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ORIGINAL ARTICLE

Obesity increases the surgical complexity and risk of recurrence after midline primary ventral hernia repair: results on 2307 patients from the French Society of hernia surgery (SFCP-CH) registry database

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Abstract

Purpose Obesity is a known risk factor of recurrence after hernia surgery, but available data often concern pooled cases of primary and incisional hernia, with short follow-up. We aimed to analyze the impact of severe obesity (BMI ≥ 35 kg/m^2) on the results of midline primary ventral hernia repair (mPVHR), in comparison with non-severely obese patients.

Methods Data were extracted from a multicentric registry, in which patients' data are consecutively and anonymously collected. We conducted a retrospective comparative study on patients with severe obesity (sOb) versus non-severely obese patients (non-sOb), who underwent surgery, with a minimal 2-year follow-up after their mPVHR.

Results Among 2307 patients, 267 sOb and 2040 non-sOb matched inclusion criteria. Compared with non-sOb, sOb group gathered all the worse conditions and risk factors: more ASA3-4 (39.3% vs. 10.2%; $p < 0.001$), symptomatic hernia (15.7% vs. 6.8%; $p < 0.001$), defect > 4 cm in diameter (24.3% vs. 8.8%; $p < 0.001$), emergency surgery (6.1% vs. 2.5%; $p = 0.003$), and Altemeir class > 1 (9.4% vs. 2.9%; $p < 0.001$). Laparoscopic IPOM was used more often in sOb patients (40% vs. 32%; $p = 0.016$), but with smaller Hauters' ratio (46 vs. 73; $p < 0.001$). Compared with the non-sOb, the rate of day-case surgery was lower (48% vs. 68%; $p < 0.001$), the surgical site occurrences were significantly more frequent (6.4 %vs. 2.5%; $p < 0.001$). The main outcome, 2-year recurrence, was 5.9% in the sOb vs. 2.1% ($p = 0.008$), and 2-year reoperations was 3% vs. 0.3% ($p = 0.006$). In the adjusted analysis, severe obesity was an independent risk factor for recurrence [OR = 2.82, (95%CI, 1.45; 5.22); $p = 0.003$].

Conclusion In patients with severe obesity, mPVHR is technically challenging and recurrence rate is three times higher than that of non-severely obese patients.

Keywords Mesh · Obesity · Recurrence · Ventral hernia · Ventral hernia repair

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Introduction

According to the European Hernia Society, midline primary ventral hernias (mPVH) are defined as umbilical and epigastric hernias [1]. They are a common pathology, representing 4% of operated hernias [2].

Obesity is a pathology increasingly frequent in our society, affecting 17% of the French population in 2020, representing 8.5 million people (ObEpi national survey, 2020), and 42% of the US population, constantly increasing. Almost 5% of the population have a body mass index (BMI) over 35 kg/m^2 [3]. It is a known risk factor for recurrence and morbidity after a hernia surgery (HS) [4–9]. In France, the annual costs of incisional hernia care are over 250 million Euros, and a 5% reduction in hernia incidence would allow a savings of 4 million Euros [10]. Consequently, this represents a major public health problem.

The impact of obesity on the natural evolution of a hernia and its consequences on the surgical procedure and complications are known, but are still being studied and precise recommendations are missing [11–16]. Moreover, all these studies are methodically limited, with low patient numbers and frequent loss to follow-up. Moreover, almost all of them pool together primary and incisional hernias. Nevertheless, sufficient weight loss before surgery is urged and recommended nowadays as a bridge to midline primary ventral hernia repair (mPVHR) [17, 18].

Considering these frequent limitations in the design of available studies, we decided to analyze in a nationwide multicentric database the impact of severe obesity in a homogenous population comprising only mPVH (umbilical or epigastric) with a systematic follow-up of 2 years. Our objective was then to compare the occurrence of mPVH recurrence 2 years after surgery between patients with severe obesity and non-severely obese patients, with a focus on surgical complexity and postoperative morbidity.

Methods

Design and data collection

This study was an observational retrospective multicentric cohort study, using the prospectively maintained registry of the French "Club Hernie". This surgical society includes French surgeons specialising in hernia repair, working in both public and private hospitals. A total of 35 centers are currently participating to this registry with data on 52,000 hernia repairs in 48,790 individuals included from November 2001 to September 2022 with up to a 5 years follow-up. This database gathers data registered by operating surgeons: demographic characteristics, medical condition and comorbidities, information on surgery procedures and 2-years and 5-years follow-up visits, after information and approval of the patients for data collection. The data were systematically, consecutively and anonymously collected on the online registry by allocating a random number to each patient, and stored in a specialized Swiss data bank where they were protected against network intrusion. The only persons who could associate the random number and the identity of a patient were the surgeon and the clinical research assistant (CRA) of the Club (principal and co-principal investigators). The surgeon performed the initial follow-up at the first month visit. Then, if any systematic surgical visit was performed, the patient was contacted by the CRA using a phone questionnaire at 2 years and, if possible, at 5 years postoperative. The registry complies with the requirements of the General Data Protection Regulation (GDRP), the French "Méthodologies de reference de la Commission Nationale Informatique et Libertés" (MR001, MR003) and the different specific French ethics committees. STROBE (Strengthening the Reporting of Observational studies in Epidemiology) and the European Registry of Abdominal Wall Hernias (EuraHS) recommendations were used for the conduct and reporting of our study [19, 20].

Inclusion and exclusion criteria

The inclusion criteria were: patients who underwent mPVHR (umbilical or epigastric) between November 2011 and March 2020. The exclusion criteria were: having less than 16 years old at the surgery time, missing BMI information, and patients who were lost to follow-up before 2 years.

Outcomes and exposure

Our primary endpoint was the recurrence of mPVH at 2 years after surgery. It was evaluated clinically and, in cases of suspected clinical recurrence, with ultrasonography or CT scan. In the recent ASMBS/IFSO guidelines on indications for metabolic and bariatric surgery [21], weight loss interventions are suggested in patients with severe obesity (BMI $\geq$ 35 kg/m^2, class II, III and IV of the World Health Organization) before mPVHR to reduce the rate of complications associated with mPVHR and increase durability of the repair. Consequently, we chose to analyze patients operated on for mPVH with a severe obesity (BMI $\geq$ 35 kg/m^2, sOb group), in comparison with non-severely obese patients (non-sOb group). We analyzed the impact of suspected risk factors for hernia recurrence at 2 years such as patients' baseline characteristics, surgery in an emergency context, surgical technique used (laparoscopic or laparotomy), mesh location, and the occurrence of surgical site infection. Surgical morbidity was described according to the Dindo–Clavien classification [22]. We also analyzed factors related to technical difficulty, such as multiple hernia location, and defect size and Hauters' ratio, defined by the ratio of mesh area to defect area and known to be associated with an increased recurrence risk if above 17 [23].

Statistical analysis

Descriptive statistics in the overall population and according to obesity group were presented with mean, standard deviation, median, interquartile range (IQR), minimum and maximum for quantitative variables; and number and percentages for qualitative variables. Quantitative and qualitative variables were compared between obesity groups with Wilcoxon and Fisher tests, respectively. Numbers of missing values were also reported. A 0.05 level will be retained as statistically significant.

Factors associated with hernia recurrence within 2 years post-surgery were first studied with univariate logistic regressions, using clinically relevant variables and known risk factors. Variables with more than 20% of missing data were not considered. For a given covariate, if the p-value associated to the odds ratio (OR) and its associated 95% confidence interval (CI) was less than 0.20, the covariate was selected to be included in the multivariate analysis.

Then, all covariates selected in univariate analyses were included in a multivariate logistic regression. Subsequently, a backward covariate selection was carried using the Akaike Information Criterion (AIC). 2×2 interactions were also tested and integrated to the multivariate model if significant ($p < 0.05$). The results of the final multivariate logistic regression were reported with descriptive statistics, adjusted OR (OR_a), 95% CI and p-value.

Results

Study population

Between November 2011 and March 2020, 2307 patients with mPVHR and their information were clearly uploaded in the French Hernia Club registry (Fig. 1). In this population, 267 (11.6%) and 2040 (88.4%) were in severe obesity (BMI ≥ 35 kg/m^2, sOb) or non-severely obese (BMI < 35 kg/m^2, non-sOb), respectively. In both groups, the mean age was 59 years old [range: 16–97 in the sOb group and 31–87 in the non-sOb group] the majority of whom were male (57% in the sOb group, 62% in the non-sOb group, $p = 0.082$). In the sOb group, the ASA score was higher (ASA ≥ 3: 39.3% vs. 10.2%, $p < 0.001$), hernia was more frequently symptomatic before surgery (16% vs. 7%, $p < 0.001$) and the hernia defect was wider (diameter > 4 cm: 24.3% vs. 8.8%, $p < 0.001$). However, there were no differences concerning tobacco use (21.6% vs. 23.1%, $p = 0.6$) (Table 1).

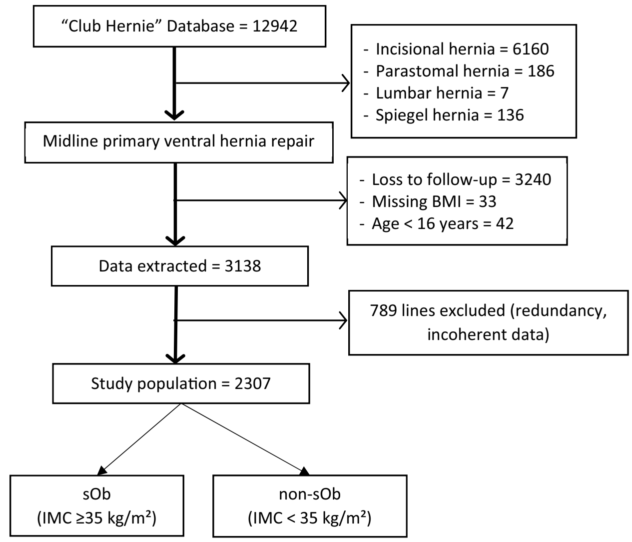

Fig. 1 Flowchart. *sOb* patients with severe obesity (BMI ≥ 35 kg/m^2), *non-sOb* non-severely obese patients (BMI < 35 kg/m^2)

Regarding the repair characteristics (Table 1), they were more urgent (6.1% vs. 2.5%, $p = 0.003$), contaminated (Altemeier ≥ 2) (9.4% vs. $< 2.9\%$, $p < 0.001$) and laparoscopic surgeries (40% vs. 32%, $p = 0.016$) in the sOb group. More mesh was used in the sOb group (82% vs. 68%, $p < 0.001$), the majority of which was placed intraperitoneally (81% vs. 72%, $p = 0.026$). The Hauters ratio was higher in the non-sOb group (73 vs. 46, $p < 0.001$) and patients in this group were more frequently eligible for an ambulatory procedure than sOb patients (68% vs. 48%, $p < 0.001$).

Finally, concerning the postoperative characteristics (Table 1), complications were more frequent and more severe in the sOb group, including those involving the surgical site (infectious and non-infectious), which were three times more frequent (6.4% vs. 2.5%, $p < 0.001$). The global morbidity (estimated by a higher Dindo–Clavien classification) was not significantly different between groups (3.4% vs. 1.9%, $p = 0.052$). The mean delay before the first follow-up evaluation was 2.07 ± 0.69 years. At this time, the recurrence rate was higher in patients in the sOb group (6%) vs. non-severely obese patients (2.1%) ($p < 0.001$), with a higher rate of reintervention (3.6% vs. 1.4%, $p = 0.017$).

Univariate analyse of recurrence risk at 2 years (Table 2).

In the univariate analysis, several factors were associated with an increased risk of recurrence of mPVH within 2 years

Table 1 Patients' characteristics

	Overall ($n = 2307$)	sOb ($n = 267$)	non-sOb ($n = 2040$)	p-value
Male	1426 (62%)	152 (57%)	1274 (62%)	0.082
Age	59 ± 14 [16, 97]	59 ± 12 [31, 87]	59 ± 15 [16, 97]	0.9
BMI (kg/m^2)	27.9 ± 6.0 **[15.2, 58]**	39.5 ± 4.6 **[35.0, 58.0]**	26.4 ± 4.3 **[15.2, 35.0]**	< 0.001
ASA-score				< 0.001
1–2	1982 (86%)	161 (47.4%)	1821 (89.3%)	
≥ 3	314 (14%)	105 (39.3%)	209 (10.2%)	
Active tobacco use	523 (23%)	57 (22%)	466 (23%)	0.6
Pre-operative symptomatology				< 0.001
None	2110 (92%)	225 (84%)	1885 (93%)	
Infatuation	113 (4.9%)	25 (9.4%)	88 (4.3%)	
Strangulation	68 (3.0%)	17 (6.3%)	51 (2.5%)	
Defect diameter				< 0.001
< 4 cm	2063 (89%)	202 (76%)	1861 (91%)	
≥ 4 cm	244 (11%)	65 (24%)	179 (8.8%)	
Emergency surgery	67 (2.9%)	16 (6.1%)	51 (2.5%)	0.003
Altemeier				< 0.001
Clean (A1)	2216 (96%)	242 (91%)	1974 (97%)	
Contamined (A2-3-4)	84 (3.7%)	25 (9.4%)	59 (2.9%)	
Laparoscopic	766 (33%)	106 (40%)	660 (32%)	0.016
Mesh	1604 (70%)	217 (82%)	1387 (68%)	< 0.001
Mesh placement site				0.026
Intraperitoneal	1179 (74%)	175 (81%)	1004 (72%)	
Preperitoneal (sublay)	364 (23%)	33 (15%)	331 (24%)	
Prefascial retromuscular (sublay)	48 (3%)	7 (3.2%)	41 (3%)	
Premusculo-aponeurotic (onlay)	13 (0.8%)	2 (0.9%)	11 (0.8%)	
Hauters' ratio	70 ± 127	46 ± 53	73 ± 135	< 0.001
Overlap ≥ 5 cm	727 (51%)	110 (54%)	617 (51%)	0.4
Ambulatory procedure	1425 (65%)	125 (48%)	1300 (68%)	< 0.001
Readmission	7 (0.9%)	0	7 (1%)	> 0.9
SSO	68 (3.1%)	17 (6.6%)	51 (2.6%)	0.002
Morbidity				0.059
Dindo 1–2	48 (2.2%)	9 (3.5%)	39 (2%)	
Dindo 3–4	16 (0.7%)	4 (1.6%)	12 (0.6%)	
Recurrence (2 years)	59 (2.6%)	16 (6%)	43 (2.1%)	< 0.001
Reintervention (2 years)	36 (1.6%)	9 (3.6%)	27 (1.4%)	0.017

Bold indicates [min-max]

Results are expressed in n (%) for categorical data and mean (SD) and [min, max] for quantitative data; $p < 0.05$ is significant

BMI body mass index, *sOb* patients with severe obesity (BMI ≥ 35 kg/m^2), *non-sOb* non-severely obese patients (BMI < 35 kg/m^2), *ASA* American Society of Anesthesiologists physical status score, *SSO* surgical site occurrence

post-surgery. The main factor was severe obesity [OR = 2.96, 95%CI (1.60; 5.23), $p < 0.001$], followed by the existence of previous hernia surgery [OR = 2.04, 95%CI (1.09; 3.62), $p = 0.028$], an ASA score ≥ 3 [OR = 2.06, 95%CI (1.07; 3.7), $p = 0.031$] and an urgent [OR = 3.25, 95%CI (1.1; 7.69), $p = 0.034$] or contaminated procedure [OR = 4.47, 95%CI (1.91; 9.25), $p = 0.001$]. The use of mesh was univariately associated with a decrease in the rate of recurrence [OR = 0.54, 95%CI (0.32; 0.92), $p = 0.025$].

However, some factors known as risk factors of incisional hernia were not significant, such as an ongoing anticoagulant treatment, tobacco use, defect size and surgical site infection.

Table 2 Univariate analysis* for the risk of recurrence

	Overall (n = 2307)	Recurrence (n = 59)	No recurrence (n = 2248)	OR	CI	p-value
Age	59 [48, 70]	61 [50, 72]	59 [48, 70]	1.01	[0.99; 1.03]	0.31
Missing data	6	0	6			
Sex				1.38	[0.81; 2.31]	0.23
Male	1426 (62%)	32 (54%)	1394 (62%)			
Female	881 (38%)	27 (46%)	854 (38%)			
Obesity status				**2.96**	**[1.6; 5.23]**	**< 0.001**
Severe obesity	267 (12%)	16 (27%)	251 (11%)			
Non-severe obesity	2040 (88%)	43 (73%)	1997 (89%)			
WHO BMI classification						**0.004**
Normal weight or overweight	1580/2307 (68%)	29/59 (49%)	1551/2248 (69%)	–	–	
Obesity class 1	460/2307 (20%)	14/59 (24%)	446/2248 (20%)	1.68	0.85, 3.15	
Obesity class 2	178/2307 (7.7%)	10/59 (17%)	168/2248 (7.5%)	3.18	1.45, 6.44	
Obesity classes 3/4/5	89/2307 (3.9%)	6/59 (10%)	83/2248 (3.7%)	3.87	1.42, 8.97	
Personal history of hernia				2.04	[1.09; 3.62]	0.028
No	1963 (85%)	44 (75%)	1919 (86%)			
Yes	336 (15%)	15 (25%)	321 (14%)			
Missing data	8	0	8			
Tobacco use				1.29	[0.70; 2.26]	0.4
Non-active smoker	1756 (77%)	42 (72%)	1714 (77%)			
Active smoker	523 (23%)	16 (28%)	507 (23%)			
Missing data	28	1	27			
Ongoing anticoagulant or anti-platelet treatment				2.16	[0.98; 4.26]	0.056
No	2113 (92%)	50 (85%)	2063 (92%)			
Yes	181 (7.9%)	9 (15%)	172 (7.7%)			
Missing data	13	0	13			
ASA score				2.06	[1.07; 3.7]	0.031
ASA < 3	1982 (86%)	44 (76%)	1938 (87%)			
ASA ≥ 3	314 (14%)	14 (24%)	300 (13%)			
Missing data	11	1	10			
Localisation of ventral hernia						
Epigastric/white line	483 (21%)	12 (21%)	471 (21%)			0.086
Periumbilical	1770 (78%)	43 (74%)	1727 (78%)	0.98	[0.53; 1.95]	
White line + umbilical	25 (1.1%)	3 (5.2%)	22 (1.0%)	5.35	[1.16; 18.4]	
Missing data	29	1	28			
Defect diameter				1.98	[0.97; 3.73]	0.061
Defect < 4 cm	2063 (89%)	48 (81%)	2015 (90%)			
Defect ≥ 4 cm	244 (11%)	11 (19%)	233 (10%)			
Emergency surgery				3.25	[1.1; 7.69]	0.034
No	2232 (97%)	54 (92%)	2178 (97%)			
Yes	67 (2.9%)	5 (8.5%)	62 (2.8%)			
Missing data	8	0	8			
Altemeier score				4.47	[1.91; 9.25]	0.001
Altemeier 1	2,216 (> 99.9%)	51 (86%)	2165 (97%)			
Altemeier ≥ 2	84 (< 0.1%)	8 (14%)	76 (3.4%)			
Missing data	7	0	7			
Approach				1.47	[0.83; 2.75]	0.19
Mini-invasive (Laparoscopy or robot)	766 (33%)	15 (25%)	751 (33%)			
Laparotomy only	1540 (67%)	44 (75%)	1496 (67%)			
Missing data	1	0	1			
Mesh				0.54	[0.32; 0.92]	0.025

Table 2 (continued)

	Overall ($n=2307$)	Recurrence (n = 59)	No recurrence ($n=2248$)	OR	CI	p-value
No	700 (30%)	26 (44%)	674 (30%)			
Yes	1604 (70%)	33 (56%)	1571 (70%)			
Missing data	3	0	3			
SSI				1.84	[0.44; 5.17]	0.35
No	2126 (97%)	52 (95%)	2,074 (97%)			
Yes	68 (3.1%)	3 (5.5%)	65/2139 (3.0%)			
Missing data	113	14	109			

Bold indicates OR: Odds Ratio; CI: Confidence Interval

Results are expressed in n (%) for categorical data and mean (SD) and [min, max] for quantitative data; $p < 0.05$ is significant

ASA American Society of Anesthesiologists physical status score, *BMI* body mass index; *SSI* surgical site infection, *WHO* World Health organization, *SSI* surgical site infection

*Logistic regression model

Multivariate analyse of recurrence risk at 2 years (Table 3).

In the multivariate adjusted analysis, severe obesity was revealed as an independent risk factor with a strong association [adjusted OR (OR_a) = 2.82, 95%CI (1.45; 5.22), $p = 0.003$]. Double localisation (umbilical + epigastric) [$OR_a = 6.5$, 95%CI (1.38; 23), $p = 0.035$], an anticoagulant or antiplatelet treatment [$OR_a = 2.4$, 95%CI (1.07; 4.84), $p = 0.035$] and an Altemeier score ≥ 2 [$OR_a = 2.87$, 95%CI (1.15; 6.45), $p = 0.026$] also appeared to be independently associated with an increased risk of recurrence. The use of mesh during repair was revealed as an independent protective factor [$OR_a = 0.5$, 95%CI (0.28; 0.89), $p = 0.02$]. There was a gradual increase in the adjusted odds ratio associated with an increase in the BMI class according to the WHO classification (Tables 2, 3). There was a significant increase in recurrences at 2 years in the "obesity grade II" and "obesity grade III/IV/V" compared with the reference (normal weight or overweight). However, there was no statistically significant difference between the reference and "obesity grade I".

Discussion

In this large national multicentre registered study, including a homogenous population of mPVHR with a minimum follow-up of 2 years, we identified a strong correlation between severe obesity and the risk of recurrence after mPVHR, with an almost three times higher risk in the population with a BMI ≥ 35 kg/m^2. Above this threshold, there was a gradual increase in the adjusted odds ratio associated with a rise in the BMI class.

From a technical point of view, the Hauters ratio was significantly higher in the nOb group, indicating that the surgery was less optimal and satisfying in patients with obesity, with increased pressure on the mesh. However, this ratio is broadly above the cut-off of 17 originally described in the princeps article (23), which was associated with a 0% recurrence rate. Also, the rate of laparoscopic surgery was higher in the Ob group, but without being a risk factor in the univariate and multivariate analyses. A meta-analysis published in 2017 by Hajibandeh et al. [24] regarding the outcomes of laparoscopic and open repair of umbilical and paraumbilical hernias suggested that laparoscopic repair may be associated with a lower risk of wound infection, wound dehiscence and recurrence. Unfortunately, only a limited number of RCTs were available and they showed no difference in recurrence rates. An article published in 2020 by Fafaj et al. [25] comparing laparoscopic vs. open repair of primary hernias in patients with obesity, showed no difference between the recurrence rates of these two methods. However, long-term data were lacking, in contrast to our study.

Considering the fact that obesity increases the risk for impaired wound healing, local infection, and increases the risk of recurrence (11), it is currently recommended to not perform an elective mPVHR for patients with a BMI ≥ 50 kg/m^2 [17, 21], and to propose a tailored management of BMI between 35 and 50 kg/m^2. All those studies allow us to hypothesise that preoperative weight loss before HS is the best way to minimise the risk of recurrence, even if no consensus is available about the minimum or optimal BMI. For this purpose, every surgeon must suggest that patients lose weight, and if necessary initiate a bariatric process and set a BMI goal, usually a BMI < 35 in common practice. To help patients achieve this goal, several strategies have been evaluated.

Based on actual recommendations in preoperative optimization, the weight loss must be associated with good

Table 3 Multivariate analysis* for the risk of recurrence

	Overall ($n=2307$)	Recurrence ($n=59$)	No recurrence ($n=2248$)	OR	CI	p-value
Obesity status				**2.82**	[1.45; 5.22]	0.003
Severe obesity	267 (12%)	16 (27%)	251 (11%)			
Non-severe obesity	2040 (88%)	43 (73%)	1997 (89%)			
WHO BMI classification						0.009
Normal weight or overweight	1580/2307 (68%)	29/59 (49%)	1551/2248 (69%)	–	–	
Obesity class 1	460/2307 (20%)	14/59 (24%)	446/2248 (20%)	1.76	0.88, 3.37	
Obesity class 2	178/2307 (7.7%)	10/59 (17%)	168/2248 (7.5%)	3.12	1.33, 6.67	
Obesity classes 3/4/5	89/2307 (3.9%)	6/59 (10%)	83/2248 (3.7%)	3.72	1.31, 9.13	
Personal history of hernia						
No	1963 (85%)	44 (75%)	1919 (86%)			
Yes	336 (15%)	15 (25%)	321 (14%)			
Tobacco use						
Non-active smoker	1756 (77%)	42 (72%)	1714 (77%)			
Active smoker	523 (23%)	16 (28%)	507 (23%)			
Missing data	8	0	8			
Ongoing anticoagulant or anti-platelet treatment				2.4	[1.07; 4.84]	0.035
No	2113 (92%)	2063 (92%)	50 (85%)			
Yes	181 (7.9%)	172 (7.7%)	9 (15%)			
Missing data	13	0	13			
ASA score				/	/	/
ASA < 3	1982 (86%)	44 (76%)	1938 (87%)			
ASA ≥ 3	314 (14%)	14 (24%)	300 (13%)			
Missing data	11	1	10			
Localisation of ventral hernia						0.035
Epigastric/white line	483 (21%)	12 (21%)	471 (21%)			
Periumbilical	1770 (78%)	43 (74%)	1727 (78%)	0.82	[0.44; 1.66]	
White line + umbilical	25 (1.1%)	3 (5.2%)	22 (1.0%)	6.5	[1.38; 23]	
Missing data	29	1	28			
Defect diameter				/	/	/
Defect < 4 cm	2063 (89%)	48 (81%)	2015 (90%)			
Defect ≥ 4 cm	244 (11%)	11 (19%)	233 (10%)			
Emergency surgery				/	/	/
No	2232 (97%)	54 (92%)	2178 (97%)			
Yes	67 (2.9%)	5 (8.5%)	62 (2.8%)			
Missing data	8	0	8			
Altemeier score				2.87	[1.15; 6.45]	0.026
Altemeier 1	2216 (> 99.9%)	51 (86%)	2165 (97%)			
Altemeier ≥ 2	84 (< 0.1%)	8 (14%)	76 (3.4%)			
Missing data	7	0	7			
Approach				/	/	/
Mini-invasive (Laparoscopy or robot)	766 (33%)	15 (25%)	751 (33%)			
Laparotomy only	1540 (67%)	44 (75%)	1496 (67%)			
Missing data	1	0	1			
Mesh				0.5	[0.28; 0.89]	0.02
No	700 (30%)	26 (44%)	674 (30%)			
Yes	1604 (70%)	33 (56%)	1571 (70%)			
Missing data	3	0	3			
SSI				/	/	/
No	2126 (97%)	52 (95%)	2074 (97%)			
Yes	68 (3.1%)	3 (5.5%)	65 (3%)			
Missing data	113	14	109			

Bold indicates OR: Odds Ratio; CI: Confidence Interval

Results are expressed in n (%) for categorical data and mean (SD) for quantitative data; $p < 0.05$ is significant

Table 3 (continued)

ASA American Society of Anaesthesiologists physical status score, *BMI* body mass index, *SSI* surgical site infection, *WHO* World Health organization

*Logistic regression model

glycaemic balance (HbA1c < 8%), complete smoking cessation and respiratory and abdominal muscular training physiotherapy [26]. In everyday practice, the objectives usually set are a weight loss of 7% with medical treatments or a BMI < 35 and/or a weight "in double digits". Urging patients to lose weight by the surgeon is ineffective in achieving preoperative weight loss. A study showed that this strategy was associated with more than 80% failure (60% had a stable weight, 20% lost more than one point of BMI and 20% gained weight before surgery) [27]. Nutritional prehabilitation before HS had been studied in a randomised study on 118 patients, compared to standard counselling. It allowed an increase in the access rate to parietal surgery (82% vs. 57%), but only 27% of the nutrition group achieved their weight loss objective of more than 7%. During this phase of weight loss, 7% of the patients left the trial and 7% of the nutritional group underwent emergency surgery for a small bowel obstruction [28]. At 2 years, the study was negative on the primary outcome, which was the absence of hernia and complications at the end of the follow-up period (73% in the nutritional group vs. 66% in the standard group, $p = 0.42$) [29]. Medical treatments such as GLP-1 analogues (weekly semaglutide) seem to be interesting to achieve weight loss in patients with obesity and comorbidities [30] but have not been validated in this specific population. Non-surgical invasive methods to optimise weight loss, such as endoscopic gastric plication or gastric embolisation, have not yet been proved efficient [31–33], moreover in a population undergoing mPVHR.

Finally, only initial bariatric surgery (BS) is known to be useful to achieve significant weight loss and help reduce recurrence after HS, compared to HS in patients with obesity, without an increase in the morbidity of HS [34]. In this case control study, 41 patients underwent BS previously to HS. They were matched at a 2:1 ratio to 82 patients with obesity according to defect size (< 7 or ≥ 7 cm) and obesity grade (< 40 or ≥ 40 kg/m^2). Postoperative morbidity was identical, but hospital stay was shorter in the BS group (6.2 ± 2.6 vs. 10.7 ± 9.3 days, $p = 0.002$). After a follow-up of 4.6 ± 4.1 years, recurrence rate was lower in the BS group (6.7% vs. 24%; $p = 0.048$). One French randomised study is ongoing (NCT05488288), evaluating the recurrence rate between simultaneous BS and mPVHR and delay mPVHR after BS. A preliminary study on the prospective national hospital discharge [35] has shown that about one-quarter of bariatric patients undergoing mPVHR before BS will present with a recurrence. It seems that a concomitant repair during the BS is the best option because it had the lowest recurrence rate and least mesh infection. Nevertheless, in practice, patients with obesity requesting HS are often too old or hostile to a weight loss process. Moreover, with invasive techniques, it is necessary to further investigate the medical and endoscopic methods to optimise weight loss before HS.

It should not be ignored that this period of weight loss can be quite long, and that during this time, it is possible to observe an increase in the size of the defect and the hernia sac [36]. This could adversely affect subsequent repair possibilities.

Yet, several limits in the construction of this study can be highlighted. First, our data were from expert surgeons, which could result in a decrease in the possible complications or surgical errors. Thus, they may not reflect the current general practice of French surgeons and overestimate the quality of the repair. This element could underestimate the number of recurrences. Also, our primary endpoint number is low, limiting the quantity of analysable variables. These two elements can explain why multiple known risk factors (such as surgical site infection or the defect size) were not significant in our univariate or multivariate analyses. There is an obvious risk for systematic selection bias with constitutional differences between the two study groups formed. Unfortunately, the statistical methods applied here were not able to compensate for this selection bias. Further work will be required to investigate this issue.

Conclusion

From our nationwide database, we have shown that obesity with BMI over 35 kg/m^2 increases by almost three times the recurrence risk after a ventral hernia repair compared to patients with a BMI under 35. This should encourage every surgeon to initiate weight loss as staged procedure to definitive ventral hernia repair if the patient's BMI is over 35 kg/m^2. Synchronous mPVHR and bariatric surgery is the subject of current studies.

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Author contributions Study concept and design: DM, J-FG. Acquisition, analysis, or interpretation of data: JT, A-MF, CT, J-FG, GP, DM. Drafting of the manuscript: JT, DM, J-FG. Critical revision of the manuscript for important intellectual content: JT, A-MF, CT, J-FG, GP, DM. Statistical analysis: A-MF, CT. Administrative, technical, or material support: J-FG. Study supervision: GP, J-FG, DM.

Declarations

Competing interests None reported.

Ethical approval The registry complies with the requirements of the General Data Protection Regulation (GDRP), the French "Méthodologies de reference de la Commission Nationale Informatique et Libertés" (MR001, MR003) and the different specific French ethics committees. STROBE (Strengthening the Reporting of Observational studies in Epidemiology) and the European Registry of Abdominal Wall Hernias (EuraHS) recommendations were used for the conduct and reporting of our study.

Patient consent Obtained for every case.

Human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent All participants provided informed consent prior to their participation.

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