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CT evidence of fluid in the hernia sac predicts surgical site infection following mesh repair of acutely incarcerated ventral and groin hernias

Tyler J. Loftus, MD, Kristina L. Go, MD, Janeen R. Jordan, MD, FACS, Chasen A. Croft, MD, FACS, R. Stephen Smith, MD, FACS, Frederick A. Moore, MD, FACS, MCCM, Philip A. Efron, MD, FACS, FCCM, Alicia M. Mohr, MD, FACS, FCCM, and Scott C. Brakenridge, MD, MSCS
University of Florida Health, Department of Surgery and Sepsis and Critical Illness Research Center in Gainesville, Florida

Abstract

Background—Mesh placement during repair of acutely incarcerated ventral and groin hernias is associated with high rates of surgical site infection (SSI). The utility of preoperative CT in this setting is unclear. We hypothesized that CT evidence of bowel wall compromise would predict SSI while accounting for physiologic parameters.

Methods—We performed a four-year retrospective cohort analysis of 50 consecutive patients who underwent mesh repair of acutely incarcerated ventral or groin hernias. We analyzed chronic disease burden, acute illness severity, CT findings, operative management, and herniorrhaphy-specific outcomes within 180 days. The primary outcome was SSI by CDC criteria. Multiple logistic regression was performed to identify independent predictors of SSI.

Results—Eighty-four percent of all patients were ASA class III or IV, 28% were active smokers, and mean body mass index (BMI) was 35. Fifty-four percent had ventral hernias, 40% had inguinal hernias, and 6% had femoral or combined inguinal/ femoral hernias. Seventy percent of preoperative CT scans had features suggesting bowel compromise, abdominal free fluid, or fluid in the hernia sac. SSI occurred in 32% of all patients (8% superficial, 24% deep or organ/space). The strongest predictors of SSI were CT evidence of fluid in the hernia sac (OR 8.3, 95% CI 1.7–41), initial heart rate 90 (OR 6.3, 95% CI 1.1–34), and BMI 35 (OR 5.8, 95% CI 1.2–28). SSI rates were significantly higher among patients who had CT evidence of fluid in the hernia sac (56% vs. 19%, $p=0.012$).

Conclusions—Over half of all patients with CT scan evidence fluid in the hernia sac developed a SSI. CT evidence of fluid in the hernia sac was the strongest predictor of SSI, followed by heart

Please address correspondence to: Scott C. Brakenridge MD, MSCS, University of Florida Health, Gainesville, FL, 1600 SW Archer Road Room M-602, Gainesville, Florida, 32610-3003, 972-415-2447, Scott.Brakenridge@surgery.ufl.edu.

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Author Contributions

TJL and SCB contributed to literature review and study design. TJL and KLG contributed to data collection, analysis, and interpretation. JRJ, CAC, RSS, FAM, PAE, AMM, and SCB contributed to data interpretation and made critical revisions.

rate and BMI. Together, these parameters identify high risk patients for whom better strategies are needed to avoid SSI without sacrificing durability.

Level of Evidence—prognostic study – level III

Keywords

incarcerated hernia; mesh; surgical site infection; infection; risk factors

Introduction

Prolonged periods of bowel wall compromise are associated with increased risk for postoperative infectious complications (1, 2). This is likely due to bacterial translocation, the process by which intestinal bacteria cross the intestinal mucosal barrier and reach the mesenteric lymph nodes (3, 4). Bacteria may then spread and cause local and systemic infections (4, 5). This phenomenon has important implications for patients with acutely incarcerated ventral and groin hernias. These patients are at increased risk for bacterial translocation due to bowel ischemia, and may also undergo bowel resection, further increasing the likelihood of surgical site infection (SSI) (6).

Mesh placement allows for tension-free herniorrhaphy, decreasing the risk of hernia recurrence, but also introduces a nidus for infection (7–11). The use of prosthetic mesh in the setting of hernia incarceration or surgical field contamination remains controversial, as SSI rates under these circumstances are relatively high (12–15). There may be a subgroup of patients with acutely incarcerated hernias for which SSI risk is so high that primary herniorrhaphy without mesh placement would be preferable. However, consistent and accurate prediction of SSI remains elusive (16, 17). The prognostic utility of imaging findings remains unclear, though it is plausible that preoperative computed tomography (CT) scan findings may be useful in stratifying risk for postoperative SSI (18). The purpose of this study was to evaluate the utility of CT scan findings in predicting SSI following open mesh repair of acutely incarcerated ventral and groin hernias, and to identify the strongest predictors of SSI in this population. We hypothesized that CT evidence of bowel wall compromise would predict SSI while accounting for salient physiologic parameters.

Methods

We performed a retrospective cohort analysis of 50 consecutive patients who had a preoperative CT scan and underwent open mesh repair of an acutely incarcerated ventral or groin hernia at our tertiary care center during a four-year period ending November 2015. Patients were identified by CPT codes for incarcerated ventral or inguinal hernia repair (49507, 49521, 49553, 49557, 49561, 49566, 49568, 49572, and 49587). Exclusion criteria were age < 18, duration of symptoms > 4 days, contaminated or dirty wound class (e.g. gross spillage of enteric contents), prior herniorrhaphy within 30 days, laparoscopic herniorrhaphy, primary herniorrhaphy without mesh, and patients who were lost to outpatient follow-up. Patients with incarcerated fat but no bowel in the hernia sac were excluded to reduce heterogeneity in the study population. The primary outcome was surgical site infection within 180 days according to CDC criteria (19). Seventy-seven percent of all

patients had active follow-up for 180 days. Average follow-up for the other 33% of the study population was 55 days. Secondary outcomes included mesh explantation for infection, redo herniorrhaphy for recurrence, and mortality.

Data were obtained by query of our institutional database and electronic medical record review. We collected demographic information and risk factors for SSI identified by previous studies (16–18, 20–26). CT scans were often obtained prior to surgical consultation, were reviewed by the investigators, and the findings reported herein were obtained from completed reports signed by the board-certified attending radiologist on-call at the time of admission. HbA1c values were obtained for a twelve week range prior to surgery, albumin values were obtained for a three week range prior to surgery, and prealbumin values were obtained for a three day range prior to surgery. For these three parameters, the value recorded closest to the date of surgery was used. Herniorrhaphy technique was at the discretion of the attending surgeon.

Statistical analysis was performed in SPSS (version 23, IBM, Armonk, NY). Continuous variables were assessed by one-way analysis of variance and reported as mean $\pm$ standard deviation. Discrete variables were assessed by Fisher's Exact test and reported as n (%). Prediction models were generated by identifying independent variables with significant correlation ($r \geq 0.2$ and $p < 0.05$) to SSI and minimal collinearity ($r < 0.2$) to selected covariates. Included variables were entered into the multiple logistic regression equation. Model covariates were reported as odds ratio (OR) with 95% confidence interval (CI). Model strength was evaluated by calculating the area under the receiver operating characteristic curve (AUC).

Results

Patient characteristics are listed in Table 1. The predominant phenotype was an obese middle aged patient (age 58, BMI 35) with severe or incapacitating systemic illness (84% with ASA class III or IV) and 1–2 days of symptoms prior to admission. The most common hernia type was ventral (54%), followed by inguinal (40%), and the remaining patients had femoral or combined inguinal and femoral hernias. On average, herniorrhaphy was performed within one day of admission. Two thirds of all patients underwent synthetic mesh repair, one third had biologic mesh, and none had biosynthetic mesh. The biologic mesh cohort had higher BMI (42 vs. 31, $p = 0.016$) and white blood cell count on admission (11.4 vs. $8.8 \times 10^3/\mu\text{L}$, $p = 0.034$). This cohort also had higher incidence of bowel resection (25% vs. 3%, $p = 0.031$) and longer duration of surgery (265 vs. 171 minutes, $p = 0.001$).

Imaging findings are listed in Table 2. The most common abnormalities were fat stranding and fluid in the hernia sac, each identified in 36% of all patients. Evidence of fluid in the hernia sac was more common than free peritoneal fluid (14%). Seventy percent of all CT scans had at least one complicating feature. Of the 27 ventral hernia repairs, mesh was placed in the underlay position for 22 patients, overlay position for 4 patients, and retrorectus space for 1 patient. Of the 23 groin hernia repairs, 12 were performed with the mesh plug and patch technique; 11 were performed with patch only. Postoperatively,

antibiotics were continued for 24 hours for 30 patients (60%), including 16 patients in the synthetic mesh cohort and 14 patients in the biologic mesh cohort (47% vs. 88%, $p = 0.012$).

Outcomes are listed in Table 3. On average, patients spent two days in the ICU and one week in the hospital. The overall SSI rate within 180 days was 32%. By CDC criteria, most of these were classified as deep or organ/space infections ($n = 12$), and each of these cases involved mesh infection. All five patients who underwent bowel resection developed a SSI; there were 11 SSIs among the 45 patients who did not require bowel resection (100% vs. 24%, $p = 0.002$). Two patients with deep or organ/space infections required mesh explantation, and the other 10 were managed with a combination of antibiotics, drain placement, and surgical debridement (Figure 1). None of the patients who had attempted mesh salvage required mesh explantation or redo herniorrhaphy for recurrence within the follow-up period.

The multivariate prediction model is illustrated in Table 4. The strongest independent predictor of SSI was CT evidence of fluid in the hernia sac, followed by heart rate ≥ 90 on admission BMI ≥ 35 . This multivariate model was highly significant (chi-square 16.6, $p = 0.001$), accounted for 41% of the variability in SSI (Nagelkerke $R^2 = 0.407$), and had AUC 0.813 (95% CI 0.685–0.942). SSI rates were significantly higher among patients who had CT evidence of fluid in the hernia sac (56% vs. 19%, $p = 0.012$), and fluid in the hernia sac was strongly associated with SSI on univariate analysis (OR 5.4, 95% CI 1.5–20). There were nine patients who didn't have any of the three risk factors, and none of these patients developed a SSI. On univariate analysis, ventral hernia type was associated with surgical site infection (OR 3.8, 95% CI 1.02–14). This variable was not included in the prediction model as it was collinear with BMI ($r = 0.437$, $p = 0.002$), but was not as strong a predictor as BMI. Performance of bowel resection was also associated with SSI, but was collinear with both heart rate ≥ 90 ($r = 0.347$, $p = 0.014$) and fluid in the hernia sac on CT ($r = 0.306$, $p = 0.031$), and cannot be assessed in the preoperative setting. None of the other patient characteristics reported in Table 1 were predictive of SSI.

Discussion

In a population with substantial risk factors for postoperative morbidity, about one in three patients developed a SSI following mesh repair of an acutely incarcerated ventral or groin hernia. The anecdotal experience of the acute care surgeons at our institution was that SSI was occurring at an alarming rate in patients with acutely incarcerated hernias but grossly clean surgical fields, prompting the hypothesis that bacterial translocation may be responsible, and inciting this investigation. Multivariate analysis identified a subgroup of patients at high risk for postoperative SSI. These risk factors included CT evidence of fluid in the hernia sac, admission heart rate ≥ 90 , and BMI ≥ 35 . The performance of bowel resection was also evaluated as a predictor of SSI, but was collinear with heart rate and fluid in the hernia sac, and was therefore excluded from the multivariate model in favor of parameters that are available in the preoperative setting. In addition, this approach accounts for patients who develop a SSI even though they did not undergo bowel resection ($n = 11/45$ in this study). Notably, over half of all patients with CT evidence of fluid in the hernia sac

developed a SSI. This observation alone should give pause to the clinician who is weighing operative management strategies for patients with this highly morbid imaging sign.

Previous studies have reported lower SSI rates than our study. Nieuwenhuizen et al. (14) analyzed 203 patients with incarcerated or strangulated abdominal wall and inguinal hernias, 99 of whom had mesh repair. The wound infection rate among patients who underwent mesh repair was 7% (7/99). Bessa et al. (13) prospectively studied 80 patients with incarcerated or strangulated ventral hernias; the wound infection rate was 11%. CT scan findings were not included in either study. These lower SSI rates may reflect differences in patient populations. Unfortunately, it is difficult to determine the magnitude of acute and chronic disease burden in the Nieuwenhuizen study. In the Bessa study, 10% of all patients were ASA class III or IV (compared to 84% in our study). Technical factors may also have contributed to our high SSI rate, though this is impossible to determine retrospectively.

The major limitations of this study are its retrospective design and small sample size. A prospective multicenter trial would address both of these limitations by reducing bias and increasing power by obtaining a larger sample. Although recent evidence suggests that mesh may be safely used in non-elective ventral hernia repair (27), future research should revisit the utility of primary repair for high risk patients with acutely incarcerated groin hernias, and seek to determine whether or not the performance of preoperative CT scan affects operative management or outcomes compared to clinical assessment alone.

Conclusions

The strongest predictors of SSI following mesh repair of acutely incarcerated ventral and groin hernias were CT evidence of fluid in the hernia sac, heart rate ≥ 90 , and BMI ≥ 35 . These parameters had strong negative predictive value; nine patients had none of these risk factors, and none developed a SSI. Conversely, over half of all patients with CT scan evidence fluid in the hernia sac developed a SSI. Together, preoperative CT scan findings and physiologic parameters identify a subgroup of high risk patients for whom better strategies are needed to avoid SSI in the acute setting, without compromising the ultimate goal of a durable and definitive repair.

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Figure 1.
Management strategies and outcomes following mesh infection.

Table 1

Patient characteristics and operative management.

	All patients n = 50	Synthetic mesh n = 34	Biologic mesh n = 16	p
Age (years)	58 ±15	60 ±15	55 ±13	0.243
Male	27 (54%)	22 (65%)	5 (31%)	0.036
ASA class	3.0 ±0.6	2.9 ±0.7	3.2 ±0.4	0.115
ASA class III or IV	42 (84%)	26 (77%)	16 (100%)	0.043
Active smoker	14 (28%)	9 (27%)	5 (31%)	0.728
Chronic obstructive pulmonary disease	11 (22%)	7 (21%)	4 (25%)	0.728
Body mass index	35 ±12	31 ±10	42 ±14	0.016
HbA1c (%)	7.6 ±2.1	6.7 ±1.1	8.7 ±2.8	0.216
Albumin (g/dl)	3.7 ±0.7	3.8 ±0.6	3.5 ±0.7	0.194
Prealbumin (mg/dl)	9.3 ±4.5	10.9 ±3.2	7.6 ±5.2	0.225
Duration of symptoms				
From onset to admission (hours)	40 ±27	40 ±29	40 ±22	0.958
From admission to surgery (hours)	23 ±25	19 ±23	32 ±28	0.111
On admission				
Heart rate	91 ±18	90 ±19	92 ±17	0.758
Respiratory rate	18 ±3	18 ±3	19 ±4	0.548
Temperature (°C)	36.7 ±0.4	36.6 ±0.3	36.8 ±0.4	0.276
WBC count (×10 ³ /μl)	9.6 ±3.6	8.8 ±2.9	11.4 ±4.2	0.034
Max glucose within 24h of incision (mg/dl)	157 ±63	148 ±64	175 ±57	0.140
PRBC transfusion during admission	7 (14%)	2 (6%)	5 (31%)	0.027
Hernia type				
Ventral	27 (54%)	13 (38%)	14 (88%)	0.002
Inguinal	20 (40%)	18 (53%)	2 (13%)	0.012
Femoral	2 (4%)	2 (6%)	0	>0.999
Inguinal and femoral	1 (2%)	1 (3%)	0	>0.999
Recurrent hernia	13 (26%)	7 (21%)	6 (38%)	0.301
Antibiotics within 30 minutes of incision	50 (100%)	34 (100%)	16 (100%)	-
Inadequate antibiotic dose	6 (12%)	4 (12%)	2 (13%)	>0.999
Inadequate antibiotic re-dosing	10 (20%)	6 (18%)	4 (25%)	0.707
Bowel resection	5 (10%)	1 (3%)	4 (25%)	0.031
Antibiotics covered enteric organisms	32 (64%)	20 (59%)	12 (75%)	0.351
Duration of operation (minutes)	201 ±79	171 ±54	265 ±86	0.001

ASA: American Society of Anesthesiology, WBC: white blood cell, PRBC: packed red blood cell. Data are presented as mean ±standard deviation or n (%).

Table 2

Preoperative computed tomography findings.

	All patients n = 50	Synthetic mesh n = 34	Biologic mesh n = 16	p
Fat stranding	18 (36%)	11 (32%)	7 (44%)	0.532
Fluid in hernia sac	18 (36%)	10 (29%)	8 (50%)	0.211
Bowel wall edema	8 (16%)	6 (18%)	2 (13%)	>0.999
Free peritoneal fluid (> trace)	7 (14%)	5 (15%)	2 (13%)	>0.999
Bowel wall hyperemia	6 (12%)	6 (18%)	0	0.159
Mesenteric edema	2 (4%)	2 (6%)	0	>0.999
Bowel wall attenuation	0	0	0	-
Bowel wall pneumatosis	0	0	0	-
Extraluminal air	0	0	0	-
Portal venous air	0	0	0	-
Mesenteric swirl	0	0	0	-
Any complicating feature	35 (70%)	21 (62%)	14 (88%)	0.099

Data are presented as n (%).

Table 3

Outcomes.

	All patients n = 50	Synthetic mesh n = 34	Biologic mesh n = 16	<i>p</i>
Hospital length of stay	7.5 ±6.6	5.0 ±4.6	12.6 ±7.3	0.001
ICU length of stay	2.3 ±4.8	1.2 ±3.9	4.6 ±5.8	0.043
In-hospital mortality	0	0	0	-
SSI within 180 days	16 (32%)	6 (18%)	10 (63%)	0.003
Superficial SSI	4 (8%)	2 (6%)	2 (13%)	0.584
Deep or organ/space SSI	12 (24%)	4 (12%)	8 (50%)	0.010
Mortality within 180 days	4 (8%)	2 (6%)	2 (13%)	0.584

ICU: intensive care unit, SSI: surgical site infection. Data are presented as mean ±standard deviation or n (%).

Table 4

Multivariable predictors of surgical site infection following mesh repair of acutely incarcerated ventral or groin hernia.

	OR	95% CI	<i>p</i>
Fluid in hernia sac on CT	8.3	1.7–41	0.009
Initial heart rate 90	6.3	1.1–34	0.034
Body mass index 35	5.8	1.2–28	0.030

OR: odds ratio, CI: confidence interval, CT: computed tomography. Area under the receiver operating characteristic curve for this model was 0.813 (95% CI 0.685–0.942). Ventral hernia and bowel resection were also significant on univariate analysis, but were excluded from the multivariate model. Ventral hernia was excluded because it was collinear with body mass index, which was a stronger predictor. Bowel resection was excluded because it was collinear with fluid in the hernia sac and heart rate 90, and cannot be assessed in the preoperative setting.