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High incidence of trocar site hernia after laparoscopic or robotic Roux-en-Y gastric bypass

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Abstract
Background
Trocar Site Hernia (TSH) seems to represent a rare surgical complication, but available data are based only on symptomatic patients and clinically diagnosed cases; moreover, no data are available concerning TSH incidence after robotic-assisted procedures. Aims of the study were to asses TSH incidence in obese patients who underwent Roux-en-Y gastric bypass (RYGB) and to compare it between robotic-assisted and standard laparoscopy.
Methods
Patients who underwent RYGB between November 2007 and June 2012 underwent a clinical examination and an ultrasonography study of the abdominal wall by a single operator.
Results
150 patients entered the study, 102 in the laparoscopic and 48 in the robotic group. Mean pre-operative weight and BMI were 129.3 kg and 47.4 kg/m^2, respectively; both were higher in the laparoscopic group (134.7 vs 117.6 kg, $p < 0.001$; 49.2 vs 43.8 kg/m^2, $p < 0.001$), while pre-operative comorbidities were not significantly different between groups. Operative time was lower in the laparoscopic group (182.7 vs 284.0 min, $p < 0.001$), while post-operative complications were not different between groups. The overall incidence of TSH was 39.3 % (59/150); incidence was 35.3 % (36/102) in the laparoscopic and 47.9 % (23/48) in the robotic group ($p = 0.195$). There were no significant differences between patients with and without TSH, except for higher post-operative wound complication in patients without TSH (22 vs 6.8 %, $p = 0.024$; OR 0.26).
Conclusions
TSH revealed a high incidence in a bariatric surgery population, suggesting that it represents a strongly underestimated complication; furthermore, the present study showed a trend towards a higher incidence of TSH in patients who underwent robotic-assisted bariatric surgery.
Keywords
Trocarsite hernia Port-site hernia Laparoscopy complications Robotic-assisted surgery Robot complications
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Trocar Site Hernia (TSH) has been defined as an incisional hernia occurring after laparoscopic procedures at the trocar incision site [*1*, *2*]. The clinical importance of TSH is due to the fact that it can lead to significant morbidity, often requiring surgical intervention [*2*–*6*], frequently as emergency [*7*]. TSH seems to represent a rare surgical complication: a recent systematic review reported a pooled prevalence of 0.5 % with incidence ranging between 0 and 5.2 % [*8*], but it is important to underline that, to date, available data are based only on symptomatic patients [*3*, *8*]. Moreover, most available data are based on clinically diagnosed TSH, which could be ineffective, especially in obese subjects. Furthermore, most of the available literature is based on short-term follow-up [*4*, *9*], while long-term studies are lacking. When routinely assessed, both in symptomatic and asymptomatic cases, with a more efficient diagnostic tool such as ultrasonographic (US) examination of the abdominal wall, with long-term follow-up, the overall incidence might be higher. Moreover, although obesity has been reported as a risk factor for TSH [*2*, *3*, *10–17*], to date, the real incidence of TSH in bariatric surgery is not completely understood, with reported frequencies between 0.2 % [*18–20*] and 1.2 % [*21*] for gastric bypass procedures.

In the last two decades, laparoscopic surgery has seen significant developments with the introduction of the da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA, USA) [*22*]. In bariatric surgery, robotic-assistance has the potential to overcome the technical limitations that standard laparoscopy encounters in the obese subject, mainly the limited freedom of motion for the instruments related to the thick abdominal wall, with consequent loss of dexterity and greater musculo-skeletal discomfort for the surgeon [*23*]. The da Vinci System greatly improves the surgeon's ergonomics by reducing muscular fatigue caused by the torque effect applied to trocars and instruments [*24*]. Nevertheless, the strong mechanical power of the robotic arms could potentially lead to higher lateral stretch effects on muscular and fascial abdominal wall layers, thus potentially increasing TSH incidence. To date, no data are available in the published literature concerning TSH incidence after robotic-assisted abdominal procedures.

The aim of the study was to compare TSH incidence in robotic-assisted and standard laparoscopic surgery, by comparing obese patients undergoing the same bariatric procedure, both for symptomatic and asymptomatic cases.

Materials and methods

Study population

Patients who had undergone laparoscopic or robotic-assisted Roux-en-Y gastric bypass (RYGB) at the Department of Surgical Sciences of the University of Torino between November 2007 and June 2012 were asked to participate in the study. Patients were informed that the study protocol would involve a clinical visit and a non-invasive, painless procedure, and were thus unaware of the aim of the study, in order to minimise any 'volunteer bias' related to symptomatic hernias.

Inclusion criteria were laparoscopic or robot-assisted RYGB, primary RYGB (thus excluding all patients converted from a previous bariatric procedure), RYGB with no subsequent abdominal surgical procedures except for incisional hernia repairs, minimum follow-up of 12 months.

Surgical technique

All the surgical procedures were performed by two experienced bariatric surgeons (M.T., M.M.). The RYGB was performed using a laparoscopic approach; in all cases, pneumoperitoneum was established with a Veress needle inserted 2 cm below the left costal margin. In all patients, 6 trocars were used: two reusable metal pyramidal 5-mm trocars, one reusable metal pyramidal 10-mm trocar and 3 disposable metal bladed 12-mm Ethicon trocars (Ethicon Endosurgery, Cincinnati, OH, USA); the trocar port sites are shown in Fig. 1. In all robotic cases, the 3-arm da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA, USA) was used. The robotic-assisted procedures were performed by means of a 'double-cannulation technique', with the da Vinci ports placed inside conventional laparoscopic Ethicon ports [*25*]. In all cases, at the end of surgical procedure, the closure of 12-mm ports was performed by means of trans-parietal resorbable stitches by using a Reverdin needle. The fascial defects of 5- and 10-mm ports were not closed.

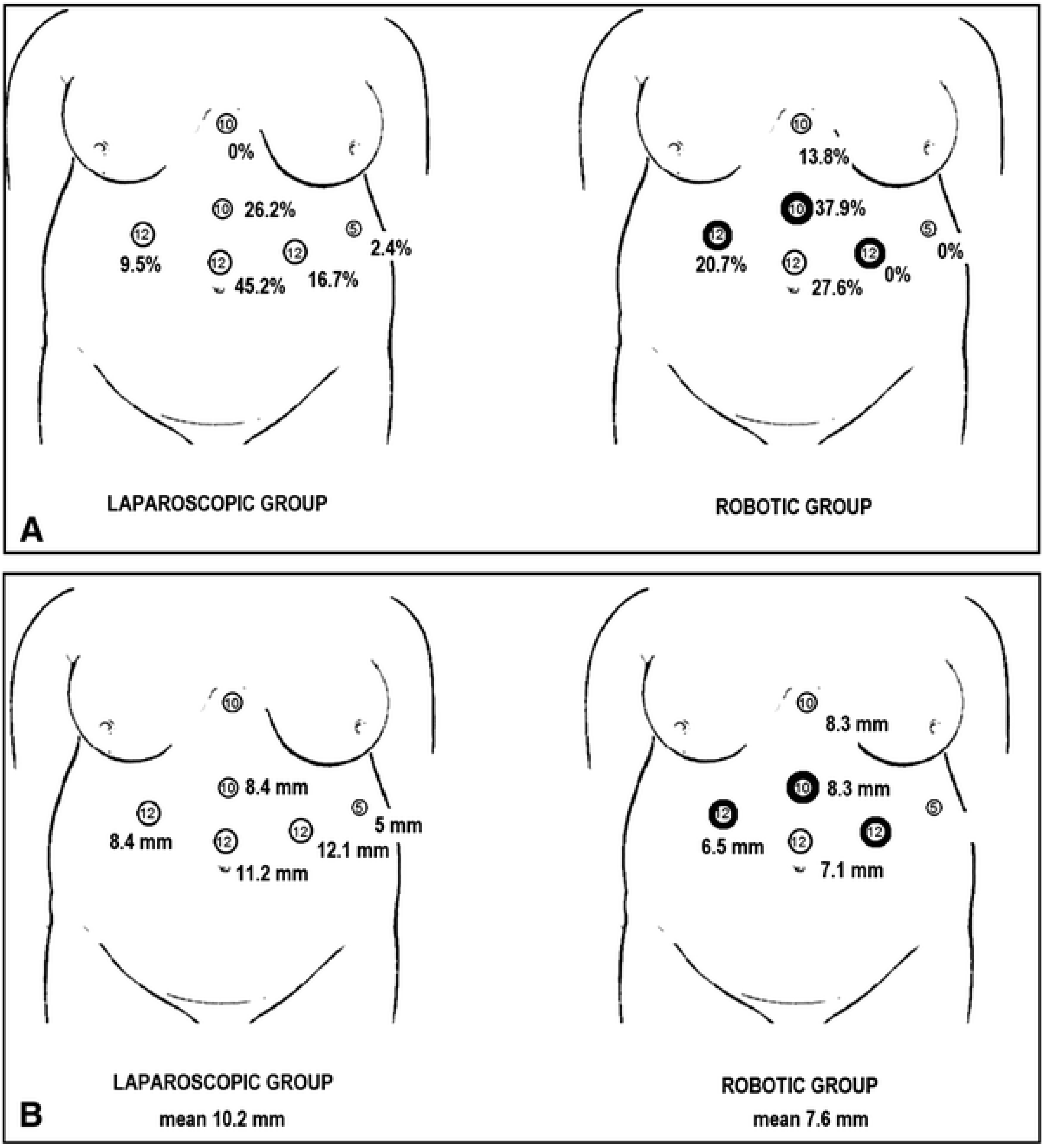

Fig. 1
TSH site distribution (A) and mean size (B). The number indicates the trocar's diameter. Bold circles indicate the port sites used for robotic arms

Follow-up assessment

All patients enrolled in the study underwent a clinical examination aiming to assess the abdominal wall for hernias and other clinically evident pathologies. The clinical examinations were performed by a surgeon who did not participate in the surgery. Furthermore, patients underwent an ultrasonography (US) study of the abdominal wall using Mylab™ 50 (Esaote, Genoa, Italy) with a 7.5 MHz linear probe. The US diagnosis of TSH was defined as any discontinuation of the fascial layer. US examination was performed by a single operator (M.Z.), who was unaware of the patients' group.
For each patient enrolled in the study, the hospital and follow-up records were reviewed by a third operator not involved in the study, to collect the following data: gender; pre-operative age in years;

weight in kilograms and height in metres; BMI (calculated as weight in kilograms divided by height in metres squared); the pre-operative presence and treatment of the following obesity-related comorbidities: arterial hypertension (defined as PAD >90 mmHg and/or PAS >140 mmHg and/or use of any anti-hypertensive medication), type II diabetes (defined as blood glycaemia >126 mg/dl and/or HbA1c >7 % and/or use of oral hypoglycaemic agents and/or insulin), sleep apnoea syndrome (defined as the use of domiciliary CPAP), tobacco use (defined as positive when actively smoking or use within the previous 10 years); operative time in minutes; intra-operative complications; post-operative length of stay in days; the following early complications: wound complications (defined as the presence of wound infection and/or dehiscence in the first 30 post-operative days), post-operative anaemia (defined as the presence of anaemia <10 g/dl and/or requiring blood transfusion in the first 30 post-operative days), respiratory complications (defined as the presence of respiratory infections requiring antibiotics and/or respiratory failure requiring ICU admission in the first 30 post-operative days); late complications (hernia surgical repair and other surgical procedures); follow-up weight-loss results (assessed by residual BMI and % of pre-operative BMI loss).

Statistical analysis

The main outcome was the post-operative occurrence of TSH after RYGB (dependent variable); its potential association to different risk factors (independent variables) was investigated by different univariate and multivariate binary logistic regression models. The selected predictors were gender (male vs female); age at surgery (<50 vs ≥50 years); pre-operative BMI (classified in <50 and ≥50 kg/m^2, defining the latter as the cutoff for 'super-obesity'); type II diabetes (any vs none); arterial hypertension (any vs none); sleep apnoea syndrome (any vs none); tobacco use (yes, when ≥3 cigarette/day vs no); operative time (<180 vs ≥180 min); post-operative wound complications (present vs absent); post-operative anaemia (present vs absent); post-operative respiratory complications (present vs absent). The patients' characteristics were analysed by the Fisher exact test for categorical variables and by the Mann–Whitney test for continuous ones. All reported p values were obtained by the 2-sided exact method, at the conventional 5 % significance level. Data were analysed as of July 2013 with SPSS 21.0.0 and R 3.0.1. No ethical approval was required for this study in accordance with Italian law.

Results

Between November 2007 and June 2012, 700 bariatric procedures were performed at the University of Torino. Among these, 335 were RYGB. In 48 cases, the RYGB was a revisional procedure, and in 4 cases, the operation was carried out by an open approach. Among the 283 patients eligible for the present study, 150 accepted to be enrolled (53 %).

Thus, globally, 150 patients entered the study, 38 males (25.3 %) and 112 females (74.7 %). Mean pre-operative age was 44.2 years (range, 22.7–65.3); at surgery, 105 patients were aged up to 50 and 45 were ≥50 years (30 %). Mean pre-operative weight and BMI were 129.3 kg (range, 85–205) and 47.4 kg/m^2 (range, 34.2–64), respectively. Pre-operative BMI was up to 50 kg/m^2 in 104 cases and ≥50 kg/m^2 in 46 patients (30.7 %). At surgery, 43 patients were diabetic (28.7 %), 66 had arterial hypertension (44 %), 55 had sleep apnoea syndrome (36.7 %), and 43 were smokers (28.7 %). Mean operative time was 215.1 min (range, 90–405); operative time was less than 180 min in 60 cases and ≥180 min in 90 (60 %). Median length of hospital stay was 5 days (range, 3–37). Post-operative wound infection and/or dehiscence incidence rate was 16 % (24/150), while incidence rates for anaemia and respiratory complications were 7.3 % (11/150) and 12 % (18/150), respectively.

Among the 150 patients, 102 were in the laparoscopic group and 48 in the robotic one. Gender distribution and mean pre-operative age (43.6 vs 45.3 years) were not significantly different between groups. Mean pre-operative weight and BMI were significantly higher in the laparoscopic group (134.7 vs 117.6 kg, $p < 0.001$ and 49.2 vs 43.8 kg/m^2, $p < 0.001$, respectively). The incidence of main pre-operative comorbidities (diabetes, hypertension, sleep apnoea and tobacco use) were not significantly different between groups. The mean operative time was significantly lower in the laparoscopic compared to the robotic group: 182.7 vs 284.0 min ($p < 0.001$). Mean hospital length of stay and post-operative incidence of wound complications, anaemia and respiratory complications were not significantly different between groups. Demographic characteristics of the study population are summarised in Table 1.

Table 1

TSH results, comparison between laparoscopic and robotic patients

Variable	**All**	**Laparoscopic**	**Robotic**	**p value**
N	150	102	48	
M/F	38/112	27/75	11/37	ns
Age, years	44.2 ± 10.1	43.6 ± 10.7	45.3 ± 8.5	ns
Weight, kg	129.3 ± 20.6	134.7 ± 20.4	117.6 ± 15.5	<0.001
BMI, kg/m^2	47.4 ± 6.1	49.2 ± 6.1	43.8 ± 4.5	<0.001
Smokers, %	43 (28.7 %)	28 (27.5 %)	15 (31.3 %)	ns
DM, %	43 (28.7 %)	27 (26.5 %)	16 (33.3 %)	ns
Sleep apnoea, %	55 (36.7 %)	39 (38.2 %)	16 (33.3 %)	ns
HT, %	66 (44 %)	41 (40.2 %)	25 (52.1 %)	ns
Operative time, min	215.1 ± 62.8	182.7 ± 40.3	284.0 ± 43.2	<0.001
LOS, days	5.6 ± 3.4	5.4 ± 2.0	6.0 ± 5.2	ns
Wound complications	24 (16 %)	16 (15.7 %)	8 (16.7 %)	ns
Anaemia	11 (7.3 %)	7 (6.9 %)	4 (8.3 %)	ns
Respiratory complications	18 (12 %)	14 (13.7 %)	4 (8.3 %)	ns
Follow-up, months	37.5 (median 39)	40.5 ± 12.6 (median 41)	31.1 ± 17.9 (median 29)	<0.001
TSH, surgical repair	2	2	0	
TSH, US diagnosis	57	34	23	
TSH, clinical diagnosis	4	3	1	
TSH, overall	59 (39.3 %)	36 (35.3 %)	23 (47.9 %)	ns
TSH number				
0	93	68	25	ns
1	43	26	17	ns
2	14	8	6	ns
TSH site				
Sub-xiphoid	4	0	4 (13.8 %)	ns (p = 0.051)
Epigastric	22	11 (26.2 %)	11 (37.9 %)	ns

Variable	All	Laparoscopic	Robotic	p value
Sovra-umbilical	27	19 (45.2 %)	8 (27.6 %)	ns
Right flank	10	4 (9.5 %)	6 (20.7 %)	ns
Left flank	7	7 (16.7 %)	0	ns (p = 0.056)
Left subcostal margin	1	1 (2.4 %)	0	ns
TSH dimension, mm				
Overall	9.1	10.2 ± 6.7	7.6 ± 4.2	ns
Sub-xiphoid	8.3	–	8.3 ± 3.8	ns
Epigastric	8.3	8.4 ± 5.6	8.3 ± 3.6	ns
Sovra-umbilical	10	11.2 ± 6.7	7.1 ± 5.4	ns
Right flank	7.3	8.4 ± 4.0	6.5 ± 3.5	ns
Left flank	12.1	12.1 ± 8.4	–	ns
Left subcostal margin	5.0	5.0	–	ns

Data are expressed as mean ± DS or number and percentages. BMI body mass index; DM diabetes mellitus; HT hypertension; LOS length of hospital stay; TSH trocar site hernia; US ultrasonography; ns not significant

Follow-up evaluation was performed at a median of 39 months (range, 12–62.4). Mean follow-up was 40.5 months in the laparoscopic group (median value 41 months) and 31.1 months (median value 29 months) in the robotic one ($p < 0.001$). Weight loss results were not different between laparoscopic and robotic cases.

TSH results are shown in Table 1. Globally, two patients underwent surgical repair of symptomatic TSH during follow-up, while in 57 cases, an asymptomatic TSH was US-diagnosed at the follow-up evaluation, only four of which were clinically evident at the abdominal wall examination. Thus, the overall incidence of TSH was 39.3 % (59/150). In the laparoscopic group, during follow-up two patients underwent surgical repair of a symptomatic TSH (2.0 %), while no patients in the robotic group underwent any TSH repair. In the laparoscopic group, a US abdominal wall evaluation diagnosed the presence of one or more TSHs in 34 cases, with only three of them evident at the clinical examination. In the robotic group, a US evaluation reported TSH in 23 patients, in only one of whom the TSH was clinically evident. Thus, the overall incidence of TSH was 35.3 % (36/102) in the laparoscopic group and 47.9 % (23/48) in the robotic group ($p = 0.195$). Among US-diagnosed TSHs, in the laparoscopic group, 26 out of 34 patients had only one TSH (76.5 %) and eight had two TSHs (23.5 %), while in the robotic group, 17 had one TSH (73.9 %) and six had two (26.1 %), with no differences between groups (Table 1).

TSH site distribution is shown in Fig. 1; the incidence was higher in greater ports: 1.4 % in the 5-mm port, 36.6 % in the 10-mm ports and 62 % in the 12-mm ports. Although not statistically different, the robotic group showed higher TSH incidence at the epigastric (37.9 vs 26.2 %) and right flank (20.7 vs 9.5 %) ports, i.e. two of the three port sites used for robotic arms; at the left flank site, the third port used for the robotic arm, there were no TSHs in the robotic group but seven in the laparoscopic one. The mean dimension of TSH was 9.1 mm (range, 2.7–31) and was different for different sites, as follows: 8.3 mm for subxiphoid, 8.3 mm for epigastrium, 10 mm for sovra-umbilical, 7.3 mm for right flank, 12.1 mm for left flank and 5 mm for left subcostal margin. TSH mean size was 10.2 mm in the laparoscopic group vs 7.6 mm in the robotic one ($p = 0.069$); mean size for the different site TSHs is reported in Fig. 1.

A comparison between patients with and without TSH is shown in Table 2. There were no significant differences in pre-operative and peri-operative variables. With regard to post-operative complications, there was a statistical difference in wound complication incidence rate, significantly higher in patients without TSH (22 vs 6.8 %, p = 0.024). Both in the univariate and multivariate logistic models, the only significant predictor for TSH was the wound complication incidence rate (OR 0.26, 95 % CI 0.08–0.80, p = 0.019); thus the probability of TSH occurrence appeared about four-fold lesser, in patients suffering for this complication (Table 3).

Table 2

TSH risk factors, comparison between patients with and patients without TSH

Variable	**TSH**	**No TSH**	**p value**
N	59	91	
M/F	14/45	24/67	ns
Age, years	43.5 ± 9.7	44.6 ± 10.3	ns
Weight, kg	128 ± 21.1	130.1 ± 20.2	ns
BMI, kg/m^2	47.1 ± 6.1	47.6 ± 6.1	ns
DM, %	17 (28.8 %)	26 (28.6 %)	ns
HT, %	24 (40.7 %)	42 (46.2 %)	ns
Sleep apnoea, %	20 (33.9 %)	35 (38.5 %)	ns
Smokers, %	18 (30.5 %)	25 (27.5 %)	ns
Operative time, min	225.1 ± 61.9	208.6 ± 62.5	ns
LOS, days	6.3 ± 5.0	5.2 ± 1.5	ns
Wound complications	4 (6.8 %)	20 (22 %)	0.024
Anaemia	6 (10.2 %)	5 (5.5 %)	ns
Respiratory complications	6 (10.2 %)	11 (12.1 %)	ns
Follow-up, months	37.8 ± 16.2	37.3 ± 14.4	ns
6-month % BMI loss	26.8 ± 6.4	26.1 ± 7.4	ns
1-year % BMI loss	32.0 ± 8.9	33.5 ± 7.4	ns
2-year % BMI loss	34.5 ± 10.2	35.0 ± 9.4	ns
3-year % BMI loss	32.6 ± 10.6	33.4 ± 9.0	ns

Data are expressed as mean ± DS or number and percentages. BMI body mass index; DM diabetes mellitus; HT hypertension; LOS length of hospital stay; ns not significant

Table 3

Univariate logistic model for TSH predictor

Variable	**OR**	**95 % CI**	**p value**
Gender	0.87	0.41–1.86	0.716
Age ≥50 years	0.80	0.39–1.64	0.536
BMI ≥50 kg/m^2	1.13	0.56–2.28	0.742
Tobacco smoke	1.16	0.56–2.38	0.688
Sleep apnoea	0.82	0.41–1.63	0.571
DM	1.01	0.49–2.09	0.974
HT	0.80	0.41–1.55	0.510
Operative time ≥180 min	1.36	0.69–2.67	0.376
Wound complications	0.26*	0.08–0.80	0.019
Anaemia	1.95	0.57–6.70	0.290

Variable	OR	95 % CI	p value
Respiratory complications	0.75	0.26–2.11	0.580

BMI body mass index; DM diabetes mellitus; HT hypertension
* Statistically significant

Discussion

The term ‘Trocar Site Hernia’ (TSH) refers to an incisional hernia occurring after laparoscopic procedures at the trocar incision site [*1*, *2*]. This complication, first described in gynaecological surgery by Fear [*26*], seems to represent a rare event: the reported incidence rates range between 0.02 and 5.4 % [*2*, *3*, *10–12*, *27*], and the most recent available review [*8*] reported a pooled prevalence of 0.5 %. In bariatric surgery, reported frequencies are between 0.2 % [*18–20*] and 1.2 % [*21*] for RYGB, and 0.6 % [*28–30*] and 1 % [*31*] for sleeve gastrectomy and gastric band. Nevertheless, the TSH reported incidence might be underestimated, since most papers refer only to symptomatic cases [*3*, *8*], or with short follow-up [*4*, *9*]. Since different bariatric procedures may involve different levels of risk of TSH, with higher risk in procedures involving device insertion (gastric band) or specimen extraction (sleeve gastrectomy) compared to RYGB, we analysed only patients who underwent RYGB to avoid any procedure-related confounding factors. Furthermore, the clinical evaluation of the abdominal wall could be ineffective in diagnosing TSH, specifically in the obese subject due to the thick abdominal wall, even once weight loss has occurred. In our results, by analysing all patients who underwent the same bariatric procedure, both symptomatic and asymptomatic, with a very long follow-up (median value 39 months), we noted an overall incidence of 39 %, significantly higher than those generally reported in previous papers.
The clinical importance of TSH is due to the fact that it can lead to significant morbidity, often requiring surgical intervention [*5*]; besides pain, it can lead to bowel obstruction or strangulation and perforation [*2–6*]. In a 12-year study [*7*] of more than 7,000 patients following a laparoscopic procedure, the overall TSH incidence was 1.3 %. Interestingly, 16 % of TSH repairs were performed as an emergency procedure, thus suggesting that TSH involves a non-negligible risk of emergency presentation. Several risk factors for TSH have been described. They can be related to the patient including, for example, older age [*3*, *4*, *11*]; pre-existing umbilical or para-umbilical hernia; medical comorbidities [*8*] including diabetes mellitus [*3*, *32*, *33*], chronic obstructive pulmonary disease, renal failure, acquired immune deficiency syndrome [*9*]; pre-operative obesity [*2*, *3*, *8*, *10–12*, *17*]. Pre-operative obesity represents a well-described risk factor for incisional hernias after open abdominal surgery [*34*], suggesting a main patho-physiological link with the increased intra-abdominal pressure in the obese subject [*35*]. In laparoscopy, obesity has been described as a risk factor also for TSH by many authors [*2*, *3*, *10–16*], and Samia et al. [*17*] reported that BMI of patients who developed TSH was significantly higher than that of patients with no TSH (31 vs 28 kg/m^2). Nevertheless, while the study by Uslu et al. [*3*] reached statistical significance at multivariate analysis for BMI $\geq$ 28 kg/m^2, others studies showed no statistically significant differences [*2*, *11*, *30*]. In our experience, gender, age, pre-operative BMI and comorbidities were not significantly related to TSH development (Tables 2, 3). With regard to the potential effects of pre-operative obesity, pre-operative BMI was no different for patients who developed TSH from those who did not (47.1 vs 47.6 kg/m^2), as was the pre-operative percentage of super-obese patients (32.2 vs 29.7 %). In the robotic group, pre-operative weight and BMI were significantly lower than for laparoscopic cases, since in our Hospital, robotic surgery is performed in a multi-disciplinary robotic operating theatre, rather than in a specially equipped bariatric room, as for standard laparoscopic cases. Even if pre-operative BMI was lower in robotic cases, these experienced higher TSH incidence.

On the other hand, risk factors for TSH can be related to technical and peri-operative factors, such as trocar diameter ≥10-mm [2, *9*, *34*, *36–38*], as confirmed in our results showing higher TSH incidence in greater ports; cutting-type trocars [*20*, *21*, *39–41*]; mid-line trocar site [2, *10–12*, *14*, *17*, *27*, *42–44*], due to the lack of muscular support at the linea alba [*5*]: our experience seems to support these data, with 53 TSHs out of 71 at the midline sites (74.6 %) versus 18 at the off-midline sites (25.4 %); non-closure of the fascial defect [2, *3*, *8*, *12*, *21*, *37*]; post-operative wound complications [*1*, *2*, *12*, *34*, *44*]. Although non-closure of the fascial defect is supposed to be a risk factor for TSH [2, *3*, *11*, *37*] and the fascial closure of ports ≥10 mm has been suggested to prevent TSH formation [2, *8*, *21*], TSH has been reported also when fascial closure was performed [*11*, *36*, *37*, *45*], thus demonstrating that it is not effectively preventative. In our experience, only the 12-mm ports were closed; nevertheless, these showed the higher incidence of TSH compared with the 5- and 10-mm ports, where no fascial closure was performed. Operative time might represent a further risk factor for TSH: in the multivariate analysis by Uslu et al. [*3*], an increased surgical time was associated with increased TSH incidence, with a cut-off point of 80 min. Using a cut-off of 180 min, we observed no differences in TSH incidence; furthermore, mean operative times in patients who developed TSH were very similar to those of patients who did not (225 vs 209 min). Robotic-assisted cases involved longer operative times compared with standard laparoscopy, as previously reported [*25*]. Nevertheless, the higher incidence of TSH in robotic cases does not seem to be related to a longer operative time since the latter did not prove to be related to TSH onset (Table 3). With regard to post-operative complications, we analysed the potential effects of poor oxygen delivery to tissue as a result of anaemia and respiratory complications, and the potential effects of wound complications, which have been implicated in the pathogenesis of TSH [*1*, *2*, *4*, *11*, *34*, *46*]. In open bariatric surgery, Christou et al. [*47*] reported an incisional hernia rate of 14 % in patients without wound infection, compared to 38 % in those with wound infection. In our experience, we noted a surprisingly higher incidence of wound complications in patients who did not develop TSH compared with those who did (22 vs 6.8 %) and at the multivariate analysis wound complications proved significant in protective against TSH (OR 0.26). A possible explanation for this unexpected result could be the fact that patients with wound complications underwent a strict follow-up with frequent medication which led to a complete healing of the wound, while in obese patients, due to the thickness of the abdominal wall, it is possible that some subcutaneous infections were clinically silent leading to late TSH onset.

Another unexpected result of the present study was that TSH incidence was higher in robotic-assisted rather than laparoscopic RYGB. The greater lateral stretch created by the robotic arms might be the main cause of higher TSH incidence: unlike traditional laparoscopy, the robotic arms might lead to a greater torque effect on the abdominal wall, ultimately leading to a greater fascial defect [*48*]. The effects of higher stress on fascial planes have been suggested in a previous observation that, in laparoscopic cholecystectomy, the extraction of large diameter gallstones has been recognised as a risk factor for TSH [*12*]. In the published literature, only scarce data can be found referring to TSH incidence in robotic case series. In urological surgery, the reported incidence is very low, less than 1 % in radical prostatectomies [*49–51*]. Indeed, most of the data on TSH after robotic-assisted abdominal procedures are in the form of isolated case-reports [*48*, *51*, *52*] and no studies specifically aiming at assessing TSH incidence in robotic surgery have been reported; thus, the present study is, to the best of our knowledge, the first to report a comparison between TSH incidence in standard laparoscopy and robotic-assisted bariatric procedures.

The main strengths of the study are the significant number of patients enrolled, the inclusion of patients irrespective of the presence of symptoms, the very long follow-up, the use of US evaluation as diagnostic tool, and the double-blinded protocol, with patients invited to take part without knowing the aim of the follow-up visit, and the data collected by operators who did not participate in surgery; furthermore, the US evaluations were all carried out by the same operator, unaware of the patient's group.

We can conclude that in post-bariatric surgery patients, the clinical evaluation of the abdominal wall is highly inaccurate, with only 4 out of 57 TSHs clinically evident at examination, while the US study, a non-invasive and inexpensive procedure, proved to be an efficient diagnostic tool. Moreover, although clinically silent, TSH revealed a high incidence rate in a bariatric surgery population, thus suggesting that it represents a strongly underestimated post-operative complication, potentially leading to large hernias, abdominal pain and surgical re-operations. Furthermore, the present study showed a trend towards a higher incidence of TSH in patients who underwent bariatric surgery with the da Vinci Robotic System, compared with those operated on using standard laparoscopy. Although not statistically significant, these results might reflect a stronger mechanical effect of the robotic arms on abdominal wall structures and should be further studied by larger, prospective comparative studies.

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