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ORIGINAL ARTICLE

Primary uncomplicated midline ventral hernias: factors that influence and guide the surgical approach

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Abstract

Background Considering recently published high-level evidence on the management of primary midline ventral hernias, we set out to review current practices and reevaluate the literature surrounding this topic.

Methods The Americas Hernia Society Quality Collaborative (AHSQC) was used to abstract all uncomplicated primary midline ventral hernias. The primary outcomes of interest were surgical approaches, including the use of mesh, the type and position of mesh, and the use of minimally invasive surgery (MIS).

Results A total of 7030 met inclusion criteria; mean age of 52 ± 14, 71% male, with a median hernia width of 2 [1, 2]. A total 69% underwent mesh repair, while 31% underwent suture repair. The most commonly used mesh was permanent synthetic (98%), placed in either the intraperitoneal (46%) or preperitoneal (42%) spaces. The majority of repairs were performed through an open approach (72%). When mesh was used through an open approach (58%), the majority were patches (70%) placed in the preperitoneal space (50%). Through an MIS approach (95%), the majority were flat meshes (53%) placed in the intraperitoneal space (58%).

Conclusion Recent high-level literature recommends the use of mesh repair (flat mesh) in all patients with hernia width ≥ 1 cm. This evidence is limited to the use of flat mesh through an open approach. While AHSQC surgeons do offer mesh repair in the majority of cases, this is most commonly using a mesh patch, and is selective towards larger hernias and obese patients. Further research is required to evaluate the safety of mesh patches, and a mesh repair should be offered to a young non-obese healthy patient, as they benefit similarly from the use of mesh.

Keywords Primary · Ventral · Hernia · Epigastric · Umbilical · Mesh

Introduction

When presented with a primary ventral hernia, the surgeon and patient have a myriad of different approaches available to them. These range from a choice between suture and mesh repair, various mesh types, and a minimally invasive or open approach. Despite numerous publications on the topic, there is limited high-level evidence, and surgeons do not have a consensus on the best approaches for these patients [1].

Moreover, patients with a primary ventral hernia tend to have heterogeneity in their characteristics and presentation, adding a level of complexity to the preoperative evaluation [2]. The presence of a concomitant rectus diastasis and a female patient within reproductive age can alter the management plan for a primary ventral hernia repair. Furthermore, a young or thin patient may benefit from a different repair than an older or obese patient.

While previous studies have identified mesh repair as superior in larger ventral hernias, mesh repair in smaller hernias remained contentious, supported mainly by retrospective studies, registry-based data, and meta-analysis [3–7]. However, a recent randomized control trial evaluating mesh repair in primary umbilical hernias between 1 and 4 cm found similar improved recurrence rates with the use of mesh [8]. Furthermore, a meta-analysis of all randomized control trials conducted on this issue found similar outcomes with strong recommendation towards mesh use even in smaller hernias [9].

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In this invited review, we discuss recent additions to the literature and recommendations for primary ventral hernias while concurrently evaluating current practices by surgeons participating in the Americas Hernia Society Quality Collaborative (AHSQC) to address any divergences and potential for improvement.

Methods

After receiving institutional review board (IRB) approval, the Americas Hernia Society Quality Collaborative (AHSQC) was used to acquire data for all primary ventral hernias. The AHSQC data registry is a prospectively maintained, surgeon-entered, point of care continuous quality improvement registry. Details regarding the design, implementation, and data quality assurance of the registry are discussed elsewhere [10].

A total of 224 surgeons in 215 sites contributed to the data, with 47% of patients from academic settings, 35% from private practice setting, and 18% from private practice with academic affiliation. The study population included patients with uncomplicated primary epigastric or umbilical hernias. An uncomplicated primary ventral hernia was defined as elective, non-recurrent, and with hernia width ≤ 10 cm. Patients that had concomitant procedures performed and non-clean wounds were also considered to have complicated hernias and were excluded. Patients that did not have mesh used and fascial closure was not achieved were excluded, as this was not considered a durable hernia repair. Figure 1 describes the inclusion and exclusion criteria for identifying the study population.

A retrospective review of the prospectively collected data was conducted. Relevant variables included patient demographics, comorbidities, operative information, and post-operative outcomes.

The primary outcomes of interest were the surgical approach, including the use of mesh, the type of mesh used, the position of mesh, and the use of minimally invasive approaches. The type of mesh used was defined as follows: (1) flat mesh: a flat sheet of mesh excluding preformed meshes; (2) mesh patch: a flat mesh with mesh arms or deployment system to aid in mesh fixation; and (3) others: preformed meshes, mesh plugs, and bilayer meshes with a connector.

Secondary outcomes of interest include post-operative wound and medical morbidity at 30 day follow-up. Post-operative wound events collected in the AHSQC include Surgical Site Infection (SSI), Surgical Site Occurrence (SSO), and SSO requiring procedural intervention (SSOPI) [11]. SSI was defined according to the Center for Disease Control and Prevention (CDC) classifications as superficial, deep, or organ space [12]. Surgical Site Occurrence (SSO) included any SSI, in addition to wound cellulitis, non-healing incisional wound, fascial disruption, skin or soft-tissue ischemia, skin or soft-tissue necrosis, serous or purulent wound drainage, stitch abscess, seroma, hematoma, infected or exposed mesh, or development of an enterocutaneous fistula. Procedural interventions to be considered SSOPI included wound opening, wound debridement, suture excision, percutaneous drainage, partial mesh removal, and/or complete mesh removal.

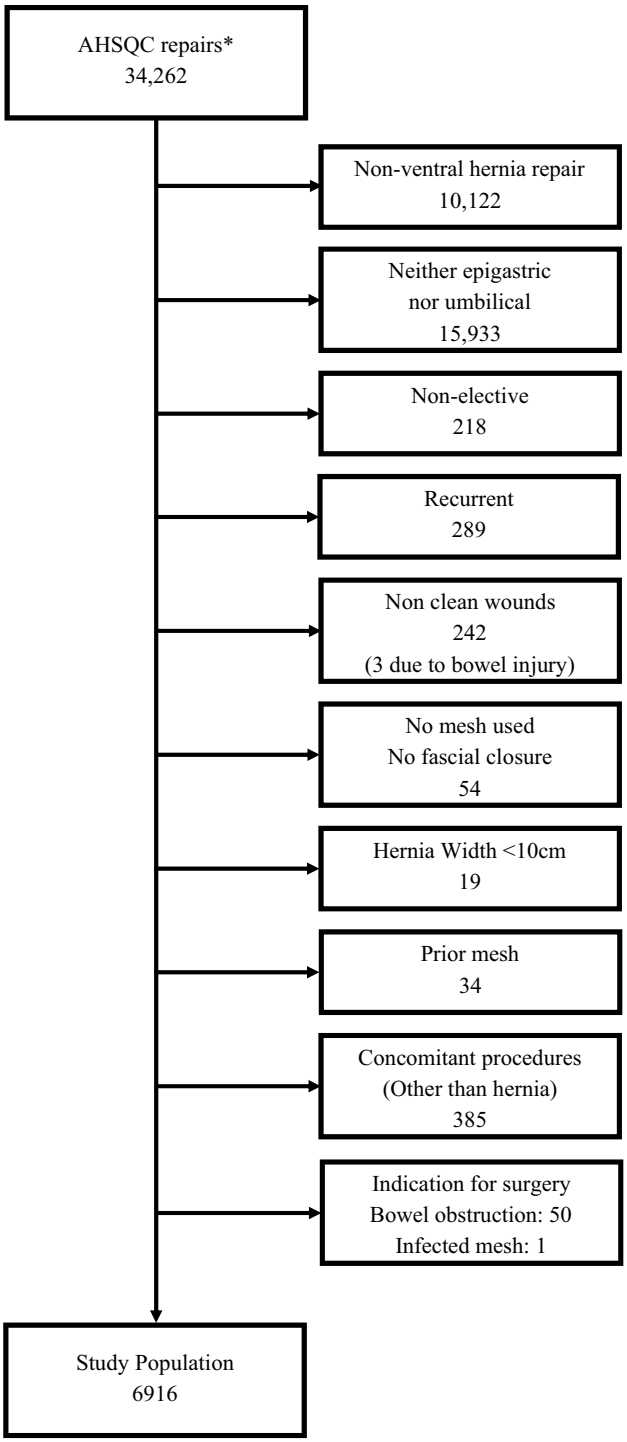

Fig. 1 Inclusion and exclusion criteria

Descriptive statistics were used to analyze the data, using exact frequencies, percentages, means and standard deviations, as well as medians and interquartile ranges wherever appropriate. The results are summaries of observed events in the study sample and not adjusted for potential confounders. To emphasize the descriptive nature of the analysis, no population inference was performed and no *p* values were reported. Two separate analyses were conducted, one looking at the use of mesh vs suture repair, and one looking at open vs minimally invasive repairs.

Results

Mesh vs suture

A total of 7030 patients met inclusion criteria. Of those, 69% underwent mesh repair, and 31% underwent suture repair. The cohort included 80% umbilical hernias and 20% epigastric hernias. The mean age was similar between mesh and suture repair (52 ± 13 vs 50 ± 15, respectively). The sample mean BMI was higher in the mesh group (32 ± 7 vs 28 ± 5). Consequently, the prevalence of obesity (≥ 30 kg/m^2) in the mesh group was twice as much as its prevalence in the suture group (61% vs 35%, respectively) in the study sample. Patients undergoing mesh repair were more likely to have comorbidities (55% vs 43%). This was driven mostly by diabetes (12 vs 6%) and hypertension (37% vs 26%). The sample median hernia width in the mesh group was higher than the suture group (2 [2, 3] vs 1 [1, 2], respectively). Pain and an enlarging hernia that is interfering with activity were the two most common indications for repair (pain: 81% in mesh vs 80% in suture; enlarging hernia: 61% in mesh vs 39% in suture). Table 1 highlights the demographics, patient, and hernia characteristics for this cohort.

Table 1 Demographics, patient, and hernia characteristics

	Mesh	Suture	MIS	Open	All
N	4772	2144	1964	4952	6916
Age, years (mean ± SD)	52 ± 13	50 ± 15	52 ± 13	51 ± 14	52 ± 14
Gender (female)	1285 (27)	686 (32)	620 (32)	1351 (27)	1971 (28)
BMI, kg/m^2 (mean ± SD)	32 ± 7	28 ± 5	33 ± 7	30 ± 6	31 ± 7
BMI categories					
< 30	1880 (39)	1397 (65)	664 (34)	2613 (53)	3277 (47)
≥ 30	2887 (61)	745 (35)	1299 (66)	2333 (47)	3632 (53)
ASA class					
1	740 (16)	617 (29)	287 (15)	1070 (22)	1357 (20)
2	2736 (57)	1152 (54)	1066 (54)	2822 (57)	3888 (56)
3	1244 (26)	352 (16)	587 (30)	1009 (20)	1596 (23)
4	48 (1)	17 (1)	22 (1)	43 (1)	65 (1)
None assigned	4 (< 1)	6 (< 1)	2 (< 1)	8 (< 1)	10 (< 1)
Procedure category					
Epigastric	939 (20)	296 (14)	450 (23)	785 (16)	1235 (18)
Umbilical	3833 (80)	1848 (86)	1514 (77)	4167 (84)	5681 (82)
Hernia width, cm [median (Q1–Q3)]	2 (2, 3)	1 (1, 2)	2 (2, 3)	2 (1, 2)	2 (1, 2)
Indications for repair					
Enlarging hernia/interfering with activities	2850 (61)	776 (39)	1217 (63)	2409 (51)	3626 (55)
Pain	3751 (81)	1597 (80)	1592 (83)	3756 (79)	5348 (80)
Prevalence of comorbidities	2642 (55)	922 (43)	1123 (57)	2441 (49)	3564 (52)
Immunosuppressant	95 (2)	29 (1)	34 (2)	90 (2)	124 (2)
Smoking (within 1 year)	629 (13)	268 (12)	280 (14)	617 (12)	897 (13)
Hypertension	1813 (37)	559 (26)	771 (39)	1581 (32)	2352 (34)
Diabetes mellitus	560 (12)	129 (6)	272 (14)	417 (8)	689 (10)
Dyspnea	102 (2)	17 (1)	53 (3)	66 (1)	119 (2)
COPD	160 (3)	57 (3)	64 (3)	153 (3)	217 (3)
History of abdominal wall SSI	8 (< 1)	3 (< 1)	3 (< 1)	8 (< 1)	11 (< 1)
History of component separation	3 (< 1)	0 (0)	2 (< 1)	1 (< 1)	3 (< 1)
History of open abdomen	84 (2)	32 (1)	45 (2)	71 (1)	116 (2)
Current steroid use	53 (1)	17 (1)	19 (1)	51 (1)	70 (1)

The majority of the operations were performed through an open approach (60% for mesh repair and 97% for the suture repair). The most common mesh material used was permanent synthetic (98%), placed in the intraperitoneal space (46%) or the preperitoneal space (42%). The most common type of mesh used was flat (53%) and patch (46%). Table 2 provides the operative details for this cohort.

Table 3 details all 30-day wound morbidity. At 30 day follow-up, there were more SSOs and SSOPIs reported for mesh repairs (SSO: 6% vs 3% and SSOPI: 2% vs < 1%). In the mesh group, the most common procedural management was percutaneous drainage (59% vs 0% in the suture group). In the suture group, wound opening was the most common procedure (71% vs 31% in the mesh group). SSI rate was similar in both groups. Table 4 illustrates 30-day medical morbidity, readmission, and reoperation. Note that the comparisons of 30-day outcomes are not adjusted for potential confounding factors or patient characteristics; rather, the results are simple summaries of observed events in the study sample.

Minimally invasive (MIS) vs open

Of the entire cohort, 28% underwent minimally invasive repair, while 72% underwent open repair. The mean age was similar in both groups (52 ± 13 in the MIS group vs 51 ± 14 in the open group). The sample mean BMI for the MIS group was higher than the open group (33 ± 7 vs 30 ± 6). Consequently, the MIS group had higher rates of obesity (66% vs 47%) in the study sample. Patient undergoing MIS repair were more likely to have comorbidities (57% vs 49%). This was mostly driven by diabetes (14% vs 8%) and hypertension (39% vs 32%). Table 1 highlights the demographics, patient and hernia characteristics for this cohort.

The majority of the MIS repairs were performed with the robot (55%) followed by laparoscopy (38%). Mesh was used in 96% of the MIS repairs and in 58% of the open repairs. The most common mesh was permanent synthetic (98% in MIS repairs and 99% in open repairs). The mesh was more likely to be place in the preperitoneal position when performing an open repair (50% in open repairs vs 29% in MIS repairs), while the intraperitoneal position was most common when performing MIS repairs (58% in MIS repairs vs 37% in open repair). A flat sheet was used for the majority of MIS repairs (88% in MIS repair vs 29% in open repairs), while a mesh patch was the most common in open repairs (70% in open repairs vs 8% in MIS repairs).

Table 3 details all 30-day wound morbidity. Similar rate of SSOs, SSIs, and SSOPIs was observed between the two groups. Table 4 illustrates 30-day medical morbidity, readmission, and reoperation. Again, these results are descriptive summaries of observed events in the study sample.

Tables 5 and 6 provide descriptive details of operative and demographic details for each group of surgeon affiliation (academic, private, private with academic affiliation).

Discussion

In this analysis, we report on the current practices of surgeons participating in the AHSQC for primary uncomplicated umbilical and epigastric ventral hernia repair. Only one-third of this cohort received a suture repair, while the rest received a mesh repair. The majority of the mesh repairs were performed through an open approach with a permanent synthetic mesh patch placed preperitoneally, while less than one-third received MIS repair with a flat sheet of permanent synthetic mesh placed intraperitoneally. The use of the robot was more common than laparoscopy. In general, patients receiving a hernia repair with mesh or with an MIS approach tended to be more complex (higher BMI, larger hernias, and more comorbidities). To better evaluate these practices, it is important to contrast our findings to the current literature available for primary ventral hernia repair.

The initial consideration for patients presenting with a primary umbilical hernia is whether to use mesh or a tissue repair. Several studies with different designs report a tendency towards improved recurrence rates with the use of mesh. In 2001, a randomized control trial comparing suture to mesh repair found significant improvement in recurrence rates with mesh repair (1% with mesh vs 11% with suture at mean 64 months of follow-up) [13]. Although these were promising findings, the study had no hernia size cutoff, and almost one-third of the population had hernias larger than 3 cm repaired with a different mesh than smaller hernias. Therefore, the question of whether to provide a mesh repair in smaller umbilical hernias remained relevant. This predicament was the study question of a randomized control trial published in 2018 by Kaufmann et al. which included only patients with hernia diameters between 1 and 4 cm. In their study, they found a recurrence rate of 4% in the mesh group compared to 12% in the suture group at a median follow-up of 25.1 months [8]. These results were similar to reports in prior registry-based data and meta-analysis [5, 7]. Subsequently, a meta-analysis of all randomized control trials conducted to assess suture vs mesh repair for umbilical hernias found that mesh repair reduced the risk of recurrence with a relative risk of 0.28. Conclusively, the use of mesh for the repair was recommended for all hernias between 1 and 4 cm [9].

As the recommendation for mesh use is backed by multiple studies in the literature with different designs and similar conclusions, it is important to investigate the proper indications for its use, especially in an era of mesh apprehension and mesh litigation. In both previously mentioned

Table 2 Operative details

	Mesh	Suture	MIS	Open	All
N	4772	2144	1964	4952	6916
Operative approach					
Open	2881 (60)	2071 (97)	0 (0)	4952 (100)	4952 (72)
Laparoscopic	682 (14)	54 (2)	736 (37)	0 (0)	736 (11)
Laparoscopy-assisted	77 (2)	2 (< 1)	79 (4)	0 (0)	79 (1)
Robotic	1077 (22)	13 (1)	1090 (55)	0 (0)	1090 (16)
Robotic-assisted	50 (1)	4 (< 1)	54 (3)	0 (0)	54 (1)
MIS convert to open	5 (< 1)	0 (0)	5 (< 1)	0 (0)	5 (< 1)
Subcutaneous flaps raised	508 (12)	72 (3)	34 (3)	546 (11)	580 (9)
Operative time					
0–59	2710 (57)	1650 (77)	660 (34)	3700 (75)	4360 (63)
60–119	1607 (34)	385 (18)	963 (49)	1029 (21)	1992 (29)
120–179	349 (7)	92 (4)	252 (13)	189 (4)	441 (6)
180–239	81 (2)	12 (1)	66 (3)	27 (1)	93 (1)
240+	25 (1)	5 (< 1)	23 (1)	7 (< 1)	30 (< 1)
Concomitant separate hernia repair	341 (7)	417 (19)	163 (8)	593 (12)	756 (11)
Fascial closure	4293 (90)	2144 (100)	1699 (87)	4738 (96)	6437 (93)
Myofascial release	146 (3)	1 (< 1)	87 (4)	60 (1)	142 (2)
Anterior rectus sheath incision	6 (4)	0 (0)	2 (2)	4 (7)	6 (4)
External oblique	2 (1)	0 (0)	0 (0)	2 (3)	2 (1)
Post rectus sheath incision	131 (90)	1 (100)	80 (92)	52 (87)	132 (90)
Transversus abdominis	26 (18)	1 (100)	21 (24)	6 (10)	27 (18)
Mesh used	4772 (100)	0 (0)	1891 (96)	2881 (58)	4772 (69)
Mesh type					
Permanent synthetic	4692 (98)	0 (0)	1845 (98)	2847 (99)	4692 (98)
Resorbable synthetic	74 (2)	0 (0)	42 (2)	32 (1)	74 (2)
Biological tissue-derived	4 (< 1)	0 (0)	3 (< 1)	1 (< 1)	4 (< 1)
Other/unknown	2 (< 1)	0 (0)	1 (< 1)	1 (< 1)	2 (< 1)
Mesh location					
Inlay	132 (3)	0 (0)	52 (3)	80 (3)	132 (3)
Onlay	207 (4)	0 (0)	69 (4)	138 (5)	207 (4)
Intraperitoneal	2171 (45)	0 (0)	1093 (58)	1078 (38)	2171 (46)
Retrorectus/retromuscular	265 (6)	0 (0)	117 (6)	154 (5)	265 (6)
Preperitoneal	1997 (42)	0 (0)	560 (30)	1462 (51)	1997 (42)
Mesh category					
Flatsheet	2494 (52)	0 (0)	1662 (88)	832 (29)	2494 (52)
Patch	2147 (46)	0 (0)	141 (7)	2006 (70)	2147 (46)
Other	47 (1)	0 (0)	14 (1)	33 (1)	47 (1)
Unknown	2 (< 1)	0 (0)	1 (< 1)	1 (< 1)	2 (< 1)
Mesh fixation	4457 (92)	0 (0)	1717 (89)	2740 (93)	4457 (92)
Mesh fixation type					
Adhesives	70 (2)	0 (0)	6 (< 1)	64 (2)	70 (2)
Staples	53 (1)	0 (0)	5 (< 1)	48 (2)	53 (1)
Sutures	3944 (90)	0 (0)	1337 (79)	2611 (97)	3944 (90)
Tacks	770 (18)	0 (0)	726 (43)	44 (2)	770 (18)
Length of stay (days)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Conversion to open	13 (< 1)	2 (< 1)	15 (1)	N/A	15 (< 1)
Any intra-op complications	8 (< 1)	3 (< 1)	4 (< 1)	7 (< 1)	11 (< 1)
Bowel injury	2 (25)	0 (0)	2 (50)	0 (0)	2 (18)
Other	5 (62)	3 (100)	2 (50)	6 (86)	8 (73)

Table 3 30 day medical morbidity, readmission, and reoperation

	Mesh	Suture	MIS	Open	All
N	4772	2144	1964	4952	6916
Medical complications					
Pulmonary embolism	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stroke	1 (< 1)	0 (0)	1 (< 1)	0 (0)	1 (< 1)
DVT	4 (< 1)	0 (0)	3 (< 1)	1 (< 1)	4 (< 1)
MI	2 (< 1)	0 (0)	1 (< 1)	1 (< 1)	2 (< 1)
Cardiac arrest	1 (< 1)	0 (0)	0 (0)	1 (< 1)	1 (< 1)
UTI	9 (< 1)	2 (< 1)	4 (< 1)	7 (< 1)	11 (< 1)
Renal insufficiency	1 (< 1)	0 (0)	1 (< 1)	0 (0)	1 (< 1)
Acute renal failure	1 (< 1)	0 (0)	1 (< 1)	0 (0)	1 (< 1)
Pain requiring intervention	1 (< 1)	3 (< 1)	4 (< 1)	0 (0)	4 (< 1)
Other	16 (< 1)	7 (< 1)	9 (1)	14 (< 1)	23 (< 1)
Readmission	42 (1)	13 (1)	24 (1)	31 (1)	55 (1)
Pain	12 (34)	3 (33)	8 (40)	7 (29)	15 (34)
Prosthetic related complication	4 (11)	0 (0)	0 (0)	4 (17)	4 (9)
Wound complication	8 (23)	1 (11)	2 (10)	7 (29)	9 (20)
Bleeding complication	2 (6)	1 (11)	1 (5)	2 (8)	3 (7)
Thrombotic complication	2 (6)	0 (0)	2 (10)	0 (0)	2 (5)
Gastrointestinal complication	13 (37)	5 (56)	11 (55)	7 (29)	18 (41)
Reoperation	18 (< 1)	9 (< 1)	8 (< 1)	19 (< 1)	27 (< 1)
Unrecognized bowel injury	0 (0)	1 (12)	0 (0)	1 (6)	1 (4)
Major wound complication	7 (41)	0 (0)	1 (12)	6 (35)	7 (28)
Post-operative bleeding	3 (18)	1 (12)	1 (12)	3 (18)	4 (16)
Early recurrence	1 (6)	4 (50)	2 (25)	3 (18)	5 (20)
Bowel obstruction	6 (35)	1 (12)	5 (62)	2 (12)	7 (28)
Mesh excision	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Unrelated intra-abdominal pathology	1 (6)	1 (12)	0 (0)	2 (12)	2 (8)
Hernia recurrence (Within 30 days)	6 (< 1)	7 (< 1)	6 (< 1)	7 (< 1)	13 (< 1)

randomized control trials, the mean age of the entire cohort was in the mid-50s. Whether a young healthy patient would have the same benefit when using mesh is unknown. In the trial by Kaufmann, the patient population was composed mostly of male patients (almost 84%), with a mean BMI of 28 kg/m^2. Finally, most of the cohort in that study (71%) had hernias between 1 and 2 cm, and when analyzed separately, the difference in the recurrence rate slightly diminishes, but remains statistically significant (2% in the mesh group and 8% in the suture group) [8]. In the setting of an 88–92% success rate in patients with small hernias repaired primarily, a suture repair in a non-obese patient remains reasonable, especially if they do not desire mesh. However, if an obese patient presents, the benefit of mesh repair may be more pronounced, as an increasing BMI has been found to be associated with recurrence [14]. Therefore, in an obese population, mesh repair may be better indicated. While our analysis has shown that surgeons are more likely to offer a mesh repair, this was more selective towards more complex patients and hernias (patients that are obese have larger hernia widths and have more comorbidities). While the selection towards providing suture repair for thinner healthier patients with smaller hernias is understandable, the recent randomized control trial suggests that even in those patients, a significant benefit is seen with mesh repair. Therefore, it is important to share those results with these patients and involve them early in decision making to individualize each treatment plan.

Female patients within reproductive age with a primary ventral hernia present a predicament within this discussion. If the hernia is left unrepaired, there is a possibility for incarceration and obstruction with pregnancy due to the increased intra-abdominal pressure. However, if repaired, future pregnancies may disrupt the durability of the repair. Retrospective reviews found that pregnancy was independently associated with recurrence [15, 16], with mesh repair reported to result in less recurrences after pregnancy compared to suture repair [17]. Female patients within reproductive age should be counselled on the potential implications of their hernia management. As no current studies report on the risk of incarceration during pregnancy, asymptomatic primary ventral hernia may be managed by watchful waiting. When symptomatic, a mesh repair provides better durability.

Table 4 30 day wound morbidity

	Mesh	Suture	MIS	Open	All
N	4772	2144	1964	4952	6916
Surgical site infection (SSI)	36 (1)	7 (< 1)	13 (1)	30 (1)	45 (1)
Superficial SSI	34 (94)	7 (100)	13 (100)	28 (93)	43 (96)
Deep incisional SSI	4 (11)	0 (0)	0 (0)	4 (13)	4 (9)
Organ space SSI	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Surgical site infection or occurrence (SSO)	236 (6)	62 (3)	89 (5)	209 (5)	298 (5)
Seroma	130 (55)	35 (56)	60 (67)	105 (50)	165 (55)
Wound serous drainage	23 (10)	8 (13)	6 (7)	25 (12)	31 (10)
Exposed synthetic mesh	2 (1)	0 (0)	0 (0)	2 (1)	2 (1)
Fascial disruption	2 (1)	0 (0)	0 (0)	2 (1)	2 (1)
Hematoma	20 (8)	5 (8)	5 (6)	20 (10)	25 (8)
Non-healing incisional wound	4 (2)	1 (2)	0 (0)	5 (2)	5 (2)
Wound cellulitis	16 (7)	5 (8)	1 (1)	20 (10)	21 (7)
Skin or soft-tissue ischemia	12 (5)	2 (3)	1 (1)	13 (6)	14 (5)
Skin or soft-tissue necrosis	11 (5)	1 (2)	4 (4)	8 (4)	12 (4)
Stitch abscess	1 (< 1)	2 (3)	1 (1)	2 (1)	3 (1)
Infected hematoma	1 (< 1)	0 (0)	0 (0)	1 (< 1)	1 (< 1)
Infected seroma	2 (1)	0 (0)	0 (0)	2 (1)	2 (1)
Infected synthetic mesh	2 (1)	0 (0)	0 (0)	2 (1)	2 (1)
Unspecified SSO	8 (3)	1 (2)	2 (2)	7 (3)	9 (3)
Wound purulent drainage	4 (2)	0 (0)	0 (0)	4 (2)	4 (1)
SSO requiring procedural intervention	70 (2)	6 (< 1)	16 (1)	60 (1)	76 (1)
Wound opening	22 (31)	4 (67)	3 (19)	23 (38)	26 (34)
Wound debridement	11 (16)	1 (17)	2 (13)	10 (17)	12 (16)
Suture excision	2 (3)	1 (17)	1 (6)	2 (3)	3 (4)
Percutaneous drainage	41 (59)	0 (0)	10 (63)	31 (52)	41 (54)
Partial mesh removal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete mesh removal	5 (7)	0 (0)	0 (0)	5 (8)	5 (7)

However, if a recurrence occurs, a reoperation after suture repair may be more feasible, and therefore, mesh repair can be postponed until reproduction is complete. Further research is required to assess these hypotheses before any formal recommendation can be made.

If mesh repair is deemed appropriate by the surgeon and the patient, another consideration is the type of mesh to use. While mesh has been shown to improve recurrence, the type of the mesh used differs amongst the aforementioned studies. In the trial by Kaufmann and colleagues, the mesh used was a flat sheet of mesh placed in the preperitoneal plane [8]. The trial by Arryyo et al. used two meshes, a flat sheet for larger hernias, and mesh plug for smaller ones [13]. Other meshes have been noted in the literature, most prominently mesh patches, mesh plugs, and bilayer mesh with a connector. In our study, the majority of the surgeons used either a flat mesh (52%) or a mesh patch (45%). Several studies have reported low recurrence rates with the use of the patch (0–9%) and no concerning complications [18–21]. However, when comparing mesh patch to a flat mesh, the MOROHEUS Trial, a randomized control trial, found no benefit to the patch, increased reoperations due to complications, and slight increase in recurrence rates (7.8% in patch repair vs 3.3% in flat mesh repair) [22]. The trial, however, was not powered enough to detect this difference. This reiterates the importance of studying these meshes in a research setting, ensuring adequate power and correct comparisons to detect differences in outcomes. The use of mesh plugs and bilayer mesh is similarly limited by the retrospective nature of the literature [23, 24] and a randomized control trial that is not powered to detect specific differences [25]. Therefore, evidence for the use of mesh in primary ventral hernias is limited to a flat mesh. While other options are viable, their use should be cautioned until high-level evidence is available. In our analysis, the majority of surgeons performing hernia repair through an open approach used a mesh patch (70%). A thorough study evaluating long-term recurrence rates and complication is required before any recommendation is provided. Preferably, this would be through a randomized control trial powered to detect these potential differences in outcomes.

Table 5 Surgeon affiliation operative details

	Academic	Private	Private with academic affiliation
N	3202	2425	1964
Operative approach			
Open	2447 (76)	1552 (64)	942 (74)
MIS	755 (24)	873 (36)	330 (26)
Mesh/suture			
Mesh	1883 (59)	1943 (80)	935 (74)
Suture	1319 (41)	482 (20)	337 (26)
Mesh categories			
Flatsheet	976 (53)	1106 (58)	403 (44)
Patch	843 (46)	791 (41)	511 (56)
Other	28 (2)	16 (1)	3 (< 1)
Unknown	1 (< 1)	1 (< 1)	0 (0)
Subcutaneous flaps raised	1690 (53)	1280 (53)	650 (51)
Operative time			
0–59	598 (19)	513 (21)	242 (19)
60–119	1728 (54)	1397 (58)	757 (60)
120–179	843 (26)	496 (20)	250 (20)
180–239	28 (1)	19 (1)	18 (1)
240+	5 (< 1)	0 (0)	5 (< 1)

A minimally invasive approach to primary hernia repair is also available as an option for these patients. A laparoscopic repair with mesh placed in the intraperitoneal position is the more traditional approach; however, our cohort had higher rates of robotic repair compared to laparoscopy. A propensity score matched analysis comparing laparoscopy to open repair found similar recurrence rates, fewer SSIs, with increased risk of port-site hernias and developing a bulge (not related to recurrence or seroma) [26]. A systemic review found similar outcomes with lower recurrence rate in the laparoscopic group. However, the pooled recurrence rate and effect size remained unknown [27]. An intraperitoneal mesh repair performed with the robot has also been described, with studies finding similar outcomes to laparoscopic repair [28, 29]. More recently, the enhanced-view totally extraperitoneal (eTEP) repair and the endoscopic mini/less open sublay technique (EMILOS) have been described for incisional and ventral hernias, with no safety concerns reported [30, 31]. The advantage of these techniques is utilizing the retromuscular space for mesh placement through an MIS approach, isolating the mesh from the abdominal viscera, and potentially avoiding complications associated with intra-abdominal access and mesh (bowel injury, port-site hernias, and adhesions between prosthetic and bowel). However, these new techniques were not studied exclusively in primary ventral hernias, and their use within this specific population is not yet described.

While minimally invasive approaches to primary ventral hernias are considered a valuable option, there is no clear evidence on the indications for these approaches. At large, studies on MIS repair for primary ventral hernias tend to have more obese populations [26, 28, 30, 32, 33]. This was similarly observed in our analysis (66% obese patient in MIS group vs 47% in the open group). While several studies have shown benefit to using laparoscopic repair in this population, they often do not report hernia width and include both incisional and primary ventral hernias with wide range of hernia sizes [34, 35]. Primary ventral hernias with smaller diameter may behave differently, and the benefit to MIS repair may not be as evident. In general, even for the non-obese population, heterogeneity of hernia sizes exists within MIS studies, and there is no clear evidence for a hernia width cutoff to benefits from such repairs.

The SAGES guidelines for laparoscopic ventral hernia repair report the advantages of laparoscopic ventral hernia repair over open repair given the decreased wound complication rate and similar recurrence rates and post-operative pain [36]. However, the use of MIS in our cohort seems to reflect an aversion to these approaches, as less than one-third of our patients received an MIS repair. Since the majority of these repairs involved placing the mesh intraperitoneally (58%), this could be driven out of fear of mesh complications related to placing the mesh in contact with abdominal viscera rather than the MIS repair itself. Of the 1% readmitted after an MIS repair, 55% were due to gastrointestinal complications (vs 29% in open repairs). Similarly, 62% of reoperations were due to bowel obstruction in MIS repairs (vs 12% in open repairs). However, due to the unadjusted nature of our analysis, associations with these complications cannot be drawn. Finally, the preperitoneal space was used for mesh positioning in 29% of MIS mesh repairs. This could be the eTEP approach as previously mentioned. However, no subgroup analysis was made to detect any differences in outcomes between the two different mesh positions.

The presence of a concomitant rectus diastasis with a primary ventral hernia requires special consideration. In a retrospective study, the presence of rectus diastasis has been linked to increased rate of recurrences with concomitant suture repair of primary hernia [37]. While other retrospective studies and a randomized control trial studying repair of rectus diastasis report acceptable recurrence rates and improved outcomes compared to baseline, they lack a comparison arm where the rectus diastasis is not repaired [38–40]. Due to paucity in the literature on this topic, a concomitant rectus diastasis repair is not currently recommended unless within a research setting to establish the potential benefit. The AHSQC does not collect the

Table 6 Surgeon affiliation demographic details

	Academic	Private	Private with academic affiliation
N	3202	2425	1964
Surgeons contributing data	98	81	39
Sites contributing data	53	120	52
Age, years (mean ± SD)	51 ± 14	52 ± 14	53 ± 14
Gender (female)	979 (31)	623 (26)	361 (28)
BMI, kg/m^2 (mean ± SD)	31 ± 7	31 ± 6	31 ± 7
BMI categories			
< 30	1508 (47)	1145 (47)	619 (49)
≥ 30	1690 (53)	1280 (53)	650 (51)
ASA class			
1	598 (19)	513 (21)	242 (19)
2	1728 (54)	1397 (58)	757 (60)
3	843 (26)	496 (20)	250 (20)
4	28 (1)	19 (1)	18 (1)
None assigned	5 (< 1)	0 (0)	5 (< 1)
Procedure category			
Epigastric	599 (19)	390 (16)	242 (19)
Umbilical	2603 (81)	2035 (84)	1030 (81)
Hernia width, cm [median (Q1–Q3)]	2 (1, 2)	2 (1–3)	2 (1, 2)
Indications for repair			
Enlarging hernia/interfering with activities	1436 (47)	1454 (62)	730 (58)
Pain	2539 (84)	1839 (79)	956 (76)
Prevalence of comorbidities	1630 (51)	1220 (50)	704 (55)
Immunosuppressant	68 (2)	24 (1)	30 (2)
Smoking (within 1 year)	408 (13)	319 (13)	169 (13)
Hypertension	1053 (33)	831 (34)	461 (36)
Diabetes mellitus	303 (9)	262 (11)	121 (10)
Dyspnea	54 (2)	41 (2)	14 (2)
COPD	91 (3)	75 (3)	51 (4)
History of abdominal wall SSI	7 (< 1)	3 (< 1)	1 (< 1)
History of component separation	0 (0)	3 (< 1)	0 (0)
History of open abdomen	50 (2)	26 (1)	40 (3)
Current steroid use	34 (1)	13 (1)	22 (2)

presence of concomitant rectus diastasis, and therefore, we are unable to comment on our cohort's current practices.

Our study has several limitations that deserve mention. As inherent in any retrospective analysis, our results reflect a selective group of patients with bias in each offered approach, and since no adjustment analysis was conducted, no inference to the larger population of hernia repairs can be drawn. We are also unable to comment specifically on outcomes of different approaches in our patient population, as our analysis was descriptive in nature and no adjustment or subgroup analysis was conducted. In addition, since this is a large database study, a degree of error in data collection and measurement is expected.

Another limitation is the exclusion criteria implemented to define an "uncomplicated primary ventral hernia". Since the AHSQC does not differentiate between planned concomitant procedures and those occurring as a complication, we elected to exclude all patients with any concomitant procedure performed. A similar limitation is present in excluding all non-clean wounds. Finally, our analysis is limited to experience and practice of AHSQC surgeons in the United States of America and their patient population. Importantly, the AHSQC represents both academic and non-academic surgeons across the United States which improves the generalizability of the results within this region.

Conclusion

Recent high-level literature recommends the use of mesh repair (flat mesh) in all patients with a primary hernia ≥ 1 cm in width. Despite this, AHSQC surgeons currently offer suture repair in one-third of cases. While the evidence for mesh use is limited to the use of flat mesh through an open approach, AHSQC surgeons most commonly performed the repair using a mesh patch and were more selective towards larger hernias and obese patients. Further research is required to evaluate the safety of mesh patches, and a mesh repair should be offered to a young non-obese healthy patient, as they benefit similarly from the use of mesh.

Compliance with ethical standards

Conflict of interest Dr. Stewart and Ms. Olsen report that the AHSQC contracts Vanderbilt Biostatistics to provide support for AHSQC projects. The work provided was performed under the umbrella of the AHSQC-Vanderbilt Biostatistics collaboration plan. Dr. Krpata reports grants from Gore for education, outside of submitted work. Dr. Alkhatib reports no conflicts of interest.

Ethical approval This study did not need approval from the local ethical committee.

Human and animal rights This study does not contain any studies with participants or animals performed by any of the authors.

Informed consent For this type of study, consent was not required.

References

1. Witherspoon P, O'Dwyer PJ (2005) Surgeon perspectives on options for ventral abdominal wall hernia repair: results of a postal questionnaire. Hernia 9(3):259–262
2. Appleby PW, Martin TA, Hope WW (2018) Umbilical hernia repair: overview of approaches and review of literature. Surg Clin N Am 98(3):561–576
3. Halm JA et al (2005) Long-term follow-up after umbilical hernia repair: are there risk factors for recurrence after simple and mesh repair. Hernia 9(4):334–337
4. Stabilini C et al (2009) Mesh versus direct suture for the repair of umbilical and epigastric hernias. Ten-year experience. Ann Ital Chir 80(3):183–187
5. Christoffersen MW et al (2013) Lower reoperation rate for recurrence after mesh versus sutured elective repair in small umbilical and epigastric hernias. A nationwide register study. World J Surg 37(11):2548–2552
6. Aslani N, Brown CJ (2010) Does mesh offer an advantage over tissue in the open repair of umbilical hernias? A systematic review and meta-analysis. Hernia 14(5):455–462
7. Nguyen MT et al (2014) Comparison of outcomes of synthetic mesh vs suture repair of elective primary ventral herniorrhaphy: a systematic review and meta-analysis. JAMA Surg 149(5):415–421
8. Kaufmann R et al (2018) Mesh versus suture repair of umbilical hernia in adults: a randomised, double-blind, controlled, multicentre trial. Lancet 391(10123):860–869
9. Bisgaard T et al (2018) Lower risk of recurrence after mesh repair versus non-mesh sutured repair in open umbilical hernia repair: a systematic review and meta-analysis of randomized controlled trials. Scand J Surg 108(3):187–193
10. Poulose BK et al (2016) Design and implementation of the Americas Hernia Society Quality Collaborative (AHSQC): improving value in hernia care. Hernia 20(2):177–189
11. Haskins IN et al (2018) A call for standardization of wound events reporting following ventral hernia repair. Hernia 22(5):729–736
12. Centers for Disease Control and Prevention web site (2018) Surgical site infection (SSI) event. [cited 2018 5 April]. https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf. Accessed 5 Apr 2018
13. Arroyo A et al (2001) Randomized clinical trial comparing suture and mesh repair of umbilical hernia in adults. Br J Surg 88(10):1321–1323
14. Shankar DA et al (2017) Factors associated with long-term outcomes of umbilical hernia repair. JAMA Surg 152(5):461–466
15. Oma E, Jensen KK, Jorgensen LN (2017) Increased risk of ventral hernia recurrence after pregnancy: a nationwide register-based study. Am J Surg 214(3):474–478
16. Lappen JR, Sheyn D, Hackney DN (2016) Does pregnancy increase the risk of abdominal hernia recurrence after prepregnancy surgical repair? Am J Obstet Gynecol 215(3):390.e1–390.e5
17. Oma E et al (2019) Nationwide propensity-score matched study of mesh versus suture repair of primary ventral hernias in women with a subsequent pregnancy. World J Surg 43(6):1497–1504
18. Vychnevskaia K et al (2010) Intraperitoneal mesh repair of small ventral abdominal wall hernias with a ventralex hernia patch. Dig Surg 27(5):433–435
19. Zarmpis N, Wassenberg D, Ambe PC (2015) Repair of small and medium size umbilical hernias with the "proceed ventral patch" in the preperitoneal position. Am Surg 81(11):1144–1148
20. Tollens T et al (2011) Retrospective analysis of umbilical, epigastric, and small incisional hernia repair using the Ventralex hernia patch. Hernia 15(5):531–540
21. Martin DF et al (2008) Ventralex mesh in umbilical/epigastric hernia repairs: clinical outcomes and complications. Hernia 12(4):379–383
22. Ponten JEH et al (2018) Mesh versus patch repair for epigastric and umbilical hernia (MORPHEUS trial); one-year results of a randomized controlled trial. World J Surg 42(5):1312–1320
23. Khera G, Berstock DA (2006) Incisional, epigastric and umbilical hernia repair using the Prolene Hernia System: describing a novel technique. Hernia 10(4):367–369
24. Xie Y et al (2016) Effectiveness of preperitoneal herniorrhaphy with Ultrapro Plug mesh for umbilical hernia repair in adults. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 30(6):739–741
25. Polat C et al (2005) Umbilical hernia repair with the prolene hernia system. Am J Surg 190(1):61–64
26. Liang MK et al (2013) Outcomes of laparoscopic vs open repair of primary ventral herniaslaparoscopic vs open repair of PVHs laparoscopic vs open repair of PVHs. JAMA Surg 148(11):1043–1048
27. Hajibandeh S et al (2017) Laparoscopic versus open umbilical or paraumbilical hernia repair: a systematic review and meta-analysis. Hernia 21(6):905–916
28. Prabhu AS et al (2017) Laparoscopic vs robotic intraperitoneal mesh repair for incisional hernia: an Americas Hernia Society Quality Collaborative Analysis. J Am Coll Surg 225(2):285–293
29. Chen YJ et al (2017) Outcomes of robot-assisted versus laparoscopic repair of small-sized ventral hernias. Surg Endosc 31(3):1275–1279

30. Belyansky I et al (2018) A novel approach using the enhanced-view totally extraperitoneal (eTEP) technique for laparoscopic retromuscular hernia repair. Surg Endosc 32(3):1525–1532
31. Schwarz J, Reinpold W, Bittner R (2017) Endoscopic mini/less open sublay technique (EMILOS)-a new technique for ventral hernia repair. Langenbecks Arch Surg 402(1):173–180
32. Cassie S et al (2014) Laparoscopic versus open elective repair of primary umbilical hernias: short-term outcomes from the American College of Surgeons National Surgery Quality Improvement Program. Surg Endosc 28(3):741–746
33. Savitch SL, Shah PC (2016) Closing the gap between the laparoscopic and open approaches to abdominal wall hernia repair: a trend and outcomes analysis of the ACS-NSQIP database. Surg Endosc 30(8):3267–3278
34. Lee J et al (2013) Laparoscopic vs open ventral hernia repair in the era of obesity. JAMA Surg 148(8):723–726
35. Novitsky YW et al (2006) Laparoscopic ventral hernia repair in obese patients: a new standard of care. JAMA Surg 141(1):57–61
36. Earle D et al (2016) SAGES guidelines for laparoscopic ventral hernia repair. Surg Endosc 30(8):3163–3183
37. Kohler G, Luketina RR, Emmanuel K (2015) Sutured repair of primary small umbilical and epigastric hernias: concomitant rectus diastasis is a significant risk factor for recurrence. World J Surg 39(1):121–126 **(discussion 127)**
38. Privett BJ, Ghusn M (2016) Proposed technique for open repair of a small umbilical hernia and rectus divarication with self-gripping mesh. Hernia 20(4):527–530
39. Kockerling F et al (2016) Endoscopic-assisted linea alba reconstruction plus mesh augmentation for treatment of umbilical and/or epigastric hernias and rectus abdominis diastasis—early results. Front Surg 3:27
40. Emanuelsson P et al (2016) Operative correction of abdominal rectus diastasis (ARD) reduces pain and improves abdominal wall muscle strength: a randomized, prospective trial comparing retromuscular mesh repair to double-row, self-retaining sutures. Surgery 160(5):1367–1375