



# The impact of frailty on ventral hernia repair outcomes in a statewide database

Quintin P. Solano<sup>1,2</sup> · Ryan Howard<sup>2,3</sup> · Cody L. Mullens<sup>2,3</sup> · Anne P. Ehlers<sup>2,3</sup> · Lia D Delaney<sup>1,2</sup> · Brian Fry<sup>2,3</sup> · Mary Shen<sup>2,3</sup> · Michael Englesbe<sup>2,3,4</sup> · Justin Dimick<sup>2,3,4,5</sup> · Dana Telem<sup>2,3,4,5</sup>

Received: 20 March 2022 / Accepted: 11 September 2022 / Published online: 7 November 2022  
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

## Abstract

**Introduction** Preoperative frailty is a strong predictor of postoperative morbidity in the general surgery population. Despite this, there are a paucity of research examining the effect of frailty on outcomes after ventral hernia repair (VHR), one of the most common abdominal operations in the USA. We examined the association of frailty with short-term postoperative outcomes while accounting for differences in preoperative, operative, and hernia characteristics.

**Methods** We retrospectively reviewed the Michigan Surgery Quality Collaborative Hernia Registry (MSQC-HR) for adult patients who underwent VHR between January 2020 and January 2022. Patient frailty was assessed using the validated 5-factor modified frailty index (mFI5) and categorized as follows: no (mFI5 = 0), moderate (mFI5 = 1), and severe frailty (mFI5 ≥ 2). Our primary outcome was any 30-day complication. Multivariable logistic regression was used to evaluate the association of frailty with outcomes while controlling for patient, operative, and hernia variables.

**Results** A total of 4406 patients underwent VHR with a mean age (SD) of 55 (15) years, 2015 (46%) females, and 3591 (82%) white patients. The mean (SD) BMI of the cohort was 33 (8) kg/m<sup>2</sup>. A total of 2077 (47%) patients had no frailty, 1604 (36%) were moderately frail, and 725 (17%) were severely frail. The median hernia size (interquartile range) was 2.5 cm (1.5–4.0 cm). Severe frailty was associated with increased odds of any complication (adjusted Odds Ratio (aOR) 3.12, 95% CI 1.78–5.47), serious complication (aOR 5.25, 95% CI 2.17–13.19), SSI (aOR 3.41, 95% CI 1.58–7.34), and post-discharge adverse events (aOR 1.70, 95% CI 1.24–2.33).

**Conclusion** After controlling for patient, operative, and hernia characteristics, frailty was independently associated with increased odds of postoperative complications. These findings highlight the importance of preoperative frailty assessment for risk stratification and to inform patient counseling.

Frailty, commonly defined as a deficit in physiologic reserve with decreased physical function beyond what is expected with normal aging, is one metric used to evaluate a patient's

fitness for surgery [1–4]. Frailty measurements have long been a part of the medical literature and more recently have gained attention as a predictive metric for postoperative outcomes [1, 5–7]. The tools used to measure frailty vary in complexity, ranging from physical tests (e.g., timed get up and go) to cumulative deficit models, such as the modified frailty index (mFI) which measures frailty based on a number of comorbidities [8, 9]. The mFI has been shown to have prognostic value across multiple surgical specialties [9–14].

There are a few studies that specifically examine frailty and its effect on outcomes after ventral hernia repair (VHR), one of the most common procedures performed in the USA. Previous studies examining frailty in the VHR population report poor outcomes in frail patients, but studies to date have been unable to control for hernia-specific variables known to effect outcomes in VHR [15–19]. For instance, frail patients in these studies may have more complex

✉ Dana Telem  
dtelem@med.umich.edu

<sup>1</sup> University of Michigan Medical School, Ann Arbor, MI, USA

<sup>2</sup> Center for Healthcare Outcomes and Policy, University of Michigan, Ann Arbor, MI, USA

<sup>3</sup> Department of Surgery, University of Michigan, Ann Arbor, MI, USA

<sup>4</sup> Michigan Surgical Quality Collaborative, Ann Arbor, MI, USA

<sup>5</sup> Division of Minimally Invasive Surgery, Department of Surgery, Michigan Medicine, 2926 Taubman Center, 1500 E Medical Center Dr, SPC 5331, Ann Arbor, MI, USA

hernias, making it difficult to discern if their poor outcomes were a result of their physical state or the nature of their hernia. This is a critical gap in the current literature, given that complication rates are recognized to vary significantly by hernia size [17, 19, 20]. Examining the association of frailty with operative outcomes in the context of predictive factors, such as hernia size, is an important step to improve perioperative risk assessment and counseling for this common general surgery procedure.

We sought to evaluate the association of preoperative frailty with short-term outcomes in VHR using the 5-factor modified frailty index, a cumulative deficit frailty model demonstrated to correlate with operative outcomes, while taking into consideration patient- and hernia-specific factors. We used data from a population level, clinically nuanced hernia data registry, the Michigan Surgery Quality Collaborative Hernia Registry (MSQC-HR) that captures patient- and hernia-specific surgical data in the state of Michigan. We hypothesized that patients with higher frailty scores would have worse short-term postoperative outcomes independent of hernia size and characteristics.

## Methods

This secondary analysis of deidentified data was deemed exempt from review by the Institutional Review Board of the University of Michigan. The requirement for informed consent was waived because of a lack of identifying information. This study follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines [21].

### Data source and patient population

Data in this study were obtained from the Michigan Surgical Quality Collaborative Hernia Registry (MSQC-HR), a state-wide surgical quality improvement collaborative of 70 hospitals in Michigan [22–24]. The MSQC is funded by Blue Cross Blue Shield of Michigan and maintains a clinical registry of prospectively collected patient characteristics, perioperative and intraoperative processes of care, hernia characteristics, and 30-day clinical outcomes. The MSQC-HR data reported in this manuscript include all payors (Medicare, Medicaid, Private, Uninsured). The process by which the MSQC abstracts data, ensures validity and reliability, and samples cases has been previously described [24].

Included patients were adults (age  $\geq 18$  years) that underwent ventral hernia repair surgery collected by the MSQC between January 1, 2020 and January 31, 2022. Operations included were open, laparoscopic, and robotic ventral and incisional hernia repairs. Procedures were identified using *Current Procedural Terminology* codes: 49,560, 49,561,

49,565, 49,566, 49,570, 49,572, 49,585, 49,587, 49,590, 49,652, 49,653, 49,654, 49,655, 49,656, and 49,657. Patients were excluded if they had an incomplete record for patient demographics, comorbidities, or hernia-specific data (Supplemental Fig. 1).

### Outcomes and covariates

The primary outcomes of this study were any 30-day postoperative complications. Secondary outcomes included serious 30-day postoperative complications, surgical site infection (SSI), non-home discharge, and a composite of post-discharge adverse events (emergency department visit, readmission, or reoperation). Serious complications were defined using a previously published definition of serious complications [25]. A full list of any and serious 30-day complications can be found in Table 1 [25, 26].

The covariate of interest was patient frailty, which was defined using the 5-factor modified frailty index (mFI5) scoring system. The mFI5 has been previously validated across multiple surgical specialties, including the VHR population, to correlate with patient outcomes [14, 15]. The variables included in the 5-factor modified frailty index include (1) congestive heart failure within 30 days prior to surgery, (2) the presence of non-insulin-dependent or insulin-dependent diabetes mellitus, (3) a history of chronic obstructive pulmonary disease (COPD) or pneumonia within 30 days prior to surgery, (4) partially dependent or totally dependent functional health status, and (5) hypertension requiring medication. Each factor counts as one point in the mFI5 score. The mFI5 scores were stratified into three categories: no frailty (mFI5 = 0), moderate frailty (mFI5 = 1), and severe frailty (mFI5  $\geq 2$ ). This stratification of mFI5 categories has been previously utilized and validated in the surgical literature [10, 14, 27, 28]. This condensed 5-item modified frailty index is relevant to the VHR population as the included variables are well-known risk factors for complications [17, 29, 30].

Patient demographic data included age, sex, payor status, and race. Clinical characteristics included body mass index (BMI), American Society of Anesthesiologists (ASA) classification, and comorbidities, including diabetes, smoking, obstructive sleep apnea (OSA), COPD, functional status, cancer, and hypertension. Hernia-specific characteristics included previous hernia repair, hernia width, hernia location, wound classification as defined by the Centers for Disease Control (CDC) guidelines, mesh use, mesh type, and mesh fixation [31, 32]. Other operative characteristics included component separation use and type, surgical priority (elective versus urgent/emergent), and surgical approach (open versus minimally invasive). Our secondary outcome was SSI.

**Table 1** Complications description

Any complication	Serious complications
Acute kidney injury	Deep incisional surgical site infection
Anastomotic leak	Intraoperative coronary arrest requiring CPR
Cardiac arrest requiring cardiopulmonary resuscitation (CPR)—intraoperatively	Myocardial infarction—intraoperatively
Cardiac arrest CPR—postoperatively	Myocardial infarction—postoperatively
Clostridium-difficile	Organ Space Surgical Site Infection
Deep incisional surgical site infection	Postoperative anastomotic leak
Deep vein thrombosis requiring therapy	Postoperative cardiac arrest requiring CPR
Myocardial infarction—intraoperatively	Septic shock
Myocardial infarction—postoperatively	Severe sepsis
Organ space surgical site infection	Stroke/cerebrovascular accident
Pneumonia	Unplanned intubation—postoperatively
Pulmonary embolism	
Sepsis	
Septic shock	
Severe sepsis	
Stroke/cerebrovascular accident	
Superficial incisional surgical site infection	
Transfusions within first 72 h postoperatively	
Unplanned intubation—postoperatively	
Urinary tract infection—catheter-associated urinary tract infection (CAUTI)	
Urinary tract infection—symptomatic urinary tract infection (SUTI)	

## Statistical analysis

Descriptive analysis was used to describe characteristics of the cohort, surgical, and other hernia-specific variables. Univariate analysis was performed using the Chi-squared and analysis of variance (ANOVA) tests where appropriate. Multivariable analyses were performed to evaluate factors associated with the primary and secondary outcomes, including the factors mFI5 score, age, sex, race, BMI, ASA class (I–II, III–IV), smoking, cancer, OSA, previous hernia repair, hernia width, hernia location, surgical priority, and surgical approach (open versus minimally invasive). Age, BMI, and hernia width were used as continuous variables in regression analysis. The individual variables included in the mFI5 score were not separately included in the multivariable regression. Race was not included in the surgical site infection regression as it was a predictor of failure for the model. For the multivariable regression analysis, the hernia location variables *suprapubic* and *infraumbilical* were combined.

All analysis were performed using StataSE version 16.1 (StataCorp, Inc., College Station, TX). All tests of statistical significance were 2-sided with an alpha of 0.05. Data were analyzed in February and March 2022.

## Results

### Patient characteristics

A total of 4406 patients that underwent VHR were included in this analysis. Baseline patient demographics, comorbidity, and hernia characteristic data are listed in Table 2. The mean (SD) age of the cohort was 55 (15) years, 2015 (46%) were female, and 3591 (82%) white. The mean (SD) BMI of the cohort was 33 (8) kg/m<sup>2</sup>. Most patients had an ASA class of I–II (54%). The median hernia size was 2.5 cm (1.5–4.0 cm). The most common comorbidity was hypertension, followed by OSA and smoking. Most patients were undergoing primary, elective VHR (83%). A majority of VHR were classified as clean (94%) and repaired with an open approach (58%) and synthetic mesh (83%). Operative characteristics of the cohort are described in Table 3.

A total of 2077 (47%) patients had no frailty (mFI5 = 0), 1604 (36%) were moderately frail (mFI5 = 1), and 725 (17%) were severely frail (mFI5 ≥ 2). The most common comorbidity contributing to mFI5 scores was hypertension, followed by diabetes. Patients with an mFI5 score ≥ 2 were on average older, had higher BMI, had higher surgical risk (83% ASA classification III–IV), and had larger hernias.

**Table 2** Patient and hernia characteristics

	Overall no (%) N=4406	mFI5=0 no (%) N=2077 (47)	mFI5=1 no (%) N=1604 (36)	mFI5=2+ no (%) N=725 (17)	p-value
Mean age (SD)	55 (15)	47 (14)	60 (13)	62 (11)	<b>&lt;0.001</b>
Female sex	2015 (46)	1049 (51)	637 (40)	329 (45)	<b>&lt;0.001</b>
Mean BMI (SD)	33 (8)	32 (7)	33 (7)	35 (8)	<b>&lt;0.001</b>
Race					<b>0.002</b>
White	3591 (82)	1702 (82)	1328 (83)	561 (77)	
Black	580 (13)	253 (12)	200 (12)	127 (18)	
Other	235 (5)	122 (6)	76 (5)	37 (5)	
Insurance status					<b>&lt;0.001</b>
Private	2175 (50)	1235 (57)	728 (34)	212 (10)	
Medicare	1214 (28)	294 (24)	602 (50)	318 (26)	
Medicaid	833 (19)	480 (58)	214 (26)	139 (17)	
Uninsured	36 (1)	23 (64)	8 (22)	5 (14)	
Other	59 (1)	24 (41)	19 (32)	16 (27)	
ASA class					<b>&lt;0.001</b>
I	214 (5)	211 (10)	3 (0)	0 (0)	
II	2149 (49)	1339 (64)	687 (43)	123 (17)	
III	1922 (44)	512 (25)	867 (54)	543 (75)	
IV	121 (3)	15 (1)	47 (3)	59 (8)	
Comorbidities					
Smoker	872 (20)	424 (20)	285 (18)	163 (22)	<b>0.019</b>
OSA	1661 (38)	330 (16)	845 (53)	486 (67)	<b>&lt;0.001</b>
Diabetes	715 (16)	0 (0)	134 (8)	581 (80)	<b>&lt;0.001</b>
HTN	2099 (48)	0 (0)	1,391 (87)	708 (98)	<b>&lt;0.001</b>
COPD	277 (6)	0 (0)	69 (4)	208 (29)	<b>&lt;0.001</b>
CHF	15 (<1)	0 (0)	2 (0)	13 (2)	<b>&lt;0.001</b>
Cancer	93 (2)	36 (2)	39 (2)	18 (2)	0.257
Functional Status					<b>&lt;0.001</b>
Independent	4379 (99)	2077 (100)	1599 (100)	703 (97)	
Partially dependent	27 (1)	0 (0)	5 (0)	22 (3)	
Surgical priority					<b>&lt;0.001</b>
Elective	4052 (92)	1949 (94)	1481 (92)	622 (86)	
Urgent	180 (4)	67 (3)	61 (4)	52 (7)	
Emergent	174 (4)	61 (3)	62 (4)	51 (7)	
Hernia location					<b>0.027</b>
Epigastric	1041 (24)	472 (23)	390 (24)	179 (25)	
Umbilical	2684 (61)	1320 (64)	943 (59)	421 (58)	
Infraumbilical	336 (8)	145 (7)	123 (8)	68 (9)	
Suprapubic	73 (2)	31 (1)	31 (2)	11 (2)	
No midline component	272 (6)	109 (5)	117 (7)	46 (6)	
Previous hernia repair	727 (17)	291 (14)	299 (19)	137 (19)	<b>&lt;0.001</b>
Hernia width (cm)					<b>&lt;0.001</b>
<2	1255 (29)	734 (35)	379 (24)	142 (20)	
2–5	2198 (50)	1010 (49)	825 (51)	363 (50)	
5–10	677 (15)	233 (11)	295 (18)	149 (21)	
>10	276 (6)	100 (5)	105 (7)	71 (10)	

Bold values indicate significance of p value ( $p < 0.05$ )

**Table 3** Operative characteristics

	Overall no (%) N=4406	mFI5=0 no (%) N=2077 (47)	mFI5=1 no (%) N=1604 (36)	mFI5=2+ no (%) N=725 (17)	p-value
Surgical approach					0.882
Open	2541 (58)	1,214 (58)	911 (57)	416 (57)	
Lap	540 (12)	239 (12)	207 (13)	94 (13)	
Robotic	1028 (23)	480 (23)	379 (24)	169 (23)	
Unknown	296 (7)	143 (7)	107 (7)	46 (6)	
Wound classification					<b>&lt; 0.001</b>
Clean	4137 (94)	1,979 (95)	1,507 (94)	651 (90)	
Clean/contaminated	188 (54)	78 (4)	68 (4)	42 (6)	
Contaminated	56 (1)	15 (1)	19 (1)	22 (3)	
Dirty/infected	25 (1)	5 (0)	10 (1)	10 (1)	
Component separation*	308 (8)	108 (6)	127 (9)	73 (11)	<b>&lt; 0.001</b>
Mesh used	3525 (80)	1563 (75)	1,357 (85)	605 (83)	<b>&lt; 0.001</b>
Type of mesh used **					0.451
Synthetic non-absorbable	405 (47)	175 (49)	175 (49)	55 (38)	
Synthetic absorbable	312 (36)	124 (34)	129 (36)	59 (41)	
Biosynthetic	77 (9)	35 (10)	27 (8)	15 (10)	
Biologic	28 (3)	12 (3)	10 (3)	6 (4)	
Other	33 (4)	13 (4)	12 (3)	8 (6)	
Mesh fixation ***					0.655
Suture	2793 (80)	1243 (81)	1070 (80)	480 (80)	
Adhesive	31 (1)	13 (1)	13 (1)	5 (1)	
Absorbable tacks	281 (8)	118 (8)	111 (8)	52 (9)	
Non-absorbable tacks	25 (1)	13 (1)	9 (1)	3 (1)	
Self-fixating	114 (3)	57 (4)	44 (3)	13 (2)	
Other	238 (5)	99 (4)	95 (6)	44 (7)	

Bold values indicate significance of p value ( $p < 0.05$ )

\*308 of 4406 patients available

\*\*855 of 4406 patients available

\*\*\*3482 of 4406 patients available

**Table 4** Unadjusted complication rates

	Overall no (%) N=4406	mFI5=0 no (%) N=2077 (47)	mFI5=1 no (%) N=1604 (36)	mFI5=2+ no (%) N=725 (17)	p-value
Any complication	141 (3)	33 (2)	59 (4)	49 (7)	<b>&lt; 0.001</b>
Serious complication	52 (1)	11 (1)	18 (1)	23 (3)	<b>&lt; 0.001</b>
Surgical site infection	79 (2)	19 (1)	37 (2)	23 (3)	<b>&lt; 0.001</b>
Readmission	142 (3)	37 (2)	55 (3)	50 (7)	<b>&lt; 0.001</b>
Reoperation	81 (2)	19 (1)	36 (2)	26 (4)	<b>&lt; 0.001</b>
ED visit	298 (7)	126 (6)	107 (7)	65 (9)	<b>0.027</b>
Post-discharge event *	454 (10)	169 (8)	166 (10)	119 (16)	<b>&lt; 0.001</b>
Non-home discharge	148 (3)	32 (2)	52 (3)	64 (9)	<b>&lt; 0.001</b>

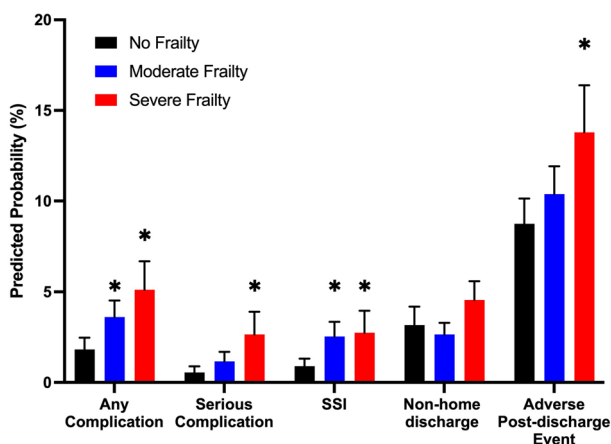
Bold values indicate significance of p value ( $p < 0.05$ )

\*Composite variable of readmission, reoperation, and ED visit

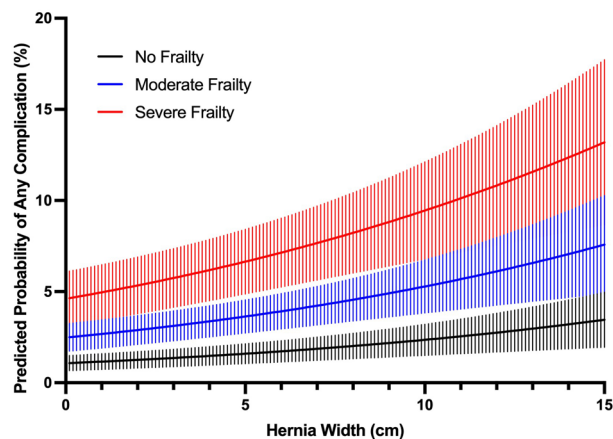
## Complications

The unadjusted incidence of primary and secondary outcomes increased in a stepwise fashion as frailty increased (Table 4). Postoperative complications occurred in 141 (3%) of patients and serious complications occurred in 52 (1%). Compared to patients with no frailty, patients with severe frailty had a higher incidence of complications (7 versus 2%,  $p < 0.001$ ), serious complications (3 versus 1%,  $p < 0.001$ ), SSI (3 versus 1%,  $p < 0.001$ ), non-home discharge (9 versus 2%,  $p < 0.001$ ), and post-discharge adverse events (16 versus 8%,  $p < 0.001$ ). Overall, the most common complications were SSI, postoperative transfusion, and postoperative sepsis. In patients with severe frailty, the most common complications were SSI, pneumonia, and postoperative transfusion.

On multivariable regression analysis, severe frailty was independently associated with increased odds of any complication (aOR 3.12, 95% CI 1.78–5.47), serious complication (aOR 5.25, 95% CI 2.17–13.19), SSI (aOR 3.41, 95% CI 1.58–7.34), and post-discharge adverse events (aOR 1.70, 95% CI 1.24–2.33), compared to patients with no frailty. This translates to predicted probabilities of 5.11% (95% CI 3.55–6.68) for any complication, 2.64% (95% CI 1.39–3.89) for serious complications, 2.74% (1.51–3.95) for surgical site infection, and 13.78% (11.18–16.38) for post-discharge adverse events (Fig. 1). Severe frailty was not associated with non-home discharge (aOR 1.64, 95% CI 0.93–2.90). Independent of hernia size, compared to patients with no frailty, patients with severe frailty had a higher predicted probability of any complication (2-cm hernia: 5.34% (95% CI 6.90–3.78) versus 1.26% (95% CI 1.71–0.80); 5-cm hernia 6.65% (95% CI 8.42–4.87) versus 1.60% (95% CI 2.14–1.05); Fig. 2), and serious complications (2-cm hernia: 2.64% (95% CI 3.79–1.49) versus 0.44%



**Fig. 1** Predicted probability of postoperative outcomes stratified by mFI5 score, Black = mFI5=0; Blue = mFI5=1; and Red = mFI5=2, \* $p$ -value < 0.05 compared to mFI5=0 (Color figure online)



**Fig. 2** Predicted probability of any postoperative complication over hernia size, Black = mFI5=0; Blue = mFI5=1; and Red = mFI5=2 (Color figure online)

(95% CI 0.71–0.16); 5-cm hernia 3.09% (95% CI 4.31–1.86) versus 0.52% (95% CI 0.82–0.21).

To evaluate if surgical approach influenced the primary and secondary outcomes in patients with severe frailty, we performed a separate multivariable analysis in the population of severely frail patients. Within the severely frail population, an open surgical approach was associated with an increased odds of any complication (aOR 2.52, 95% CI 1.14–5.56) and surgical site infection (aOR 4.52, 95% CI 1.22–16.75). An open surgical approach was not associated with increased odds of a serious complication (OR 2.02, 95% CI 0.71–5.75).

## Discussion

In this cohort of patients undergoing VHR, we found that frailty was associated 30-day complications, independent of hernia size. Hernia size has not been controlled for in previous studies of frailty in this population and therefore this analysis adds a level of nuance to the existing literature. These data are also consistent with previous reports describing an increased risk of postoperative complications in frail surgical patients [1, 6, 16, 33]. Severe frailty was also associated with experiencing a post-discharge adverse event. In short, frailty appears to be an important predictor of a surgical patient's perioperative trajectory. These results suggest that inclusion of frailty assessments, regardless of hernia size, in the preoperative period may improve risk stratification, inform postoperative resource allocation, and importantly, improve patient counseling.

Frailty is a measure of a person's physiologic reserve to withstand stressors [1, 2, 4]. An abundance of studies have demonstrated the association of frailty with worse



postoperative complications and increased mortality [16, 27, 28, 33–35]. For example, in a large analysis of 71,455 patients undergoing ambulatory hernia repair collected in the American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database, increased frailty was associated with increased odds of experiencing postoperative complications [16]. As a result, frailty assessments have been suggested for inclusion in the preoperative assessment of surgical patients. The current study demonstrates independent of hernia size that these same trends apply to the VHR population. Although a small hernia repair may not be technically complex, a frail patient's postoperative course may be. Severely frail patients undergoing VHR are more likely to experience surgical complications and adverse post-discharge events. Additionally, independent of patient- and hernia-related factors, an open surgical approach was associated with an increased risk of postoperative complications in severely frail patients. Discussion of the increased risk of complications using an open surgical approach in the preoperative counseling visit may better inform a frailer patient's decision-making for VHR.

Prior work has demonstrated an association between frailty and post-discharge adverse events, such as non-home disposition, reoperation, and hospital readmission [36–38]. Our results support these findings and suggest that frailty may be a predictor of both surgical outcomes and post-discharge events in the VHR population. In this study, the most common complications in severely frail patients were SSI, pneumonia, and postoperative transfusion. Accordingly, patients may benefit from increased focus on pre- and postoperative interventions to reduce SSI, such as preoperative antiseptic bathing, glycemic control, and maintenance of perioperative normothermia [39]. Additionally, added focus on pulmonary hygiene in patients with severe frailty may be of added benefit [40].

Frailty assessments that utilize a cumulative comorbidity model, such as the mFI5 used in this study, are simpler compared to physical assessments of frailty and can be used to screen for higher-risk surgical patients more easily. Frailty screening and subsequent focus of resources toward frail patients can improve outcomes in surgical patients without negatively impacting non-frail patients [41]. In addition, pre-surgical optimization programs for hernia patients have been shown to improve management of higher-risk patients and increase operative yield in the hernia population [42–44]. For example, at our institution patients are screened in the preoperative period for frailty and other high-risk characteristics and, if positive, are referred to our hernia optimization clinic. In the optimization clinic, patient health characteristics, functional status, and frailty can be further assessed, and patients are subsequently provided guidance and resources to meet their health needs. This intervention has

resulted in improved optimization of hernia repair patients and is an impactful example of a preoperative intervention for higher-risk patients [42].

The results of this study must be considered within the context of its limitations. First, the observational design of this study introduces the possibility of selection bias and does not allow for causal inferences from the reported data. This study analyzed a database of Michigan patients undergoing VHR limiting the generalizability of these results to the general population. Additionally, these data were collected during the COVID-19 pandemic, introducing selection bias for whom was given the option of VHR versus watchful waiting. Patients who underwent watchful waiting of their VHR are not accounted for in these data and this potentially introduces further bias. These data also do not report surgical site occurrences (e.g., seroma, dehiscence) and lack long-term follow-up data which are necessary to report hernia recurrence in this population. In addition, the number of patients with missing variables is high. Still, it is critical to understand the predictors of immediate complications given that up to 20% of patients undergoing VHR experience a complication [17]. These limitations are due to the recent implementation of the MSQC-HR data collection and long-term follow-up and reporting of this data is planned. Additionally, we only report clinical outcomes in this study and not patient-reported outcomes which are important to consider in hernia repair. Finally, the frailty score used in this study relies upon variables that reflect comorbidities of the patient. This score does not consider the physical exam or other potential frailty measures that account for physical activity such as the Timed Up and Go Test or hand-strength that have been shown to be predictive of postoperative outcomes [5, 6]. However, the mFI5 has been validated in the general surgery population and is a strong metric to analyze surgical patients and outcomes in large, population databases [14, 15, 27].

## Conclusion

In this cohort of patients undergoing VHR, when controlling for patient-, operative-, and hernia-specific factors, increased frailty was associated with a worsening risk of postoperative complications across all hernia sizes. In the severely frail population, independent of patient- and hernia-related factors, an open surgical approach was associated with an increased risk of postoperative complications. These findings highlight the importance of patient frailty assessments in the preoperative setting. Addressing frailty in the perioperative period may improve patient counseling and outcomes for this common general surgery procedure.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00464-022-09626-8>.

**Acknowledgements** Quintin P. Solano was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health (TL1TR002242) from 7/2021 to 7/2022. RH receives unrelated funding from the Blue Cross Blue Shield of Michigan Foundation and the National Institute of Diabetes and Digestive and Kidney Diseases (5T32DK108740-05). CM, AE, LD, BF, and MS have no disclosures. ME receives unrelated funding from the Michigan Department of Health and Human Services and the National Institute on Drug Abuse and salary support from Blue Cross Blue Shield of Michigan. The Michigan Surgical Quality Collaborative is funded as part of the Blue Cross Blue Shield of Michigan Value Partnership program. JD receives grant funding from the NIH, ARGQ, and Blue Cross Blue Shield of Michigan Foundation and is a cofounder of ArborMetrix, Inc. DT receives funding from AHRQ K08HS025778-01A1 and receives consulting fees from Medtronic. The content of this study is solely the responsibility of the authors and does not necessarily reflect the official views of Blue Cross Blue Shield of Michigan. No funder or sponsor had any role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. QS had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

**Funding** Agency for Healthcare Research and Quality, K08HS025778-01A1, Dana Telem, National Institutes of Health, TL1TR002242, Quintin Pedro Solano

## Declarations

**Disclosures** Quintin Solano—No conflicts of interest, Ryan Howard MD MS—No conflicts of interest, Cody Mullens MD MPH—No conflicts of interest, Anne P Ehlers MD MPH—No conflicts of interest, Lia Delaney MS—No conflicts of interest, Brian Fry MD MS—No conflicts of interest, Mary Shen MD MS—No conflicts of interest, Michael Englesbe MD – No conflicts of interest, Justin Dimick MD MPH—No conflicts of interest, and Dana Telem MD MPH—Consulting fees from Medtronic.

## References

- Farhat JS, Velanovich V, Falvo AJ et al (2012) Are the frail destined to fail? frailty index as predictor of surgical morbidity and mortality in the elderly. *J Trauma Acute Care Surg* 72(6):1526–1531. <https://doi.org/10.1097/TA.0b013e3182542fab>
- Buigues C, Juarros-Folgado P, Fernández-Garrido J, Navarro-Martínez R, Cauli O (2015) Frailty syndrome and pre-operative risk evaluation: a systematic review. *Arch Gerontol Geriatr* 61(3):309–321. <https://doi.org/10.1016/j.archger.2015.08.002>
- Kulminski AM, Ukraintseva SV, Culminskaya IV et al (2008) Cumulative deficits and physiological indices as predictors of mortality and long life. *J Gerontol A Biol Sci Med Sci* 63(10):1053–1059. <https://academic.oup.com/biomedgerontology/article/63/10/1053/559209>
- Joseph B, Pandit V, Sadoun M et al (2014) Frailty in surgery. *J Trauma Acute Care Surg* 76(4):1151–1156. <https://doi.org/10.1097/TA.000000000000103>
- Fried LP, Tangen CM, Walston J et al (2001) Frailty in older adults: evidence for a phenotype. *J Gerontol A-Biol* 56(3):M146–M157. <https://academic.oup.com/biomedgerontology/article/56/3/M146/545770>
- Makary MA, Segev DL, Pronovost PJ et al (2010) Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg* 210(6):901–908. <https://doi.org/10.1016/j.jamcollsurg.2010.01.028>
- McIsaac DI, Moloo H, Bryson GL, van Walraven C (2017) The association of frailty with outcomes and resource use after emergency general surgery: a population-based cohort study. *Anesth Analg* 124(5):1653–1661. <https://doi.org/10.1213/ANE.0000000000001960>
- Podsiadlo D, Richardson S (1991) The timed “Up & Go”: a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 39(2):142–148
- Velanovich V, Antoine H, Swartz A, Peters D, Rubinfeld I (2013) Accumulating deficits model of frailty and postoperative mortality and morbidity: its application to a national database. *J Surg Res* 183(1):104–110. <https://doi.org/10.1016/j.jss.2013.01.021>
- Tracy BM, Adams MA, Schenker ML, Gelbard RB (2020) The 5 and 11 factor modified frailty indices are equally effective at outcome prediction using TQIP. *J Surg Res* 255:456–462. <https://doi.org/10.1016/j.jss.2020.05.090>
- Ali TZ, Lehman EB, Aziz F (2018) Modified frailty index can be used to predict adverse outcomes and mortality after lower extremity bypass surgery. *Ann Vasc Surg* 46:168–177. <https://doi.org/10.1016/j.avsg.2017.07.007>
- Holzgrefe RE, Wilson JM, Staley CA, Anderson TL, Wagner ER, Gottschalk MB (2019) Modified frailty index is an effective risk-stratification tool for patients undergoing total shoulder arthroplasty. *J Shoulder Elbow Surg* 28(7):1232–1240. <https://doi.org/10.1016/j.jse.2018.12.004>
- Traven SA, Horn RW, Reeves RA, Walton ZJ, Woolf SK, Slone HS (2020) The 5-factor modified frailty index predicts complications, hospital admission, and mortality following arthroscopic rotator cuff repair. *Arthrosc J Arthrosc Related Surg* 36(2):383–388. <https://doi.org/10.1016/j.arthro.2019.08.036>
- Subramaniam S, Aalberg JJ, Soriano RP, Divino CM (2018) New 5-factor modified frailty index using American College of Surgeons NSQIP data. *J Am Coll Surg* 226(2):173–181.e8. <https://doi.org/10.1016/j.jamcollsurg.2017.11.005>
- Balla FM, Yheulon CG, Stetler JL, Patel AD, Lin E, Davis SS (2019) Ventral hernia repair outcomes predicted by a 5-item modified frailty index using NSQIP variables. *Hernia* 23(5):891–898. <https://doi.org/10.1007/s10029-019-01923-x>
- Seib CD, Rochefort H, Chomsky-Higgins K et al (2018) Association of patient frailty with increased morbidity after common ambulatory general surgery operations. *JAMA Surg* 153(2):160–168. <https://doi.org/10.1001/jamasurg.2017.4007>
- Lindmark M, Strigård K, Löwenmark T, Dahlstrand U, Gunnarsson U (2018) Risk factors for surgical complications in ventral hernia repair. *World J Surg* 42(11):3528–3536. <https://doi.org/10.1007/s00268-018-4642-6>
- Langer C, Schaper A, Liersch T et al (2005) Prognosis factors in incisional hernia surgery: 25 years of experience. *Hernia* 9(1):16–21. <https://doi.org/10.1007/s10029-004-0265-y>
- Poruk KE, Farrow N, Azar F et al (2016) Effect of hernia size on operative repair and post-operative outcomes after open ventral hernia repair. *Hernia* 20(6):805–810. <https://doi.org/10.1007/s10029-016-1542-2>
- Moreno-Egea A, Carrillo-Alcaraz A, Aguayo-Albasini JL (2012) Is the outcome of laparoscopic incisional hernia repair affected by defect size? a prospective study. *Am J Surg* 203(1):87–94. <https://doi.org/10.1016/j.amjsurg.2010.11.017>



21. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP (2007) The Strengthening of reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bull World Health Organ* 85(11):867–872. <https://doi.org/10.2471/BLT.07.045120>
22. Englesbe MJ, Dimick JB, Sonnenday CJ, Share DA, Campbell DAJ (2007) The Michigan surgical quality collaborative: will a statewide quality improvement initiative pay for itself. *Ann Surg* 246(6):1100–1103. [https://journals.lww.com/annalsurgery/Abstract/2007/12000/The\\_Michigan\\_Surgical\\_Quality\\_Collaborative\\_\\_Will.26.aspx](https://journals.lww.com/annalsurgery/Abstract/2007/12000/The_Michigan_Surgical_Quality_Collaborative__Will.26.aspx)
23. Share DA, Campbell DA, Birkmeyer N et al (2011) How a regional collaborative of hospitals and physicians in Michigan cut costs and improved the quality of care. *Health Aff* 30(4):636–645. <https://doi.org/10.1377/hlthaff.2010.0526>
24. Howard R, Ehlers A, Delaney L et al (2021) Leveraging a statewide quality collaborative to understand population-level hernia care. *Am J Surg*. <https://doi.org/10.1016/j.amjsurg.2021.05.013>
25. Howard R, Thompson M, Fan Z, Englesbe M, Dimick JB, Telem DA (2019) Costs associated with modifiable risk factors in ventral and incisional hernia repair. *JAMA Netw Open* 2(11):e1916330. <https://doi.org/10.1001/jamanetworkopen.2019.16330>
26. Howard R, Johnson E, Berlin NL et al (2021) Hospital and surgeon variation in 30-day complication rates after ventral hernia repair. *Am J Surg* 222(2):417–423. <https://doi.org/10.1016/j.amjsurg.2020.12.021>
27. Chimukangara M, Helm MC, Frelich MJ et al (2017) A 5-item frailty index based on NSQIP data correlates with outcomes following paraesophageal hernia repair. *Surg Endosc* 31(6):2509–2519. <https://doi.org/10.1007/s00464-016-5253-7>
28. Weaver DJ, Malik AT, Jain N, Yu E, Kim J, Khan SN (2019) The modified 5-item frailty index: a concise and useful tool for assessing the impact of frailty on postoperative morbidity following elective posterior lumbar fusions. *World Neurosurgery* 124:e626–e632. <https://doi.org/10.1016/j.wneu.2018.12.168>
29. Albright EL, Davenport DL, Roth JS (2011) Preoperative functional health status impacts outcomes after ventral hernia repair. *Am Surg* 78:230–234
30. Yahchouchy-Chouillard EK, Aura T, Picone O, Etienne JC, Fingerhut A (2003) Incisional hernias. *Dig Surg* 20(1):3–9. <https://doi.org/10.1159/000068850>
31. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR, Guideline for Prevention of Surgical Site Infection, (1999) Centers for disease control and prevention (CDC) hospital infection control practices advisory committee. *Am J Infect Control*. [https://doi.org/10.1016/S0196-6553\(99\)70088-X](https://doi.org/10.1016/S0196-6553(99)70088-X)
32. Garner JS (2015) CDC guideline for prevention of surgical wound infections, 1985 Supersedes guideline for prevention of surgical wound infections published in 1982 (Originally published in November 1985) Revised. *Infect Control* 7(3):193–200. <https://doi.org/10.1017/s0195941700064080>
33. Tracy BM, Wilson JM, Smith RN, Schenker ML, Gelbard RB (2020) The 5-item modified frailty index predicts adverse outcomes in trauma. *J Surg Res* 253:167–172. <https://doi.org/10.1016/j.jss.2020.03.052>
34. Saxton A, Velanovich V (2011) Preoperative frailty and quality of life as predictors of postoperative complications. *Ann Surg* 253(6):1223–1229. <https://doi.org/10.1097/SLA.0b013e318214bce7>
35. Shinall MC, Arya S, Youk A et al (2020) Association of preoperative patient frailty and operative stress with postoperative mortality. *JAMA Surg* 155(1):1–9. <https://doi.org/10.1001/jamasurg.2019.4620>
36. Runner RP, Bellamy JL, Vu CPCL, Erens GA, Schenker ML, Guild GN (2017) Modified frailty index is an effective risk assessment tool in primary total knee arthroplasty. *J Arthroplasty* 32(9):S177–S182. <https://doi.org/10.1016/j.arth.2017.03.046>
37. Wahl TS, Graham LA, Hawn MT et al (2017) Association of the modified frailty index with 30-day surgical readmission. *JAMA Surg* 152(8):749–757. <https://doi.org/10.1001/jamasurg.2017.1025>
38. Robinson TN, Wu DS, Pointer L, Dunn CL, Cleveland JC, Moss M (2013) Simple frailty score predicts postoperative complications across surgical specialties. *Am J Surg* 206(4):544–550. <https://doi.org/10.1016/j.amjsurg.2013.03.012>
39. Berriós-Torres SI, Umscheid CA, Bratzler DW et al (2017) Centers for disease control and prevention guideline for the prevention of surgical site infection, 2017. *JAMA Surg* 152(8):784–791. <https://doi.org/10.1001/jamasurg.2017.0904>
40. Paulo do Nascimento Junior, Norma SP Módolo, Sílvia Andrade, Michele MF Guimarães, Leandro G Braz, Regina El Dib, (2014) Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. *Cochrane Database of Syst Rev*. <https://doi.org/10.1002/14651858.CD006058.pub3>
41. Engelhardt KE, Reuter Q, Liu J et al (2018) Frailty screening and a frailty pathway decrease length of stay, loss of independence, and 30-day readmission rates in frail geriatric trauma and emergency general surgery patients. *J Trauma Acute Care Surg* 85(1):167–173. <https://doi.org/10.1097/TA.0000000000001931>
42. Delaney LD, Howard R, Palazzolo K et al (2021) Outcomes of a presurgical optimization program for elective hernia repairs among high-risk patients. *JAMA Netw Open* 4(11):e2130016. <https://doi.org/10.1001/jamanetworkopen.2021.30016>
43. Howard R, Delaney L, Kilbourne AM et al (2021) Development and implementation of preoperative optimization for high-risk patients with abdominal wall hernia. *JAMA Netw Open*. <https://doi.org/10.1001/jamanetworkopen.2021.6836>
44. Delaney LD, Kattapuram M, Haidar JA et al (2021) The impact of surgeon adherence to preoperative optimization of hernia repairs. *J Surg Res* 264:8–15. <https://doi.org/10.1016/j.jss.2021.01.044>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.