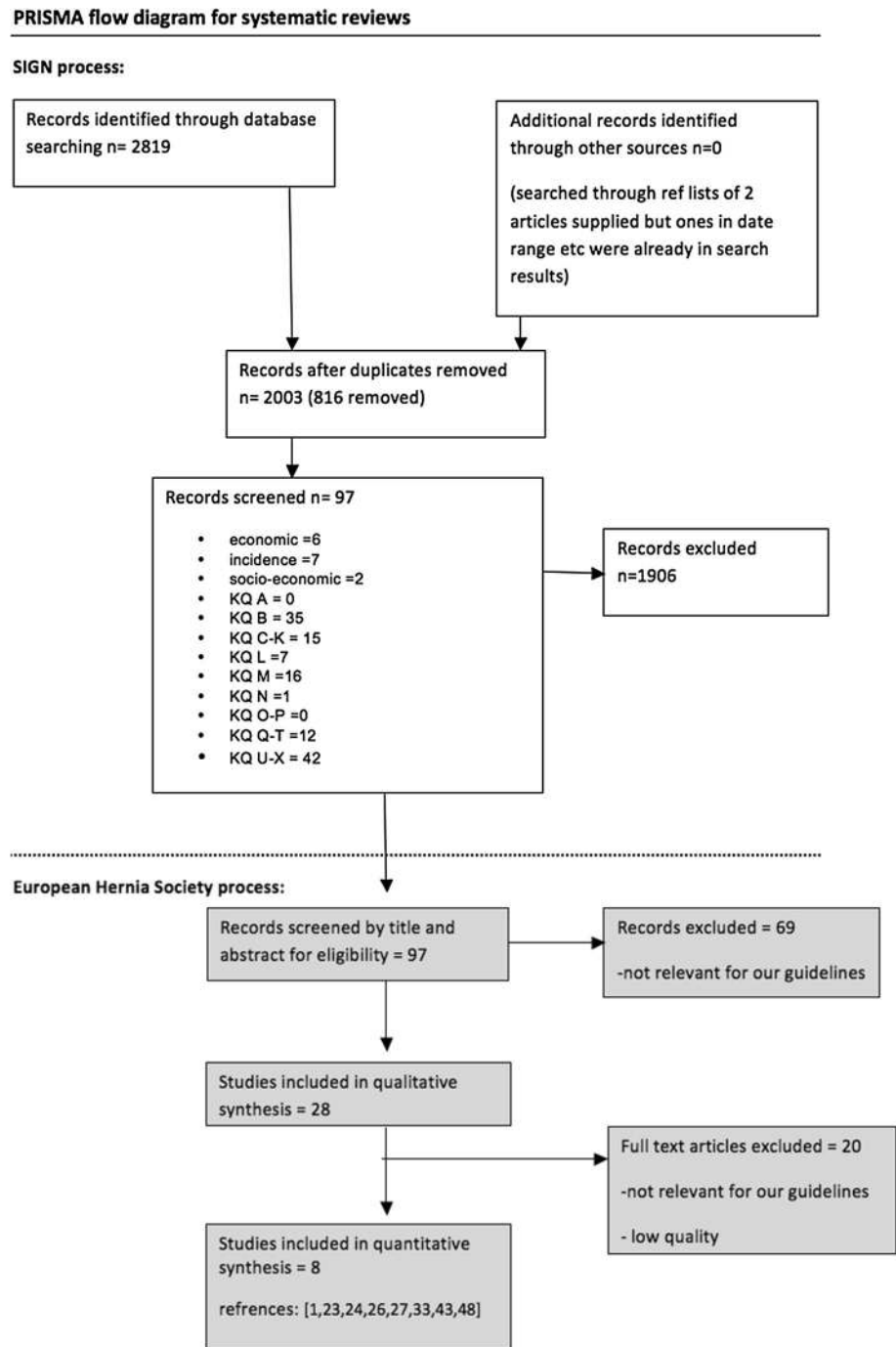
The second Guidelines Development Group meeting was held in Edinburgh on April 25th 2014. For evaluation of evidence, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used [22]. For each Key Question, a level of evidence was proposed using the GRADE approach and four levels of quality of the body of evidence were used: high, moderate, low, very low (Table 1). Based on the research evidence,

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**Fig. 1** PRISMA flow diagram for the search for systematic reviews and/or meta-analyses performed by Scottish Intercollegiate Guidelines Network (SIGN) for the Guidelines Development Group of the European Hernia Society guidelines on the closure of abdominal wall incisions. The search was performed in November 2013 and included searches in Medline, Embase, NIHR CRD, NICE and The Cochrane library



the clinical experience and patient values the Guidelines Development Group formulated a recommendation for each Key Question. In the GRADE approach only three levels of recommendation are used: strong recommendation, weak recommendation and no recommendation.

The results of the guidelines proposed by the Guidelines Development Group were presented during the 36th Annual International Congress of the European Hernia Society in Edinburgh on May 31st 2014. The manuscript was subsequently written by the first author in a uniform

manner for all Key Questions and send for review and agreement by all co-authors. Prior to submission, the manuscript of the guidelines was externally reviewed by experts and evaluated using the AGREE II instrument.

## Results

The results of the searches are shown in the PRISMA flow diagram in Fig. 1. From the 97 records detected by the

**Table 1** Using the GRADE approach to guideline development [22] the Quality of the body of evidence is rated (high/moderate/low/very low) and the recommendations are graded as strong or weak

Grading the Quality of the body of evidence for each Key Questions using the GRADE approach		Quality rating	Symbols	Definitions
<b>Underlying methodology</b>				
Randomized trials; or double-upgraded observational studies		High	☒☒☒☒	Further research is very unlikely to change our confidence in the estimate of effect
Downgraded randomized trials; or upgraded observational studies		Moderate	☒☒☒☐	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Double-downgraded randomized trials; or observational studies		Low	☒☒☐☐	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
Triple-downgraded randomized trials; or downgraded observational studies; or case series/case reports		Very low	☒☐☐☐	Any estimate of effect is very uncertain
<b>Grading of recommendations using the GRADE approach</b>				
Strong recommendation	Based on the available evidence, if clinicians are very certain that benefits do, or do not, outweigh risks and burdens they will make a strong recommendation			
Weak recommendation	Based on the available evidence, if clinicians believe that benefits and risks and burdens are finely balanced, or appreciable uncertainty exists about the magnitude of benefits and risks, they must offer a weak recommendation			
No recommendation	If based on the literature research no evidence could be found, no recommendation can be made			

SIGN process, 69 records were excluded based on the title and abstract as not being relevant to the guidelines. The remaining 28 systematic reviews [1, 23–49] were assessed by full text for their relevance to the Key Questions and if retained were assessed qualitatively using the SIGN checklist No 1 [19]. Additional searches on PubMed and by checking the references of all manuscripts were performed by the members of the Guidelines Development Group assigned to each Key Question. Relevant studies published up until April 2014 were included to provide the Summary of Evidence tables.

### Which diagnostic modality is the most suitable to detect incisional hernias?

No systematic reviews on diagnostic modalities for incisional hernias were found. The PRISMA flow diagram is shown in addendum 3 (Key Question A). Fifteen records were included in the qualitative analysis [3–6, 50–60]. Only four studies were retained as High Quality and are listed in the Summary of Findings table (Table 2) [5, 50–52].

The quality of most studies investigating the diagnostic accuracy of imaging techniques was low to very low. Only some provided a sensitivity analysis. Because no studies compared different diagnostic modalities in a similar methodology and with similar study arms, no pooling of data was useful or possible. In general, most studies show that medical imaging will increase the rate of detection of incisional hernias compared to physical examination. In an everyday clinical setting this is usually not important, because most asymptomatic hernias do not require treatment and their diagnosis is thus not necessary.

CT scan is reliable and reproducible, whereas ultrasound is more operator-dependant. However, CT scan will induce a radiation load to the patients and ultrasound is more accessible in most health care settings. A good standardisation and dynamic evaluation by ultrasound of the abdominal wall is needed, as described by Beck et al. [51] as the dynamic abdominal sonography for hernia (DASH) technique.

The difference in accuracy between physical examination and imaging technique is most important in the context of comparative studies evaluating incisional hernia rate. Next to the method of incisional hernia diagnosis the length of follow-up is important. Fink et al. [2] reported in a follow-up study of two prospective trials an increase from 12.6 % at 12 months to 22.4 % at 36 months ( $p < 0.001$ ) and concluded that follow-up for 3 years should be mandatory in any study evaluating the rate of postoperative incisional hernia after midline laparotomy.



<i>Statement</i>	It is recommended that prospective studies with incisional hernias as a primary outcome integrate medical imaging, either dynamic ultrasound or CT scan, in the follow-up.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	strong
<i>Statement</i>	It is recommended that studies with incisional hernias as a primary outcome include follow-up of at least 24 months (and preferably 36 months).	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	strong

### Does the type of abdominal wall incision influence the incidence of incisional hernias or burst abdomen?

Laparotomy incisions can be classified as midline, transverse, oblique or paramedian incisions [61]. The PRISMA flow diagram is shown in addendum 3 (Key Question B). Six systematic reviews have compared midline laparotomies to alternative incisions [26, 27, 31, 36, 38, 61], but only two were considered High Quality [26, 27]. A recent systematic review by Bickenback et al. [26] compared midline, transverse (including oblique) and paramedian incisions. This review included all relevant studies from previous reviews and no additional RCT's were detected that were published after this review. The literature search of this systematic review [26] identified studies published until 2009 and 24 RCT's directly comparing different laparotomy incisions were included in the analysis. The incisional hernia rates after non-midline incisions were significantly lower compared to the incisional hernia rates after midline incisions, for both transverse incisions (RR = 1.77; 95 % CI: 1.09–2.87) and paramedian incisions (RR = 3.41; 95 % CI: 1.02–11.45) [26]. However, data on burst abdomen (deep wound dehiscence or fascial dehiscence) were not significantly different between the different incisions types.

A Cochrane review by Brown et al. [27] published in 2005 and updated in 2011, compared transverse versus midline incisions, but excluded studies comparing paramedian incisions. A decreased incisional hernia rate after transverse incisions was reported compared to midline incisions (OR = 0.49; 95 % CI: 0.30–0.79).

Both reviews concluded that non-midline incisions significantly reduced the risk of incisional hernia compared to midline incisions, but did not influence the risk of burst abdomen. Interestingly, the Cochrane conclusions were more moderate, due to methodological and clinical heterogeneity of the studies and the risk of potential bias.

### What is the optimal technique to close a laparotomy incision?

Ten systematic reviews on the techniques and/or the materials to close abdominal wall incisions were identified [1, 32, 34, 37, 38, 42, 43, 48, 62, 63]. The PRISMA flow diagram is shown in addendum 3 (Key Question C–G). The data from the different systematic reviews are very incoherent and conclusions are often completely contradictory. The overall quality of most systematic reviews is low and therefore, several should be rejected as evidence to create guidelines. A major problem to identify the evidence from the literature is the fact that most prospective studies compared several variables between the study arms. Moreover, the populations studied are often very different: midline only or including other incisions, emergency or elective surgery, and different operative indications.

The current guidelines on techniques and materials are based on the systematic reviews by Diener et al. [1] and van't Riet et al. [48] which were evaluated as High Quality. Both systematic reviews included only studies involving midline laparotomies and the review by Diener et al. was the only one to distinguish between elective or emergency surgery. The systematic review by Sajid et al. [43] was used for the question on suture materials and a recent Cochrane review by Gurusamy et al. [63] was used for the question on peritoneal closure.

Using separate PICO's the shortcoming of many study designs to deliver clear answers becomes obvious. Another shortcoming in most studies on closure of laparotomies is the failure to monitor the technical details of the suturing technique, like the SL/WL ratio and the stitch size. As demonstrated by Israelsson [64] this might be an important confounding factor in studies comparing different suture materials. An updated systematic review taking into account the mentioned shortcomings of individual studies might be performed, but for these guidelines the conclusions are based on the data from the currently available

<i>Statement</i>	Non-midline incisions are recommended where possible.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	strong
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**Table 2** Summary of Findings table for Key Question A: which diagnostic modality is the most suitable to detect incisional hernias?

Bibliographic citation [reference]	Study type	SIGN assessment	Number of patients	Patient characteristics	Intervention	Comparison	Length of follow-up	Outcome measure
Baucom et al. Journal of the American College of Surgeons 2013; 218(3):363–6 [50]	Prospective cohort study	High Quality++	181	Patients seen at a general surgery department who had a prior abdominal operation and an available CT scan within six months before the visit	Physical examination by a surgeon	CT scan reviewed by surgeon	Not available	Physical examination had a low sensitivity (77 %) and negative predictive value (77 %). It fails to detect 23 % of hernias and in 32 % of the patients with a BMI $\geq$ 30 kg/m <sup>2</sup>
General comments: adequate designed study to compare physical examination to CT scan diagnosis of incisional hernias. CT scan was used as “gold standard” for the sensitivity analysis								
Beck et al. Journal of the American College of Surgeons 2013;216(3):447–53 [51]	Prospective cohort study	High Quality++	181	Patients seen at a general surgery department who had a prior abdominal operation and an available CT scan within six months before the visit	Dynamic abdominal ultrasound by surgeon	CT scan reviewed by surgeon	Not available	Dynamic Ultrasound has a high sensitivity (98 %) and specificity (88 %). It has a positive predictive value of 91 % and negative predictive value of 97 %. It is a good alternative to CT scan diagnosis
General comments: paper from the same group as Baucom et al. Concerns the same patient population. Adequate designed study to compare dynamic ultrasound to CT scan diagnosis of incisional hernias. CT scan was used as “gold standard” for the sensitivity analysis								
den Hartog et al. Hernia 2009;13(1):45–8 [5]	Prospective cohort study	High Quality++	40	Patients that had aortic surgery by midline incision at least 12 months before	Ultrasound by radiologist	CT scan (by 2 independent radiologists)	Mean 3.4 years	Incisional hernia prevalence was 60.0 % with CT scan and 42.5 % with ultrasound. The sensitivity of US was 70.8 % and the specificity 100 %. Us has a positive predictive value of 100 % and a negative predictive value of 69.6 %. CT scan diagnosis of the incisional hernias has a good intra- and inter -observer reliability
General comments: adequate designed study to compare ultrasound to CT scan diagnosis of incisional hernias. No comparison to physical examination. Limited number of patients. CT scan was used as “gold standard” for the sensitivity analysis								
Schreinemacher et al. Arch Surg. 2011;146:94–9 [52]	Retrospective cohort study with prospective examination	High Quality++	111	Patients that have a closure of a temporary stoma (42 % ileostomies and 58 % colostomies)	Ultrasound of the abdominal wall by surgeon	Physical examination by surgeon	Median 35 months	Incisional hernia prevalence was 32.4 % with ultrasound evaluation. Physical examination had a sensitivity of 58.3 % and a specificity of 97.3 %. The positive predictive value was 91.3 % and the negative predictive value was 83 %
General comments: both examinations were performed by the same person. Ultrasound was used a “gold standard” for the sensitivity analysis								

<i>Statement</i>	It is recommended that prospective randomized studies on the suture material to close abdominal wall incisions use the same suturing technique in both study groups.	strong
<i>Statement</i>	It is recommended that prospective randomized studies assessing the technique to close abdominal wall incisions use the same suture material in both study groups.	strong

systematic reviews. The protocol for an ongoing Cochrane review [65] was published in 2006 but the final data have not yet been published.

#### Continuous suturing versus interrupted sutures

Both meta-analyses concluded that continuous suturing for closure of midline laparotomies was beneficial compared to interrupted closure [1, 48]. Diener et al. [1] found a significant lower incisional hernia rate for continuous suturing (OR 0.59;  $p = 0.001$ ) in elective surgery. Most of the included studies were at high risk of bias because the interrupted study arm used rapidly absorbable multifilament sutures and the continuous arm used either non-absorbable or slowly absorbable monofilament sutures. van't Riet et al. [48] included studies involving emergency laparotomies and did not find any difference in incisional hernia rate between interrupted and continuous suturing. Continuous suturing was recommended because it was significantly faster.

#### Closure versus non-closure of the peritoneum

The Cochrane review by Gurusamy et al. [63] concluded that there was no short-term or long-term benefit in

peritoneal closure. Five studies were included but were heterogeneous in type of incision (midline and non-midline) and included both elective and emergency laparotomies. In all studies, the peritoneum was closed as a separate layer in the study arm with peritoneal closure.

#### Mass closure versus single layer closure

The search for the most appropriate layers to be sutured when closing a laparotomy is hampered by the lack of good definitions on what constitutes a mass closure, layered closure or single layer closure. No clinical studies directly comparing different closure methods were found.

For future research the Guidelines Development Group proposes the following definitions:

- Mass closure: the incision is closed with a suture bite including all layers of the abdominal wall except the skin.
- Layered closure: the incision is closed with more than one separate layer of fascial closure
- Single layer aponeurotic closure: the incision is closed by suturing only the abdominal fascia in one layer.

<i>Statement</i>	Continuous suturing for closure of midline abdominal wall incisions in elective surgery is recommended.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	strong
<i>Statement</i>	Closure of the peritoneum as a separate layer during closure of laparotomy incisions is NOT recommended.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	weak



<i>Statement</i>	For closure of midline abdominal wall incisions in elective surgery, a single layer aponeurotic closure is suggested.	☒☐☐☐	weak
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**Suture length to wound length ratio (SL/WL)**

The beneficial effect of a high SL/WL ratio on reducing the incidence of incisional hernias has been recognised for a long time [66], but evidence from clinical prospective studies remains scarce and most of the work addressing the topic comes from the Clinic of Sundsvall in Sweden [64, 67, 68]. A RCT, performed in Sundsvall, demonstrated the importance of the SL/WL ratio in reducing incisional hernia rate. The critical value was determined to be at a ratio of 4/1 [64]. Although a SL/WL ratio  $\geq 4$  is often mentioned in the protocol of prospective studies, many fail to document that the SL/WL ratio was recorded for the individual study patients.

**What is the optimal suture material to close a laparotomy incision?**

The PRISMA flow diagram for our search on suture materials is shown in Addendum 3 (Key Question H–K). Despite significant heterogeneity and confounders in most systematic reviews identified, a study by Sajid et al. [43] focused solely on the suture material. Table 3 defines the suture materials used in the included studies.

Rapidly absorbable suture versus non-absorbable or slowly absorbable sutures

Diener et al. [1] reported a significantly lower incisional hernia rate with slowly absorbable sutures (OR 0.65:

<i>Statement</i>	A suture to wound length ratio (SL/WL) of at least 4/1 for continuous closure of midline abdominal wall incisions in elective surgery is suggested.	☒☒☐☐	weak
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<i>Statement</i>	It is recommended that all prospective studies on the closure of laparotomy incisions will document the suture to wound length ratio (SL/WL) in all patients, as well as the number of stitches.		strong
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**Small bites versus large bites**

Millbourn et al. [69] demonstrated that closure of a midline laparotomy with a “small bites” technique resulted in significant less incisional hernias (5.6 vs 18.0 %;  $p < 0.001$ ) and less surgical site infections (5.2 vs 10.2 %;  $p = 0.02$ ). In the small bite technique the laparotomy wound is closed with a single layer aponeurotic suturing technique taking bites of fascia of 5–8 mm and placing stitches every 5 mm.

$p = 0.009$ ) in elective surgery. Subgroup analysis performed by van’t Riet et al. [48] comparing only continuous suturing studies, detected only one RCT by Wissing et al. [70] using continuous suturing in both study arms. This study, which included 21 % of emergency operations, showed significantly more incisional hernias with rapidly absorbable sutures compared to non-absorbable sutures ( $p = 0.001$ ) and compared to slowly absorbable sutures ( $p = 0.009$ ).

<i>Statement</i>	The “small bites technique” for continuous closure of midline incisions is suggested.	☒☒☒☐	weak
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<i>Statement</i>	The use of rapidly absorbable suture material for closure of midline abdominal wall incisions in elective surgery is NOT recommended.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	strong
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#### Non-absorbable versus slowly absorbable sutures

No difference in incisional hernia rate for continuous suturing of midline incisions with slowly absorbable versus non-absorbable sutures ( $p = 0.75$ ) was identified [48]. However, an increased incidence of prolonged wound pain ( $p < 0.005$ ) and suture sinus formation ( $p = 0.02$ ) with non-absorbable sutures was reported [48]. Another meta-analysis (which included non-midline incisions) identified no difference in incisional hernia rate between slowly absorbable polydioxanone and non-absorbable sutures (OR 1.10:  $p = 0.43$ ) [43]. Once again, non-absorbable sutures had a significant higher risk of suture sinus formation (OR 0.49:  $p = 0.01$ ) [43].

#### Sutures impregnated with antibiotics

Sutures coated with Triclosan as an antimicrobial agent have been introduced to decrease the rate of surgical site infection in surgery. A recent meta-analysis has demonstrated a significant beneficial effect in the prevention of surgical site infection after all kinds of surgery [71]. Surgical site infection is a risk factor for subsequent development of incisional hernias and therefore the use of antibiotics impregnated sutures to close laparotomies might be beneficial in the prevention of incisional hernias. Recently Diener et al. [72] published a large RCT on 1,224

<i>Statement</i>	Using slowly-absorbable suture material instead of non-absorbable sutures for continuous closure of midline abdominal wall incisions in elective surgery is suggested.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	weak
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#### Monofilament versus multifilament sutures

Monofilament sutures are believed to be associated with a lower surgical site infection rate than multifilament sutures [12]. However, none of the systematic reviews commented on this issue specifically. If the previous recommendation to use slowly absorbable sutures for closure of elective midline laparotomies is followed, this question becomes superfluous because the slowly absorbable sutures are all monofilament sutures.

patients undergoing an elective midline laparotomy comparing polydioxanone sutures with versus without triclosan impregnation. No reduction in the incidence of surgical site infection was reported (OR 0.91: CI 0.66–1.25;  $p = 0.39$ ). Four other RCT's have compared sutures with or without triclosan in laparotomy closure, either with polyglactin sutures (Vicryl) [73, 74] or with polydioxanone (PDS) [75, 76]. A meta-analysis on all five studies performed by

<i>Statement</i>	We suggest using monofilament suture material for continuous closure of midline abdominal wall incisions in elective surgery.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	weak
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Concerning the size of the suture, no studies comparing directly the size of the sutures used to close abdominal wall incisions were identified during our searches. For the “small bites” technique, Isrealsson et al. [12] suggest to use a suture size USP 2/0 (USP = United States Pharmacopeia).

Diener et al. showed a significant decrease in surgical site infection (OR 0.67: CI 0.47–0.98). No data on incisional hernias are available from these studies.

<i>Statement</i>	No recommendation on the size of the sutures for closure of abdominal wall incisions can be given due to lack of data.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
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<i>Statement</i>	Monofilament sutures impregnated with antibiotics for closure of elective midline incisions is NOT advised, because of insufficient data on their efficiency on prevention of surgical site infections and the lack of data on incisional hernias or burst abdomen.	☒☒☒☐	weak
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Limitations of the statements in these guidelines on suture technique and suture materials

The statements are limited by the quality of the data on which they are based. In total, 61 RCT's have been identified that compared suture materials or techniques to close laparotomy incisions. Many studies have more than one variable between study arms and therefore, analysing them in meta-analyses is difficult. Moreover, many studies have

**Suture needles and retention sutures**

Blunt tip versus sharp needles

Only one systematic review assessing the type of needle used to close the abdominal wall [23] and one RCT comparing blunt needles with sharp needles were identified. The PRISMA flow diagram is shown in Addendum 3 (Key Question L). The RCT reported no difference in SSI rate between blunt and sharp needles [77].

<i>Statement</i>	No recommendation on the type or the size of needle to close a laparotomy can be given due to lack of data.	☒☐☐☐	no
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flaws in the methodology increasing the risk of bias. We would like to encourage researchers that plan studies on abdominal wall closure to improve the methodology of their study protocol. Preferably, study arms are only different in the variable under investigation, either a suture technique or a suture material. Moreover, we recommend documenting the technical details such as SL/WL ratio, the number of stitches used in the patients and to provide a follow-up of at least 24 months.

Although some of the systematic reviews detected included non-midline incisions [43] or emergency operations [48], these guidelines are currently limited to elective midline laparotomies. For emergency operations and non-midline incisions there is currently not enough data available.

Is there a place for retention sutures when closing a laparotomy?

No systematic review on the use of retention sutures was found. The PRISMA flow diagram of our additional search is shown in Addendum 3 (Key Question M). Eight records were screened by full text [78–85]. Three RCTs on the prevention of burst abdomen using either retention sutures or a reinforced tension line suture in patients with increased risk for wound dehiscence and burst abdomen were identified [78–80]. Follow-up was too short to evaluate incisional hernia rate. The Summary of Findings is listed in Table 4. Two studies showed favourable results [78, 79], but one study reported a high number of adverse events when using retention sutures [80].

<i>Statement</i>	No recommendation on suture material or suturing technique for use in emergency surgery can be given due to lack of sufficient data.	☒☐☐☐	no
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<i>Statement</i>	No recommendation on suture material or suturing technique for use in non-midline incisions can be given due to lack of sufficient data.	☒☐☐☐	no
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<i>Statement</i>	No recommendation on the use of retention sutures in patients with multiple risk factors for burst abdomen can be given due to insufficient data.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
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**Table 3** List of the most commonly used suture materials to close abdominal wall incisions and their characteristics

	Producer	Material	Absorbable	Absorption time	Mono/multifilament	Antibiotics impregnated
Prolene	Ethicon	Polypropylene	Non		Monofilament	No
Surgipro	Covidien	Polypropylene	Non		Monofilament	No
Ethilon	Ethicon	Nylon	Non		Monofilament	No
Monosof	Covidien	Nylon	Non		Monofilament	No
Ethibond	Ethicon	Polyethylene	Non		Multifilament	No
Mersilene	Ethicon	Polyester	Non		Multifilament	No
Surgilon	Covidien	Nylon	Non		Multifilament	No
Maxon	Covidien	Polyglyconate	Slowly	180 days	Monofilament	No
PDS	Ethicon	Polydioxanone	Slowly	183–238 days	Monofilament	No
PDS plus	Ethicon	Polydioxanone + triclosan	Slowly	183–238 days	Monofilament	Yes
Monoplus	B Braun	Polydioxanone	Slowly	180–201 days	Monofilament	No
Monomax	B Braun	Poly-4-hydroxybutyrate	Slowly	390–1080 days	Monofilament	No
Vicryl	Ethicon	Polyglactin	Rapidly	56–70 days	Multifilament	No
Vicryl plus	Ethicon	Polyglactin + triclosan	Rapidly	56–70 days	Multifilament	Yes
Polysorb	Covidien	Polyglycolic acid	Rapidly	60–90 days	Multifilament	No
Dexon	Covidien	Polyglycolic acid	Rapidly	60–90 days	Multifilament	No

## Postoperative care

Postoperative management and instructions for patients are not supported by high quality prospective data, but rely mostly on surgeons' habits, tradition and common beliefs [86–88]. Long-term follow-up studies are needed to research the impact on the occurrence of incisional hernias of prescribing abdominal binders or restricting postoperative activity. The additional searches as shown in PRISMA flow diagrams in Addendum 3 (Key Question N, O, P) did not reveal any relevant study on long-term outcome. Some studies on the short-term benefits of abdominal binders were found.

## Subcutaneous drains in laparotomy incisions

Prophylactic routine placement of subcutaneous drains after laparotomy is occasionally used to decrease wound complications: infection, hematoma, seroma or wound dehiscence [86]. However, there are several disadvantages to the routine use of subcutaneous drains. Namely, they cause patient discomfort and pain at removal, they hinder early mobilisation and demand additional nursing care. Therefore, their use should be driven by a proven benefit.

One systematic review [89] and several RCTs [90–98] on the use of subcutaneous drains in abdominal surgery were found. They cover a wide range of operative indications: liver surgery, colorectal surgery, cholecystectomy, gynaecological surgery, caesarean section, and gastric bypass surgery. With few exceptions, most studies did not show a benefit for the use of subcutaneous drains. However, none of these studies had incisional hernias or burst abdomen as primary or secondary endpoint.

<i>Statement</i>	The routine placement of a subcutaneous drain during closure of abdominal wall incisions is NOT recommended.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	strong
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**Table 4** Summary of Findings table for Key Question M: is there a place for retention sutures when closing a laparotomy?

Bibliographic citation [reference]	Study type	Number of patients	Patient characteristics	Intervention	Comparison	Length of follow-up	Outcome measure
Khorgami et al. J Surg Res. 2013;180:238–43 [78]	RCT	300	Patients undergoing midline laparotomy with $\geq 2$ risk factors of a list of defined risk factors for burst abdomen	Extra retention sutures Nylon 1 (every 10 cm and with 5 cm bites of skin) kept for 3–4 weeks	Continuous loop size 1 nylon suture (1 cm from the edge/1 cm intervals)	Median 5 months	Wound dehiscence was 4.1 % (6/147) in the intervention group and 13.5 % (20/148) in the control group ( $p = 0.007$ ). “We showed that prophylactic retention sutures could reduce wound dehiscence in midline laparotomy in high-risk patients with multiple risk factors without imposing remarkable postoperative complications.”
Agrawal Trop Gastroenterol 2009;30:237–40 [79]	RCT	190	Emergency midline laparotomy	Reinforced tension line suture	Continuous suture		Burst abdomen was 0.0 % (0/90) in the intervention group and 13.0 % (13/100) in the control group ( $p = 0.0026$ ). “Closure of midline incision by RTL reduces the incidence of burst abdomen.”
Rink et al. Eur J Surg. 2000;166:932–7 [80]	RCT	95 (92 midline)	Patients needing major abdominal surgery with infective or malignant intra-abdominal diseases. + at least one risk factor	Extra retention sutures with sutures retention bridge for 12 days	Interrupted Vicryl 1 sutures	12 days	“Retention sutures used to close abdominal wounds cause inconvenience, pain, and specific morbidity.”



## Postoperative binders

One systematic review on the use of abdominal binders was found [87]. The review included four RCT's [99–102] and a national survey by questionnaire on the use of abdominal binders in French surgical practice [87]. One additional recent RCT was identified [103].

The French survey reported that postoperative support of the wound with an abdominal binder is common practice after major laparotomies in many surgical departments (94 % use them in some patients). It is expected to reduce postoperative pain and to improve early mobilisation of the patients. Moreover, 83 % of users expect a benefit in the prevention of abdominal wall dehiscence [87].

No significant improvement for the short-term benefits was found by the small RCTs from the review [98–101]. The additional study by Clay et al. [102] found a significant lower Visual Analogue Scale (VAS) score for pain at the fifth postoperative day and no adverse effect on postoperative lung function. No studies were found that had burst abdomen or incisional hernias as primary or secondary endpoints.

- The systematic review by Bhangu et al. [24] is of High Quality and offers a good and extensive evaluation of the quality of the individual studies included. However, the quality of the non RCTs was usually low and these studies were not used as evidence for these guidelines.
- Timmermans et al. [104] published a good meta-analysis on five RCT's using polypropylene mesh, including a RCT published in 2013 by Abo-Ryia et al. [105].

One additional RCT published after the review by Timmermans et al. [106] was identified. In this RCT, one hundred and sixty patients were included. This is the first trial on non-selected elective midline laparotomies (with a majority of oncological patients). All the other trials have only included patients deemed at high risk for incisional hernias. In this RCT by Caro-Tarrago et al. the mesh augmentation was performed with a light weight polypropylene mesh in the onlay position. A significant reduction

<i>Statement</i>	No recommendation can be given on the use of postoperative abdominal binders due to lack of data on their effect on incisional hernias or burst abdomen rates.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
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## Postoperative restriction of activity

No prospective studies were found on the restriction of physical activity after abdominal incisions. Nevertheless, it is advocated by some surgeons to decrease the risk of incisional hernias, but there is no consensus on the level or the duration of the restriction [88]. Postoperative restriction might have an adverse impact on the return to normal activity and delay the return to work.

in incisional hernias at 12 months was observed clinically and with CT scan in favour of prophylactic mesh, 1.5 vs 35.9 % ( $p < 0.0001$ ). A significantly higher number of postoperative seroma was detected in the mesh group, 11.3 vs 28.8 % ( $p < 0.01$ ). No major complications related to the mesh augmentation were reported.

The details of the six published RCT's using polypropylene mesh including 506 patients are listed in Table 5

<i>Statement</i>	No recommendation can be given on routine restriction of activity after abdominal surgery due to lack of data on the effect on incisional hernias or burst abdomen rates.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
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## Prophylactic mesh augmentation

The PRISMA flow diagram for prophylactic mesh augmentation is shown in Addendum 3 (Key Question Q–T). Three systematic reviews on the topic were found [24, 39, 104].

- Nachappian et al. [39] did not assess of the quality of the individual studies and included non published data. Therefore, this review did not qualify for inclusion in this guideline.

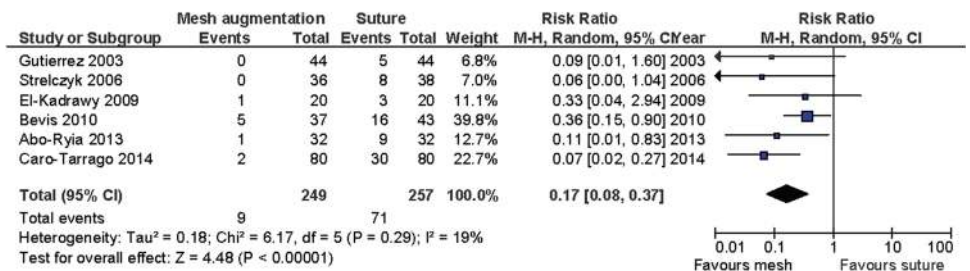
[105–110]. Using Review Manager 5.2 software a new meta-analysis was performed. The data for this meta-analysis were extracted from the Timmermans et al. meta-analysis and the additional RCT [104, 106]. A meta-analysis on the outcomes of incisional hernia, seroma and SSI was performed. The pooled analyses data are shown in a Forrest plot for each outcome in Fig. 2. Prophylactic mesh augmentation is effective in the prevention of incisional hernias (RR 0.17: CI 0.08–0.37). An increased incidence of postoperative seroma is identified, but the majority of these

**Table 5** List of the randomized clinical trials and their characteristics on prophylactic mesh augmentation using a polypropylene mesh

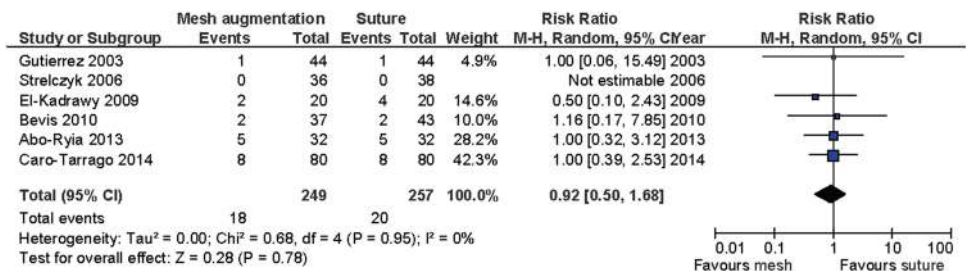
RCT [reference]	Publ. date	LoE	SIGN	n	Population	Mesh position	FU months	Incisional hernias			Effect size Risk ratio (95 % CI)
								Diagnosis incisional hernia	NO mesh	Mesh	
Gutiérrez [107]	2003	2b	+	88	High risk patients	Onlay	36	Clinical + selective CT scan	5/44	0/44	0.09 (0.01–1.60)
Strelczyk [108]	2006	1b	++	74	Obesity surgery	Retro-muscular	28	Clinical + ultrasound in all	8/38	0/36	0.06 (0.00–1.04)
El-Kadrawy [109]	2009	2b	+	40	High risk patients	Pre-peritoneal	36	Clinical	3/20	1/20	0.33 (0.04–2.94)
Bevis [110]	2010	1b	++	80	AAA	Retro-muscular	25.4	Clinical + selective ultrasound	16/43	5/37	0.36 (0.15–0.90)
Abo-Ryia [105]	2013	2b	+	64	Obesity surgery	Pre-peritoneal	48	Clinical + selective ultrasound	9/32	1/32	0.11 (0.01–0.83)
Caro-Tarrago [106]	2014	1b	++	160	Midline laparotomies	Onlay	12	Clinical + CT scan in all	30/80	2/80	0.07 (0.02–0.27)
Overall				506					71/257	9/249	0.17 (0.08–0.37)

**Fig. 2** Forrest plots of a meta-analysis performed by the Guidelines Development Group on prophylactic mesh augmentation with polypropylene mesh after laparotomy. Analysis on the outcomes of incisional hernia, seroma and surgical site infection was performed

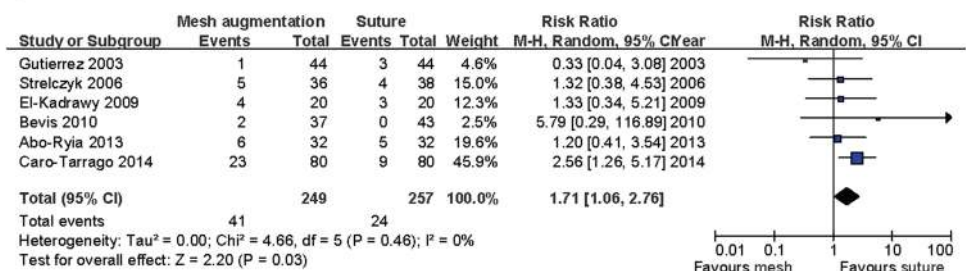
**A Incisional hernia**



**B Wound infection**



**C Seroma**



are from the single study by Caro-Tarrago et al. [106] where the mesh was placed in an onlay position, with a weight of 45.9 % on the cumulative Risk Ratio for seroma (RR = 1.71; 95 %CI: 1.06–2.76) (Fig. 2c).

Although the data are favourable and consistent for prophylactic mesh augmentation, the Guidelines Development Group decided that larger trials are needed to make a strong recommendation to perform prophylactic mesh augmentation for all patients within certain risk groups.

<i>Statement</i>	Prophylactic mesh augmentation for an elective midline laparotomy in a high-risk patient in order to reduce the risk of incisional hernia is suggested.	<input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	weak
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Which mesh type, which mesh position and which type of mesh fixation?

No comparative studies are published between different mesh type, mesh position or method of mesh fixation. Pans et al. [111] found no significant protective effect on incisional hernia rate by intra-peritoneal augmentation with a polyglactin mesh (Vicryl; Ethicon) on incisional hernia rate in a RCT on obesity surgery ( $n = 288$ ). Llaguna et al. [112] placed a biological mesh (Alloderm; LifeCell) in a retro-muscular position in bariatric patients. In this non-randomised comparative study ( $n = 106$  of which 44 with mesh) a significantly lower incisional hernia rate was observed in the mesh group, 2.3 vs 17.7 % ( $p = 0.014$ ). All other studies published used a polypropylene mesh, most often a small pore/heavy weight mesh: Prolene; Ethicon [110], Premilene; B. Braun [107], no name mentioned [105, 108, 109]. Only Caro-Tarrago et al. [106] used a large pore/light weight mesh: Biomesh Light P8; Cousin Biotech.

There is a large variation between the studies on the mesh position for the prophylactic mesh augmentation. Onlay, retro-muscular and pre-peritoneal mesh positioning was performed in two studies each. No studies on the use of intra-peritoneal augmentation with a non absorbable synthetic mesh are reported. Only one study on the use of intra-peritoneal augmentation with an absorbable synthetic mesh is reported [111]. The mesh was in all studies fixed with sutures to the fascia except for the study of Pans et al. [111] which used no fixation. No studies on mesh augmentation with glue or a self-fixating mesh are reported.

<i>Statement</i>	No recommendation on the optimal mesh position for prophylactic mesh augmentation can be given due to lack of data.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
<i>Statement</i>	No recommendation on the optimal method of mesh fixation for prophylactic mesh augmentation can be given due to lack of data.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no
<i>Statement</i>	No recommendation on the type of mesh for prophylactic mesh augmentation can be given due to lack of data.	<input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	no

## Trocar wounds for laparoscopic surgery and single port surgery

The PRISMA flow diagram for the Key Questions on laparoscopic surgery and single incision surgery are shown in Addendum 3 (Key Question U–W and K, Q, X).

Trocar size and trocar type

The first search for systematic reviews resulted in five records [33, 40, 41, 46, 49] and 25 additional records were screened by full text [113–137]. Several studies comment on the incidence of trocar-site hernia for various trocar sizes. However, the quality of many studies is insufficient and challenges the validity of results. Shortcomings of the individual studies include retrospective study design, short or unclear length of follow-up and inappropriate or no information on diagnostic methods to detect incisional hernias. Most importantly, available data derive from studies in which the same patient serves as case and control; i.e. the incidence of trocar-site hernia is measured for different sizes of trocars inserted at different abdominal sites in the same patient. This may impose significant bias, related to the strength of the abdominal wall and the wound repair mechanisms at varying sites of the abdominal wall, in particular the linea alba to other parts of the abdominal wall.

Helgstrand et al. [33] performed a systematic review on the incidence of trocar-site hernia. Although they found a risk reduction after sutured closure and a lower hernia rate for 5-mm versus larger diameter trocars, no meta-analysis was undertaken. The poor quality and design of the majority of the included reports preclude further in-depth evaluation for supporting evidence. No RCT's have investigated the incidence of trocar-site hernia after

insertion of blunt versus bladed trocars and no RCT's or case-control studies have investigated the incidence of trocar-site hernia with reference to trocar size or diameter. Available data derived from univariate and multivariate analyses of cohort studies, which have investigated the effect of potential risk factors for trocar-site hernia. Obesity, age above 60 years diabetes, long duration of

analyses were found [138–140]. Two meta-analyses of RCTs have found no difference in the incidence of trocar-site hernia between single port and multiple port surgery, although a trend in favour of multiple port surgery was demonstrated [138, 139]. The most recent meta-analysis included 19 RCTs involving 676 patients and found a higher incidence of trocar site hernia following single port surgery [140].

<i>Statement</i>	Emerging evidence suggests an increased incidence of trocar-site hernia for single-incision surgery as compared to conventional surgery; therefore meticulous closure of the incised fascia in single-port surgery is recommended.	☒☒☒☐	weak
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surgery, and the need for fascia enlargement for specimen extraction were identified as risk factors for the development of trocar-site hernia [120, 137].

<i>Statement</i>	For laparoscopic procedures, using the smallest trocar size adequate for the procedure is suggested.	☒☒☐☐	weak
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<i>Statement</i>	For laparoscopic procedures, suturing the fascial defect, if trocars larger than or equal to 10 mm have been used, in the presence of established risk factors for incisional hernia formation is suggested.	☒☐☐☐	weak
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### Closure of trocar incisions

There are no good quality comparative studies investigating different suture materials or techniques for closure of trocar fascia defects. Armananzas et al. [113] reported in a recently published RCT a benefit for prophylactic intra-peritoneal placement of a ventral patch at the umbilical site in high-risk patients to reduce the incidence of trocar-site hernia from 18.5 to 4.4 % (OR 10.1; CI 2.15–47.6;  $p < 0.001$ ). Larger sample-sized studies with a good risk-benefit assessment and longer follow-up are needed to confirm and support a stronger recommendation.

### Discussion

#### Key results

A list of the statements from these guidelines is provided in Addendum 4 as a PDF file.

#### Limitations

Not many strong recommendations could be made due to lack of sufficient evidence on many of the PICO questions.

<i>Statement</i>	For laparoscopic procedures a mesh-augmented closure may be applied in patients at high risk for trocar-site hernia.	☒☒☒☐	weak
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### Single incision laparoscopic surgery and incisional hernia

The incidence of trocar-site hernia after single port surgery has been mostly investigated as a secondary outcome measure in the setting of RCTs and 3 High Quality meta-

It is somewhat confusing to notice that the first strong recommendation in these guidelines is to avoid midline laparotomies in favour of alternative incisions and that all other recommendations are only valid for elective midline incisions. Indeed most research is focused on midline laparotomies. A midline laparotomy is still the favoured

approach for most surgeons. It allows quick entrance to the abdominal cavity and extension of the incision is easy if this is required for the operation. Nevertheless, the linea alba is probably the most vulnerable and least vascularized part of the abdominal wall. Some refer to incisional hernias as “a midline crisis”. Optimising closure of abdominal wall incisions would appear to hold a large potential in reducing the incidence of incisional hernias and the subsequent need for incisional hernia repair. This has obvious benefits for the individual patient relating to an improved quality of life, avoidance of secondary operations and at a macro-economical level a significant reduction in costs for health care resources. It is not easy to see the impact of each recommendation separately. Therefore, implementation of the optimised abdominal wall closure is probably best done by teaching all involved specialists a standardised technique described as the “Principles” of abdominal wall closure [17]. This incorporates all recommendations, although the Guidelines Development Group is aware that the level of evidence for the different aspects is sometimes low to very low. David Sackett, a pioneer in evidence-based medicine wrote: “...any external guideline must be integrated with individual clinical expertise in deciding whether and how it matches the patient’s clinical state, predicament, and preferences, and thus whether it should be applied”. [141].

## Discussions

For most Key Questions on the technique and material to close abdominal wall incisions, the grading of the Quality of Evidence and the choice of recommendation was straightforward. For several recommendations, while the quality of evidence was low, there was good consensus between the members of the Guidelines Development Group on the formulated statements. For prophylactic mesh augmentation there was disagreement on the strength of recommendation (weak or strong). For this reason, an additional meta-analysis was performed (Fig. 2). Although the effect size in favour of mesh augmentation is large and consistent over the studies, the Guidelines Development Group felt that larger trials are needed to support a strong recommendation for prophylactic mesh augmentation in high-risk patients. Indeed, the number of patients in the reported studies for each risk group separately (e.g. abdominal aortic aneurysm, obesity surgery, oncological surgery) seems too low to recommend prophylactic mesh augmentation in all these patient groups. Nevertheless, we are aware that several large RCT’s are on-going and this grade of recommendation might be changed in the light of future publications.

No recommendations could be made on non-midline incisions due to insufficient evidence. Nevertheless, it

seems reasonable to promote similar material (slowly absorbable suture) and techniques (continuous aponeurotic closure with small bites and SL/WL >4/1) for closure of non-midline incisions.

No recommendations could be made on the type or the size of the needle used to close abdominal incisions. No studies comparing the size of the sutures were identified in our searches.

No recommendation could be made for emergency surgery, which is often a contaminated procedure. The Guidelines Development Group consider that the use of retention sutures or of reinforced tension line sutures, should be prospectively studied in patients at high risk for development of burst abdomen. A risk model and score for burst abdomen has been developed by van Ramshorst et al. [142] and could be used as basis for including patients in these studies.

No recommendations could be made on the postoperative care after laparotomies. Long-term follow-up studies are needed to assess the impact on the occurrence of incisional hernias of prescribing abdominal binders or restricting or indeed encouraging early postoperative activity.

## Applicability

To adopt the guidelines and “evidence based principles” for abdominal wall closure, surgeons must be convinced that these are valid recommendations with a large impact on the outcome for the patients. These guidelines are an attempt to create awareness amongst surgeons about these principles. Adaptation can be done by systematic quality control of the suturing technique as described by van Ramshorst et al. [143]. The EuraHS, European registry for abdominal wall hernias, has developed an online platform for registration and outcome measurement of abdominal wall surgery [144]. An additional route in the database on the closure of abdominal wall incisions and for prophylactic mesh augmentation will be provided from 2015 onwards. It is hoped that such a registry database will facilitate the data collection for prospective studies.

## Validity of the guidelines

Prior to submission of the manuscript the guidelines were evaluated and scored using the AGREE II instrument. The results of these assessments are presented in Table 6. Several large multi-centre studies on the closure of abdominal wall incisions are currently on-going. High Quality data on the use of the “small bites” technique in midline incisions, on the closure of laparotomies in emergency and on prophylactic mesh augmentation will be published in the coming years. The Guidelines Development Group has decided to update these guidelines in 2017



**Table 6** Results of the scoring of the guidelines by external experts using the AGREE II instrument [20]. Each item is scored between 1 (=strongly disagree) and 7 (=strongly agree). For each domain a scaled domain score is given as a percentage

## Domain 1: Scope and purpose

Scaled domain score = 90.3 %

	Item 1	Item 2	Item 3	Total
Appraiser 1	7	5	5	17
Appraiser 2	7	7	7	21
Appraiser 3	6	6	6	18
Appraiser 4	7	7	7	21
Total	27	25	25	77

## Domain 2: Stakeholder involvement

Scaled domain score = 76.4 %

	Item 4	Item 5	Item 6	Total
Appraiser 1	6	3	5	14
Appraiser 2	7	5	7	19
Appraiser 3	6	4	4	14
Appraiser 4	6	7	7	20
Total	25	19	23	67

## Domain 3: Rigour of development

Scaled domain score = 85.9 %

	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14	Total
Appraiser 1	7	7	6	6	5	6	7	4	48
Appraiser 2	7	7	7	7	6	6	7	6	53
Appraiser 3	6	6	6	5	4	4	5	4	40
Appraiser 4	7	7	7	7	7	7	7	7	56
Total	27	27	26	25	22	23	26	21	197

## Domain 4: Clarity of presentation

Scaled domain score = 87.5 %

	Item 15	Item 16	Item 17	Total
Appraiser 1	7	5	6	18
Appraiser 2	7	7	7	21
Appraiser 3	5	5	5	15
Appraiser 4	7	7	7	21
Total	26	24	25	75

## Domain 5: Applicability

Scaled domain score = 52.1 %

	Item 18	Item 19	Item 20	Item 21	Total
Appraiser 1	5	4	5	4	18
Appraiser 2	4	3	3	1	11
Appraiser 3	3	3	3	4	13
Appraiser 4	7	7	7	3	24
Total	19	17	18	12	66

**Table 6** continued

Domain 6: Editorial independence

Scaled domain score = 95.8 %

	Item 22	Item 23	Total
Appraiser 1	7	7	14
Appraiser 2	7	7	14
Appraiser 3	6	6	12
Appraiser 4	7	7	14
Total	27	27	54

Overall assessment		
	Rating of the overall Quality of the guideline	I would recommend this guideline for use
Appraiser 1	6	Yes
Appraiser 2	6	Yes
Appraiser 3	5	Yes
Appraiser 4	7	Yes

and present the results during the 39th Annual Congress of the European Hernia Society in Vienna in May 2017.

## Conclusions

To decrease the incidence of incisional hernias it is recommended to utilise a non-midline approach to a laparotomy whenever possible. For elective midline incisions, it is strongly recommended to perform a continuous suturing technique and to avoid the use of rapidly absorbable sutures. It is suggested that the use of a slowly absorbable monofilament suture in a single layer aponeurotic closure technique without separate closure of the peritoneum and using a small bites technique with a SL/WL ratio at least 4/1 is the current recommended method of fascial closure. Currently, no recommendations can be given on the optimal technique to close emergency laparotomy incisions. Prophylactic mesh augmentation appears effective and safe and can be suggested in high-risk patients like, aortic aneurysm surgery and obese patients.

## Other information

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