Surgical Outcomes in Lateral Abdominal Wall Reconstruction: A Comparative Analysis of Surgical Techniques

Sahil K Kapur, MD, Jun Liu, PhD, Donald P Baumann, MD, FACS, Charles E Butler, MD, FACS

BACKGROUND: Lateral abdominal wall (LAW) myofascial defects are a challenging reconstructive problem, and no consensus exists on their surgical management. We hypothesized that mesh repairs anchored to the nonyielding LAW boundaries (pillar-anchored repairs [PARs]) would provide more durable reconstructions, with lower hernia recurrence and bulge occurrence rates, compared with mesh repairs anchored to the surrounding oblique muscle complexes (direct repairs [DRs]).

STUDY DESIGN: We retrospectively reviewed LAW reconstructions at a single center from 2004 to 2010. Patients were divided into 2 groups based on whether they had received a PAR or a DR. The primary outcome measure was hernia recurrence. The secondary outcome measures were surgical site occurrences (SSOs), surgical site infections (SSIs), and reoperations for complications.

RESULTS: We analyzed 106 consecutive patients with LAW reconstructions (PAR, 59 DR, 47). The median follow-up time was 28.1 months (PAR, 24.5 months; DR, 34.5 months). The baseline demographics were similar in the groups. Nineteen hernia recurrences were observed (PAR, 5 [8.5%]; DR, 14 [29.8%]; $p = 0.033$, log-rank test). The "closure type" (bridged vs reinforced repair), "mesh type" or "defect area" were not associated with hernia recurrence or bulge occurrence. The groups did not differ significantly regarding SSOs, SSIs, or reoperations for complications. In the multivariable Cox proportional regression model, PAR provided a 3.5 times lower risk of hernia recurrence than DR (adjusted hazard ratio, 0.28; 95% CI 0.09 to 0.88; $p = 0.03$).

CONCLUSIONS: The PAR technique is superior to DR for reconstructing LAW defects in order to achieve the lowest hernia recurrence rates in this complex patient population. (J Am Coll Surg 2019;229:267–276.
© 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Clinical research in the area of abdominal wall reconstruction has focused mostly on repair of the midline ventral abdominal wall. Although the rate of ventral abdominal hernia is higher than that of lateral abdominal wall (LAW) hernia, defects of the LAW are fairly common, technically challenging to repair, and associated with high rates of hernia recurrence.[1] Most LAW defects are trauma-induced or iatrogenic; rarely, they are congenital. Tumor excisions and surgical access incisions—such as flank incisions for nephrectomies, retroperitoneal incisions for vascular procedures, and subcostal incisions—can cause denervation and division of the LAW muscle/fascia, leading to a bulge and/or hernia. These defects reportedly occur in 8% to 57% of patients undergoing surgery involving the LAW.[2-4]

Many of the challenges of LAW reconstruction stem from the differences between lateral and ventral abdominal wall anatomy; therefore, appreciating these differences is integral to understanding the etiology of LAW defects and developing a reliable reconstructive plan. The LAW is defined as the area that extends from the costal margin superiorly

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Abstract presented at the American College of Surgeons 104th Annual Clinical Congress, Scientific Forum, Boston, MA, October 2018.

Received January 11, 2019; Revised March 25, 2019; Accepted March 28, 2019.

From the Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, Houston, TX.

Correspondence address: Sahil K Kapur, MD, Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, 1400 Pressler St, Unit 1488, Houston, TX 77030. email: skkapur@mdanderson.org

© 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.

https://doi.org/10.1016/j.jamcollsurg.2019.03.023
ISSN 1072-7515/19

Abbreviations and Acronyms

AIC = Akaike information criterion
DR = direct repair
HR = hazard ratio
LAW = lateral abdominal wall
OR = odds ratio
PAR = pillar-anchored repair
SSI = surgical site infection
SSO = surgical site occurrence

to the iliac crest inferiorly and from the linea semilunaris anteriorly to the paraspinous muscles posteriorly. The layers of tissue comprising the LAW include the external oblique, internal oblique, and transversus abdominis muscles and the transversalis fascia. Although there is a significant amount of information about ventral abdominal wall physiology, we have found no detailed description of LAW physiology in the literature. Our understanding of the mechanics and stresses on the lateral abdominal is based on its anatomic components and interpolation from what we know about the ventral abdominal wall. The LAW contains a higher proportion of muscle than aponeurotic tissue, which may lower its tensile integrity compared with that of the ventral midline abdominal wall, and could therefore increase risk of recurrence. Lateral abdominal wall defects are associated with weakness that extends over a much wider area due to denervation injury caused by transection of thoracoabdominal intercostal nerves or direct muscle injury caused by transection of muscle fibers. The eccentric location of LAW defects also subjects them to asymmetric distraction forces caused by the independent contraction of the contralateral hemiabdomen and ipsilateral rectus complex on 1 side and the remaining ipsilateral abdominal wall on the other. These challenges underscore the importance of a durable, well-anchored repair.[5]

There is a knowledge gap in the current literature as to the optimal surgical technique for addressing LAW defects. Accordingly, in this study, we compared 2 major mesh repair techniques: direct repair (DR) and pillar-anchored repair (PAR). A DR involves an underlay of mesh that extends beyond the immediate boundaries of the defect, followed by suturing of the mesh to oblique muscle tissue of substantial quality (Fig. 1). A PAR involves anchoring an underlay of mesh to nonyielding points of fixation along the borders of the LAW; the linea semilunaris, costal margin, inguinal ligament/iliac crest, and posterior paraspinal fascia (Fig. 2). We hypothesized that PARs provide more durable reconstructions with lower hernia recurrence and bulge occurrence rates than DRs.

METHODS

Evaluation of patients and outcomes

We retrospectively evaluated all consecutive patients who had undergone LAW reconstruction to correct either tumor resection defects or hernias and in whom an underlay of mesh was placed using either a PAR or DR technique. All reconstructions were performed at our institution over a 10-year period (2004 to 2014). The data were obtained from a prospectively maintained departmental database and from the patients' electronic medical records. This study was approved by The University of Texas MD Anderson Cancer Center's institutional review board.

The primary outcome measures were the recurrence of hernias and the occurrence of bulges. A hernia was defined as a contour deformity with a corresponding musculofascial defect of the lateral abdominal wall seen on CT scans or physical examination. None of the hernias in this study involved defects in the internal oblique and transversus abdominis with an intact external oblique muscle. All hernias involved all 3 layers of the lateral abdominal wall muscles. A bulge was defined as a contour deformity without a corresponding fascial defect. Unlike cases of hernia recurrence in which there is clear evidence of an abdominal wall defect on CT scan, the diagnosis of bulge was assigned if it was documented as such in the clinical examination.

The secondary outcome measures were surgical site occurrences (SSOs), defined as the presence of 1 or more of the following: cellulitis, abscess, wound dehiscence, enterocutaneous fistula, hematoma (defined as a collection of blood requiring percutaneous or open drainage), or seroma (defined as a collection of sterile fluid requiring percutaneous or open drainage); surgical site infections (SSIs), defined as cellulitis (requiring treatment with antibiotics) or surgical site abscess (involving an infectious process associated with a fluid collection requiring operative or bedside drainage); and reoperation. Follow-up consisted of serial physical examinations and CT imaging, as dictated by the patients' oncologic surveillance protocols.

Lateral abdominal wall defects were defined as those that were mainly contained within the formally defined boundaries of the lateral abdominal wall. Defects overlapping these boundaries were included only if a majority of the defects involved the lateral abdominal wall. These defects were then analyzed based on defect type, closure type, and mesh type. Defect type was defined as excisional or hernia defect. Excisional defects were caused by tumor resection that involved resection of abdominal wall muscle and fascia. Hernia defects were those caused by weakening of the lateral abdominal wall due to denervation,

muscle transection, and scarring from previous operations. Closure type was defined as primary closure or bridged closure. As the terms suggest, in primary closures, the overlying musculofascial layer was approximated over mesh (placed in an underlay position); in bridged closures, the overlying musculofascial layer could not be approximated over the mesh. All excisional defects were closed with a bridged closure. Hernia defects, on the other hand, could be closed either primarily (with underlay mesh) or in a bridged fashion, depending on the quality and availability of the overlying musculofascial layer.

The medical comorbidities extracted from the patients' medical records included coronary artery disease, diabetes mellitus, active alcohol use, gastrointestinal disease, hypertension, obesity (BMI $\geq$ 30 kg/m^2), peripheral vascular disease, pulmonary disease, active tobacco use, substance abuse, preoperative radiotherapy, and preoperative chemotherapy.

Surgical techniques

Lateral abdominal wall repairs were performed in a multidisciplinary setting. After a surgical oncologist completed either a tumor resection or a laparotomy with lysis of adhesions (in patients being treated for a hernia), a plastic surgeon performed LAW reconstruction. The choice between the DR and the PAR technique for LAW reconstruction was left to the discretion of the plastic surgeon. In the DR technique, an underlay of mesh was inset under healthy/sturdy surrounding tissue, with a 5-cm overlap (Fig. 3). In the PAR technique, an underlay of mesh was sutured to static points of fixation (pillars) at the boundaries of the abdominal wall. Permanent sutures were used for mesh inset and muscle/fascia closure. In either repair, the abdominal wall was closed either primarily or with a soft tissue flap (Fig. 4). Repairs were performed by 25 different plastic surgeons. In the cases that did not involve excision of the lateral abdominal wall musculature or a bridged repair, the muscles of the LAW were retained as a composite unit and were reapproximated as such over the mesh as a reinforced repair.

Because this was a retrospective study, there was no established protocol for the PAR and DR repairs. However, each operative report was reviewed to determine which repair was performed. There was enough information in the operative reports to make a clear distinction between the techniques in all cases. There was no change to either repair technique over the 10-year study period.

Statistical analysis

Descriptive statistics were used to summarize patient age, BMI, and length of follow-up. Frequencies and percentages were calculated for the categorical variables. The

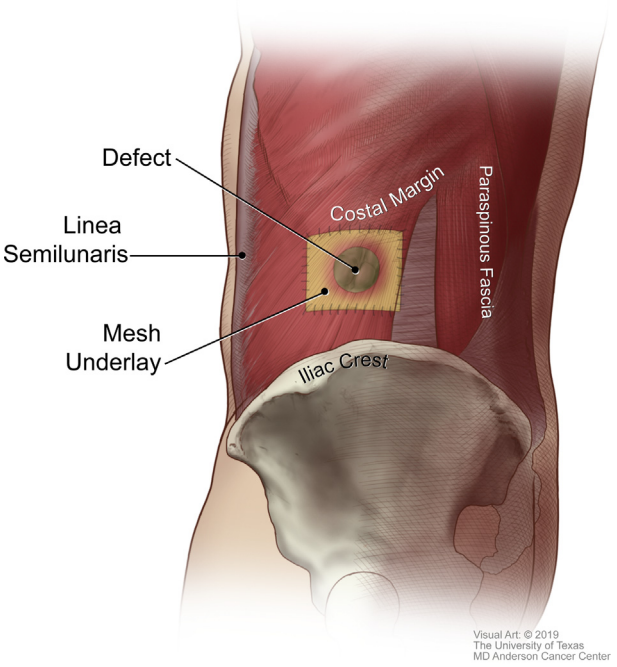

Figure 1. Direct repair with underlay mesh of a lateral abdominal wall excisional defect. Borders of the lateral abdominal wall have been labelled. (Reprinted with permission from Visual Art, The University of Texas MD Anderson Cancer Center.)

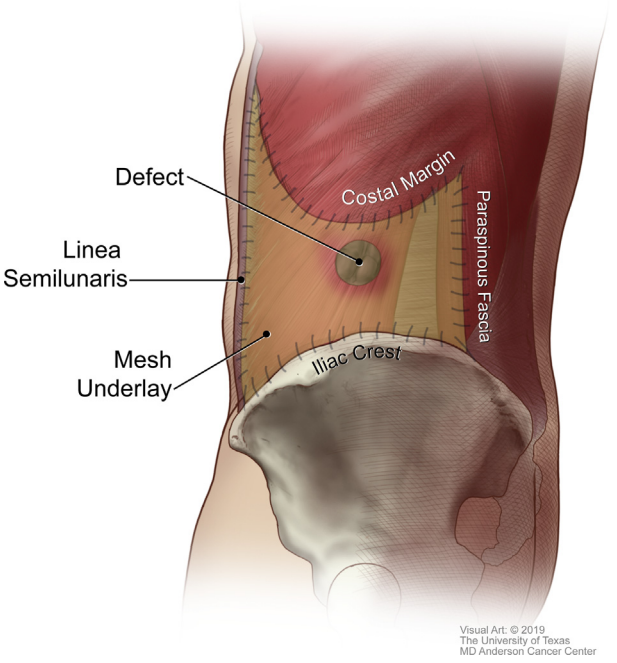

Figure 2. Illustration of pillar-anchored repair with underlay mesh of a lateral abdominal wall excisional defect. Borders of the lateral abdominal wall have been labelled. (Reprinted with permission from Visual Art, The University of Texas MD Anderson Cancer Center.)

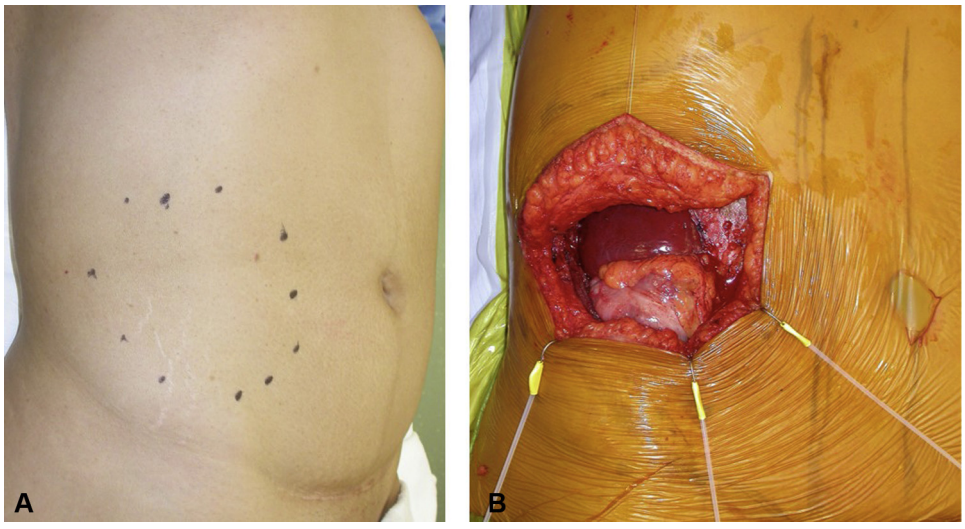

Figure 3. Direct repair technique. (A) Preoperative photo showing the planned margins for a full-thickness abdominal wall resection in a patient with a desmoid tumor. (B) Intraoperative photo showing the defect to be repaired.

time to hernia recurrence was defined as the time between the date of reconstructive surgery and the date of either the first hernia recurrence or the last follow-up, whichever occurred first. Censoring time was defined as the time interval from date of reconstructive surgery to the date of the last follow-up for patients who did not develop hernia recurrence during follow-up. Cumulative hernia recurrence rates were estimated using the Kaplan-Meier product-limit method. The patients who did not have hernia recurrence during the study period were censored in the analysis. The length of follow-up was weighted in the estimation so that the difference in follow-up would not bias the comparison of recurrence between the 2 groups. A chi-square test or Fisher's exact test was used to assess the association between the categorical variables and the DR and PAR groups. The Wilcoxon rank sum

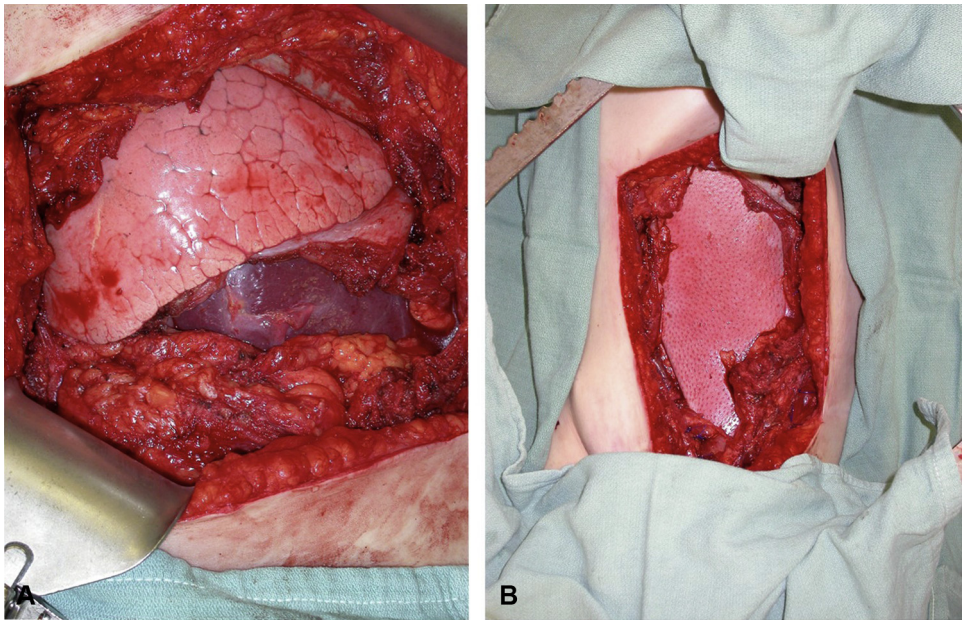

Figure 4. Pillar-anchored repair technique. (A) Intraoperative photo showing the excisional defect after resection of a flank liposarcoma. (B) Intraoperative photo showing the repair made with an underlay of bioprosthetic mesh.

test was used to compare the ordinal variables, such as defect size, between the 2 groups. The log-rank test was used to compare the distribution of time to hernia recurrence between PAR and DR groups. We performed univariate analyses to evaluate the associations between each variable and the clinical outcomes. Multivariable logistic regression models were then used to estimate the adjusted odds ratios (ORs) for SSOs, SSIs, and reoperation rates after PAR repairs. A multivariable Cox proportional hazards regression model was used to obtain an adjusted hazard ratio (HR) for the estimation of the association of PAR use on hernia recurrence. Backward stepwise model selection method was used with Akaike information criteria (AIC) value as the selection criteria to build the most fitted multivariable model. We choose AIC as a selection criterion because AIC resolves the trade-off between model fit and complexity to achieve the best predictive ability.[6] We found that including the variables, repair type (PAR vs DR), defect type (hernia vs excision) and preoperative radiation minimizes AIC in this multivariable Cox proportional hazards regression model of hernia.

In order to estimate the effect of repair type on hernia recurrence we believed it was necessary to consider certain risk factors in the multivariable model, even though they did not reach significance in univariate analysis. These risk factors, which include mesh type (synthetic vs bioprosthetic), closure type (primary vs bridged) and defect area, have been shown to play a significant effect on hernia recurrence outcomes in the ventral abdominal wall literature.[7-9] Body mass index was not included because not only was it found to be nonsignificant in univariate analysis, it has also been shown to be nonpredictive for hernia recurrence in ventral abdominal wall reconstruction in our patient population.[10] Multicollinearity was checked using variance inflation factors (VIF), and VIF < 4 implied that there was no multicollinearity.[11]

All statistical tests were 2-sided. A value of $p < 0.05$ was considered significant. Analyses were performed in SAS 9.4 (SAS Institute Inc) and R (The R Foundation for Statistical Computing).

RESULTS

A total of 106 patients underwent LAW reconstruction at our institution from 2004 through 2014. Forty-seven patients (44.3%) underwent DR, and 59 (55.6%) underwent PAR. Mean age of the patients was 54.7 years, and the median length of follow-up was 34.5 months for DR vs 24.5 months for PAR ($p = 0.04$). Patient characteristics such as sex, BMI, and medical comorbidities present at baseline, including, coronary artery disease, diabetes mellitus, obesity, and histories of preoperative radiotherapy or chemotherapy, did not differ significantly between the DR and PAR groups (Table 1).

Of the 106 patients, 72 (67.9%) had excisional defects and 34 (32.1%) had hernia defects. Of the patients who underwent reconstruction of hernia defects, 12 patients had incisions along the dermatomal lines. Because incisions along dermatomal lines may limit or eliminate thoracoabdominal intercostal nerve transection and cause less denervation injury than nondermatomal incisions (Kocher incision), we analyzed the effect of dermatomal vs nondermatomal incisions in our hernia subgroup and found no significant effect on hernia recurrence ($p = 0.84$, log-rank test).

Bioprosthetic mesh, as opposed to synthetic mesh, was used in the majority of the cases (74.5% vs 25.5%). Bioprosthetic meshes used included SurgiMend (Integra LifeSciences Corporation), Strattice Reconstructive Tissue Matrix (Allergan), and AlloDerm Regenerative Tissue Matrix (Allergan). Synthetic mesh choices included Prolene Polypropylene Mesh (Ethicon) and Marlex (Bard Davol, now a branch of Becton, Dickinson and Company). The PAR cohort had a higher proportion of bioprosthetic mesh use compared with the DR cohort (84.7% vs 61.7%, $p = 0.007$) (Table 2). For all patients combined there was no significant difference in the hernia recurrence rate between patients who received bioprosthetic mesh (19%) and those who received synthetic mesh (14.8%) ($p = 0.36$). The cumulative bulge rate was significantly higher in the synthetic mesh group than in the bioprosthetic mesh group (14.8% vs 2.5%, $p = 0.022$).

Patients undergoing PAR had a 3.5-fold lower hernia recurrence rate than those undergoing DR (8.5% vs 29.8%; $p = 0.033$). The DR group had a slightly higher rate of SSI and SSO than did the PAR group, but the differences were not significant. The incidences of seroma, abscess, hematoma, and wound dehiscence were low for all LAW reconstruction patients and did not differ significantly between the PAR and DR groups (Table 3). The PAR population had a lower reoperation rate for complications than the DR population did, but the difference was not significant.

Repairs were performed by 25 different plastic surgeons. Eleven of these surgeons performed both techniques (DR and PAR), 5 surgeons performed only the PAR technique, and 9 surgeons performed only the DR technique. The 2 senior surgeons (Butler and Baumann) performed 31 of the 59 PAR cases. In this retrospective study in which the repair type was not randomized, but was left to the discretion of the surgeon, it is important to ensure that the results were a result of the repair type (PAR vs DR) and not a result of surgeon and surgeon

Table 1. Demographic Characteristics of Patients at Baseline

Variable	All (n = 106)	DR (n = 47)	PAR (n = 59)	p Value*
Age, y, mean (SD)	54.7 (15.2)	54.9 (14.8)	54.5 (15.7)	0.87†
BMI, kg/m^2, mean (SD)	29.7 (6.5)	28.5 (5.8)	30.64 (6.4)	0.06†
Length of follow-up, mo, median (IQR)	28.1 (10–48.6)	34.5 (12.4–61)	24.5 (7.9–40.2)	0.04†
Sex, n (%)				
Female	50 (47.1)	22(46.8)	28 (47.5)	
Male	56 (52.8)	25 (53.2)	31 (52.5)	0.95
Comorbidity, n (%)				
Coronary artery disease	11 (10.4)	3 (6.4)	8 (13.6)	0.34
Diabetes mellitus	15 (14.2)	6 (12.8)	9 (15.3)	0.78
Active alcohol use	1 (0.9)	1 (2.1)	0 (0)	0.99
Gastrointestinal disease	24 (22.6)	13 (27.7)	11 (18.6)	0.27
Hypertension	43 (40.6)	18 (38.3)	25 (42.4)	0.67
Obesity (BMI $\geq$ 30 kg/m^2)	8 (7.5)	3 (6.4)	5 (8.5)	0.99
Peripheral vascular disease	3 (2.8)	2 (4.3)	1 (1.7)	0.58
Pulmonary disease	9 (8.5)	3 (6.4)	6 (10.2)	0.73
Active tobacco use	7 (6.6)	3 (6.4)	4 (6.8)	0.58
Prior substance abuse	2 (1.9)	0 (0)	2 (3.4)	0.50
History of preoperative XRT	37 (34.9)	17 (36.2)	20 (33.9)	0.80
History of preoperative chemotherapy	46 (43.4)	20 (42.6)	26 (44.1)	0.88

*Chi-squared test or Fisher's exact test.
†Wilcoxon rank sum test.
DR, direct repair; IQR, interquartile range; PAR, pillar-anchored repair; XRT, radiotherapy.

experience. We therefore analyzed surgeon (p = 0.41, log-rank test) and surgeon experience (p = 0.30, log rank test) and found that these did not have a significant effect on hernia recurrence rates.

The probability of hernia recurrence-free survival for each time point was calculated and presented in Kaplan Meier curves. The variation in length of follow-up was adjusted by taking censorship into account, and 95% CIs were calculated for the hernia recurrence rates. For PAR patients, the 5-year cumulative hernia recurrence rate was 19.5%; the rate for DR patients was 38.3%. Hernia recurrence-free survival rates differed significantly between patients undergoing PAR vs DR (p = 0.033) (Fig. 5).

No patients had a bulge before reconstruction, and only 6 developed a bulge within the study period after LAW surgery. Two of these patients had undergone a PAR repair; 4 patients had undergone a DR. The bulge occurrence rate did not differ significantly between the 2 groups (Table 3).

Although hernia recurrence was significantly affected by the repair type (PAR vs DR), other factors such as mesh

Table 2. Characteristics of Lateral Abdominal Wall Defects and Repairs

Variable	All (n = 106)	DR (n = 47)	PAR (n = 59)	p Value*
Defect type, n (%)				0.70
Excisional	72 (67.9)	31 (66.0)	41 (69.5)	
Hernial	34 (32.1)	16 (34.0)	18 (30.5)	
Defect size, cm^2, median (IQR)	123 (21–247)	105 (25–216)	180 (0–286)	0.30†
Mesh type, n (%)				0.007
Synthetic	27 (25.5)	18 (38.3)	9 (15.3)	
Bioprosthetic	79 (74.5)	29 (61.7)	50 (84.7)	
Closure type, n (%)				0.76
Reinforced	24 (22.6)	10 (21.3)	14 (23.7)	
Bridged	82 (77.4)	37 (78.7)	45 (76.3)	

*Chi-squared test or Fisher's exact test.
†Wilcoxon rank sum test.
DR, direct repair; IQR, interquartile range; PAR, pillar-anchored repair.

Table 3. Summary of Patient Outcomes after Lateral Abdominal Wall Reconstruction

Variable	All (n = 106)	DR (n = 47)	PAR (n = 59)	p Value*
Primary outcome measure, n (%)				
Hernia recurrence	19 (17.9)	14 (29.8)	5 (8.5)	0.03†
Bulge occurrence	6 (5.7)	4 (8.5)	2 (3.4)	0.36†
Secondary outcome measure, n (%)				
SSI	13 (12.23)	7 (14.9)	6 (10.2)	0.46
SSO	18 (17.0)	9 (19.1)	9 (15.3)	0.61
Seroma	5 (4.7)	1 (2.1)	4 (6.8)	0.38
Abscess	4 (3.8)	1 (2.1)	3 (5.1)	0.63
Hematoma	2 (1.9)	1 (2.1)	1 (1.7)	>0.99
Wound dehiscence	1 (0.9)	1 (2.1)	0 (0)	0.44
Reoperation for complication	12 (11.3)	8 (17)	4 (6.8)	0.13

*Chi-squared test or Fisher's exact test.
†Log-rank test.
DR, direct repair; PAR, pillar-anchored repair; SSI, surgical site infection (including abscesses or cases of cellulitis requiring antibiotic treatment and/or drainage); SSO, surgical site occurrence (defined as the presence of one or more of the following: cellulitis, abscess, wound dehiscence, enterocutaneous fistula, hematoma, or seroma).

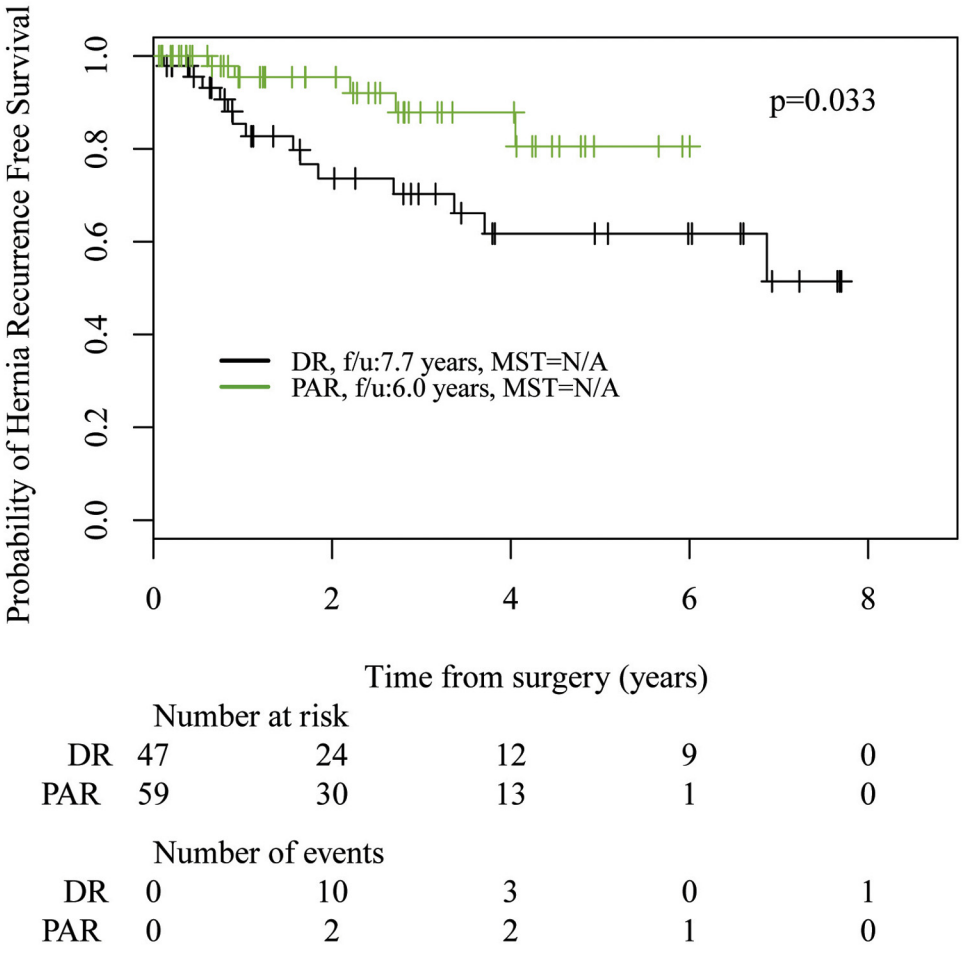

Figure 5. Kaplan-Meier curves comparing hernia recurrence-free survival in patients who underwent a direct repair (DR) vs a pillar-anchored repair (PAR) during lateral abdominal wall reconstruction. f/u, follow-up; MST, median hernia recurrence-free survival time; N/A, not applicable.

type, defect type, closure type, defect area, and preoperative radiotherapy were not significantly associated with hernia recurrence in the univariate analysis. However, due to the clinical relevance of these risk factors, as noted in the ventral abdominal wall reconstruction literature, we included them in the multivariable analysis. Use of a multivariable Cox proportional hazards regression model showed that undergoing a PAR was protective for hernia recurrence (adjusted HR, 0.28; 95% CI, 0.09 to 0.88; $p = 0.029$) after adjustment for preoperative radiation therapy, mesh type, defect type, closure type, and defect area (Table 4). This is consistent with our hypothesis that the PAR technique has superior outcomes to DR with respect to hernia recurrence. The multivariable analysis also showed the defect type (excisional vs hernia), which was nonsignificant in the univariate model, was also a significant predictor of hernia recurrence (adjusted HR, 4.19; 95% CI, 1.22 to 14.28; $p = 0.022$) (Table 4).

DISCUSSION

The results of this study—which, to our knowledge, is the largest comparative analysis to date evaluating 2 techniques in LAW reconstruction—support our hypothesis that PAR is superior to DR in avoidance of hernia recurrence. Patients whose LAWs were reconstructed with the PAR technique achieved a 3.5-fold lower rate of hernia recurrence compared with patients who underwent a DR.

Most of the published literature on LAW reconstruction includes small, retrospective, noncomparative case series that describe outcomes after use of techniques analogous to either PAR or DR. Zhou and Carlson[12] reported a qualitative review of 11 of these studies, which included approximately 350 LAW hernia repairs. Because of a lack of specific data in most of the studies, the authors were unable to differentiate between hernias and bulges, and therefore reported outcomes for all flank events.[12] In our study, we distinguished between hernias and bulges based on preoperative and postoperative CT scans and documented serial physical exams. Previously reported case series were also limited with respect to the etiologies of defects and mainly describe outcomes related to repair of hernias caused by denervation injuries related to previous surgery.[3,12-15] Our study offers a more complete analysis by also including defects caused by direct excision of LAW tissue.

Multiple studies have described LAW reconstruction with a DR, in which synthetic or biologic mesh is placed as an underlay, preperitoneally or retrorectally, with 3 to 5 cm of overlap with healthy tissue.[3,13] Some studies have acknowledged the need for wider overlaps with healthy tissue and the importance of anchoring repairs to a static support, such as the iliac crest or costal margin,[15-18] as would be done in a PAR. However, to our knowledge, there has been no formal description of the PAR technique in the literature. The PAR approach differs from previously described widely supported or bone-anchored mesh repairs. Elkwood and associates[17,18] described their experience with the BARS (Bony Anchoring Reinforcement System) repair technique. Their technique emphasizes the importance of load-bearing repair, but requires extending the mesh to support structures beyond the boundaries of the lateral abdominal wall (such as the pubic symphysis and contralateral anterior superior iliac spine).[17] Furthermore, the BARS repair technique requires placement of an inner mesh support that is anchored to bone in addition to a second piece of mesh (placed as onlay, inlay, or bridging underlay) to reinforce the hernia repair.[18] The PAR technique, on the other hand, requires a single piece of mesh to be sutured to the static pillars along the boundaries of the lateral abdominal wall which include osseus supports such as the iliac crest and costal margin as well as fascial supports such as the linea semilunaris and the paraspinous fascia. It is important to note that the PAR technique goes beyond simply placing an oversized piece of mesh. The benefits of the technique are derived from anchoring the mesh to static supports in the abdominal wall. An oversize piece of mesh alone may not necessarily overlap the pillars of the abdominal wall and may not effectively provide the load bearing support that the PAR repair provides. To our knowledge,

Table 4. Univariate and Multivariable Cox PH Model of Time to Hernia Recurrence

	Univariate model		Multivariable model	
Variable	**HR (95%CI)**	**p Value**	**HR (95%CI)**	**p Value**
PAR vs DR	0.34 (0.12−0.96)	0.04	0.28 (0.09−0.88)	0.03
Preoperative XRT, yes vs no	2.37 (0.95−5.87)	0.06	2.62 (0.96−7.15)	0.06
Defect type, hernia vs excisional	1.92 (0.77−4.76)	0.16	4.19 (1.22−14.28)	0.022
Mesh type, bioprosthetic vs synthetic	1.68 (0.55−5.20)	0.37	2.19 (0.68−7.03)	0.19
Closure type, bridged vs reinforced	0.94 (0.33−2.64)	0.91	2.37 (0.57−9.78)	0.23
Defect area, by 10 cm^2	1.00 (0.97−1.03)	0.81	1.01 (0.98−1.04)	0.46

DR, direct repair; HR, hazard ratio; PAR, pillar-anchored repair.

no previous study has directly compared the outcomes of DR and PAR for LAW reconstruction in a sizable patient population.

Irrespective of the nature, location, or etiology of the defects, use of a PAR led to a 3.5-fold lower rate of hernia recurrence. Our hernia recurrence rates after PAR (8.5%) and DR (29.8%) may be higher than those cited in other studies because of the larger sizes and greater complexity of defects in our patient population. Our SSO rates of 15.3% (PAR) and 19.1% (DR) are well within the range of the 12% to 40% reported in the literature.[12-18]

In midline ventral abdominal wall reconstruction, surgical outcomes differ for bridged and reinforced repairs. The literature is replete with studies that demonstrate higher hernia recurrence rates with abdominal wall defects that require a bridging technique with or without component separation.[9] However, in analyzing outcomes of LAW reconstruction, it appears that the repair technique (DR vs PAR) has a greater impact on hernia recurrence than the coaptation of the overlying musculofascial layer. In other words, bridged repairs do not confer the same increased risk of recurrence in the LAW as they do in the midline ventral abdominal wall (Table 4). A possible reason for this unexpected finding might be that the muscle-mesh interface in LAR repairs forms a stronger bond than the mesh-fascia interface of ventral abdominal wall repairs. However, this explanation is purely speculative because most of the published literature discusses the biophysics of the ventral abdominal wall, and not much has been published regarding the physics and force distribution of the lateral abdominal wall. Further studies to evaluate this phenomenon will be helpful.

The prevailing rationale behind DR is that the LAW is a dynamic structure, and mesh attachment to adjacent muscle tissue maintains this dynamism. On the other hand, PAR requires surgeons to suture a larger sheet of mesh to static support structures. Critics of this approach propose that PAR is more likely to fail because higher local tension at the mesh-suture interface does not account for the natural compliance of the abdominal wall. However, we believe that LAW defects include a larger area of muscle wall compromise that extends beyond the apparent defect. This is caused partly from denervation of the associated muscles and partly from direct transection of the oblique and transversalis muscle fibers. Even when dermatomal incisions are used to reduce denervation injury, there is still direct muscle injury due to the nonparallel orientation of the different LAR muscle layers. Therefore, the DR technique, which involves suturing mesh to this weakened muscle layer, may result in higher risk for hernia formation. Univariate analysis of our data supports this concept by demonstrating no significant difference in hernia recurrence rates between nerve sparing (dermatomal) and non-nerve sparing incisions. The integrity of the lateral abdominal wall repair relies on the mesh, which serves a load-bearing function in PAR repairs instead of a load-sharing function, as seen in DR.

Interestingly, we noted that defect type (excisional vs hernia defects), which was not significant in the univariate analysis, was found to be significantly associated in the multivariable model. Hernia defects were 4-fold more likely to recur than excision defects. This is not surprising given the differences in the etiology of these 2 defect types. Patients with hernia defects, are more likely to develop a recurrent hernia than those who have not had a hernia. In addition, hernia defects are caused by failure of incisional closure and the potential denervation of the muscles caused by the surgical incision.

There are limitations of this study. Unlike hernia recurrence, in which there is CT evidence of eventration, diagnosis of bulge can have more bias. This was a retrospective review of our database and diagnosis of bulge was assigned if reflected in the documented clinical examination. Other limitations include the study's retrospective design and its potential for selection bias due to the fact that patients were not randomized to receive various repair techniques.

An apparent limitation might be the difference in follow-up time for patients who received the PAR and DR. There is a much longer follow-up for patients who underwent the DR approach than for patients who underwent the PAR approach (mean difference, 13 months). However, this does not affect our conclusions because the cumulative recurrence rates are estimated by Kaplan Meier method, which counts the patients who did not experience the events during follow-up period as censored. The length of follow-up is weighted in the estimation, so the difference in follow-up does not bias the comparison of recurrence between the 2 groups. Surgical site occurrence and other postoperative complications are binary outcomes that generally occur in the early postoperative period. The follow-up length would not likely affect the analysis of these variables.

The strengths of this study include its size (to our knowledge, it is the largest single-center cumulative study of LAW reconstruction to date); its inclusion of consecutive patients at a major United States cancer center; its use of data obtained from a prospectively maintained patient database; its use of multivariable regression models; its mean patient follow-up period of 32 months (median 28 months); and its inclusion of patients who had undergone routine CT surveillance for tumor (and therefore, hernia) recurrence. In addition, collecting accurate dates of hernia recurrence enabled us to estimate hernia recurrence without bias from the different follow-up times.

We believe that our findings indicate that the durability of LAW reconstruction is determined mainly by the mesh inset technique. Anchoring the mesh to the pillars that define the boundaries of the LAW, as is done in PAR, provides a superior reconstruction, and PAR should be strongly considered by surgeons repairing LAW defects.

CONCLUSIONS

Lateral abdominal wall defects present significant challenges quite different from those associated with the more commonly encountered midline ventral hernia defects. Compared with the DR technique, the PAR technique is associated with significantly lower hernia recurrence rates. Surgeons should consider the PAR technique over the DR technique when repairing LAW defects.

Author Contributions

Study conception and design: Kapur, Baumann, Butler
Acquisition of data: Kapur, Baumann, Butler
Analysis and interpretation of data: Kapur, Liu, Baumann, Butler
Drafting of manuscript: Kapur, Liu, Baumann, Butler
Critical revision: Kapur, Liu, Baumann, Butler

Acknowledgment: The authors would like to thank Drs Adelman, Butterworth, Campbell, Chandler, Chang, Chao, Chevray, Clemens, Crosby, Hanasono, Hanson, Heller, Kanchwala, Langstein, Nguyen, Oates, Reece, Sacks, Selber, Sharaf, Skoracki, Solari, and Villa for allowing us to enter their patients into this study.

REFERENCES

1. Dakin G, Kendrick M. Challenging hernia locations: flank hernias. In: Jacob BP, Ramshaw B, eds. The SAGES Manual of Hernia Repair. New York, NY: Springer; 2013:531–540.
2. Gardner GP, Josephs LG, Rosca M, et al. The retroperitoneal incision: an evaluation of postoperative flank 'bulge'. Arch Surg 1994;129:753–756.
3. Purnell CA, Park E, Turin SY, Dumanian GA. Postoperative flank defects, hernias, and bulges: a reliable method for repair. Plast Reconstr Surg 2016;137:994–1001.
4. Nanni G, Tondolo V, Citterio F, et al. Comparison of oblique versus hockey-stick surgical incision for kidney transplantation. Transplant Proc 2005;37:2479–2481.
5. Baumann DP, Butler CE. Lateral abdominal wall reconstruction. Semin Plast Surg 2012;26:40–48.
6. Bozdogan H. Model selection and Akaike's information criterion (AIC): The general theory and its analytical extensions. Psychometrika 1987;52:345–370.
7. Carbonell AM, Criss CN, Cobb WS, et al. Outcomes of synthetic mesh in contaminated ventral hernia repairs. J Am Coll Surg 2013;217:991–998.
8. Garvey PB, Martinez RA, Baumann DP, et al. Outcomes of abdominal wall reconstruction with acellular dermal matrix are not affected by wound contamination. J Am Coll Surg 2014;219:853–864.
9. Giordano SA, Garvey PB, Baumann DP, et al. Primary fascial closure with mesh reinforcement results in lower complication and recurrence rates than bridged mesh repair for abdominal wall reconstruction: a propensity score analysis. Plast Reconstr Surg Glob Open 2016;4:112–113.
10. Giordano SA, Garvey PB, Baumann DP, et al. The impact of body mass index on abdominal wall reconstruction outcomes: a comparative study. Plast Reconstr Surg 2017;139:1234.
11. Hocking RR. Collinearity in multiple linear regression. In: Hocking, RR. Methods and Applications of Linear Models: Regression and the Analysis of Variance. 3rd ed. Hoboken NJ: John Wiley & Sons; 2013:142–178.
12. Zhou DJ, Carlson MA. Incidence, etiology, management, and outcomes of flank hernia: review of published data. Hernia 2018;22:353–361.
13. Pezeshk RA, Pulikkottil BJ, Bailey SH, et al. An evidence based model for the successful treatment of flank and lateral abdominal wall hernias. Plast Reconstr Surg 2015;136:377–385.
14. Zieren J, Menenakos C, Taymoorian K, et al. Flank hernia and bulging after open nephrectomy: mesh repair by flank or median approach? Report of a novel technique. Int Urol Nephrol 2007;39:989–993.
15. Veyrie N, Poghosyan T, Corigliano N, et al. Lateral incisional hernia repair by the retromuscular approach with polyester standard mesh: Topographic considerations and long-term follow-up of 61 consecutive patients. World J Surg 2013;37:538–544.
16. Philips MS, Krpata DM, Klatnik JA, et al. Retromuscular preperitoneal repair of flank hernias. J Gastrointest Surg 2012;16:1548–1553.
17. Elkwood AI, Kozusko SD, Patel TR, et al. The bony anchoring reinforcement system (BARS) for flank hernia repair: a versatile technique. Eur J Plast Surg 2017;40:315–322.
18. Elkwood AI, Borao FJ, Ashinoff RL, et al. Complex incisional hernias repaired in conjunction with the Bony Anchoring Reinforcement System (BARS) prevents hernia recurrence. Eur J Plast Surg 2014;37:431–436.