Original articles

3D Laparoscopic TAPP repair for incarcerated and strangulated inguinal hernias: A prospective cohort study

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Received: 27/02/2026; **Accepted:** 22/08/2026; **Published:** 25/08/2026
DOI: 10.34071/jmp.2026.4.962

Abstract

Background: Evidence regarding three-dimensional (3D) laparoscopic transabdominal preperitoneal (TAPP) repair with anatomical mesh for incarcerated and strangulated inguinal hernias remains limited. This study evaluated perioperative and follow-up outcomes of this approach in a selected cohort.

Methods: A prospective single-center longitudinal cohort study included 105 eligible adults with incarcerated or strangulated inguinal hernias who underwent 3D laparoscopic TAPP repair at Hue Central Hospital from June 2022 to June 2025. Patients with peritonitis or bowel necrosis requiring resection were excluded. All enrolled patients completed TAPP. No bowel resection, primary open operation, or conversion to open surgery occurred. Clinical, operative, postoperative, and protocol-defined follow-up outcomes were analyzed. Exploratory subgroup comparisons used the Mann-Whitney U and Fisher's exact tests.

Results: The mean age was 57.1 ± 17.0 years and 96.2% were male. There were 68 incarcerated hernias treated electively and 37 strangulated hernias treated as emergencies. Ten patients underwent bilateral repair after contralateral hernias were identified intraoperatively. Mean operative time was 82.6 ± 29.8 minutes. Hernia contents were preserved in 104/105 patients (99.0%, 95% CI, 94.8% - 99.8%). One patient required partial omentectomy and no bowel resection was performed. Early postoperative complications occurred in 3/105 patients (2.9%, 95% CI, 1.0% - 8.1%). Within 24 hours, 81.9% passed flatus and 65.7% resumed independent ambulation. Mean postoperative stay was 3.5 ± 1.2 days, and 97.1% reported returning to normal activities within 14 days. At the protocol-defined assessment at or after 6 months, all patients completed clinical examination and ultrasonography, while 99 underwent computed tomography. Six patients did not return for scheduled computed tomography. No recurrence, surgical-site infection, or mesh-related infection was identified during this limited follow-up.

Conclusion: In selected patients without peritonitis or bowel necrosis requiring resection, 3D laparoscopic TAPP repair with anatomical mesh was feasible and was associated with favorable perioperative and short-term outcomes during limited follow-up. These findings should not be generalized to contaminated surgical fields, patients requiring bowel resection, or the broader population of acute irreducible groin hernias.

Keywords: *3D laparoscopy; anatomical mesh; incarcerated inguinal hernia; strangulated inguinal hernia; TAPP.*

1. INTRODUCTION

Inguinal hernia is among the most common surgical conditions, with an estimated lifetime risk of approximately 27% in men and 3% in women [1]. Incarceration and strangulation are clinically important complications because an irreducible hernia may progress from preserved perfusion to venous congestion, ischemia, intestinal obstruction, necrosis, and sepsis. Operative management is required, but the urgency and operative strategy depend on organ viability and the presence of contamination.

Transabdominal preperitoneal (TAPP) and totally extraperitoneal repair are the most widely used minimally invasive approaches for inguinal hernia repair. TAPP, first described by Arregui et al. [2], allows direct inspection of the abdominal cavity, reduction of hernia contents, assessment of organ perfusion, and identification of a contralateral hernia. Three-dimensional laparoscopic visualization may improve depth perception and hand-eye coordination during dissection [3, 4].

Although international guidance and clinical studies support selective laparoscopic management of acute groin hernias, the use of TAPP in incarcerated and strangulated cases remains debated because

reduction of the hernia contents, assessment of organ viability, and management of possible bowel ischemia are technically demanding [5-9]. Mesh repair may be acceptable in carefully selected emergency cases with a clean surgical field, but uncertainty remains when bowel resection, enteric spillage, or contamination is present [10-13]. Evidence specifically addressing 3D laparoscopic TAPP combined with pre-shaped anatomical mesh is still limited. This study therefore aimed (1) to describe the clinical and surgical characteristics of patients with incarcerated and strangulated inguinal hernias treated using 3D laparoscopic TAPP and (2) to evaluate perioperative safety, recovery, and follow-up outcomes of this technique at Hue Central Hospital.

2. MATERIALS AND METHODS

2.1. Study population

This prospective single-center longitudinal cohort study included 105 eligible adults who underwent 3D laparoscopic TAPP repair at Hue Central Hospital from June 2022 to June 2025. Eligible patients were aged ≥ 18 years, had an index inguinal hernia diagnosed as incarcerated or strangulated by clinical examination and preoperative ultrasonography, and underwent TAPP repair using 3D laparoscopic visualization and anatomical synthetic mesh. Both primary and recurrent hernias were eligible. Elective or emergency status was recorded according to the actual surgical indication. Patients with incarcerated hernias were clinically stable, had irreducible hernia contents without clinical or Doppler evidence of vascular compromise or peritonitis, and underwent elective inpatient repair after routine preoperative assessment and optimization. The admission-to-surgery interval in this group reflects the planned inpatient pathway rather than observation of suspected strangulation. Patients with strangulated hernias were managed as surgical emergencies.

Exclusion criteria were peritonitis, bowel necrosis requiring resection, contraindications to laparoscopy, American Society of Anesthesiologists (ASA) class IV-V, cirrhosis with ascites, peritoneal dialysis, and previous abdominal surgery causing complex adhesions that precluded safe laparoscopic access. A requirement for bowel resection was a predefined reason to discontinue the TAPP-mesh pathway. This did not occur in the enrolled cohort.

During the study period, enrollment was limited to consecutive patients who met all predefined eligibility criteria and entered the 3D TAPP pathway. A separate screening log of all patients with incarcerated or strangulated inguinal hernias assessed at the hospital was not maintained, so the total number initially assessed and the reasons for non-enrollment could not be reconstructed. All 105 enrolled patients completed laparoscopic TAPP repair with anatomical mesh and were included in the final analysis. No patient in the eligible TAPP cohort underwent primary open surgery, required bowel resection, was converted to open surgery, or entered an alternative operative pathway.

An incarcerated inguinal hernia was defined as an irreducible index hernia without intraoperative evidence of impaired vascular perfusion. A strangulated inguinal hernia was defined by intraoperative vascular compromise, including venous congestion, ischemic discoloration, absent or reduced peristalsis, or impaired mesenteric pulsation. Preoperative Doppler ultrasonography supported the assessment of organ perfusion. The final classification was based on operative findings.

2.2. Variables

Collected variables included age, sex, ASA class, relevant medical and surgical history, duration of the hernia swelling, index-side laterality, primary or recurrent status, anatomical type, preoperative ultrasound findings, elective or emergency surgery, operative times, hernia contents, organ preservation, intraoperative complications, postoperative pain, time to first flatus, time to independent ambulation, postoperative hospital stay, and time to return to normal activities. Pain was assessed using the visual analogue scale at <24 hours, 24-48 hours, and 48-72 hours after surgery. The value obtained within the predefined 24-48-hour window was reported in this manuscript. Time to return to normal activities was patient-reported at the first postoperative follow-up, which was conducted in person or by telephone. It was defined as the number of days from surgery until the patient resumed usual self-care and routine daily activities without assistance. All patients underwent preoperative inguinoscrotal ultrasonography. Preoperative computed tomography was not routinely performed.

Intraoperative outcomes included organ injury, conversion to open surgery, bowel resection, and intraoperative death. Early postoperative complications detected during the index hospitalization included seroma, hematoma, surgical-site infection, mesh infection, reoperation, and death. Clinical findings at < 6 months were new or persistent findings identified at the first follow-

up, including seroma, hematoma, wound or mesh infection, groin pain, sensory disturbance, testicular complications, bowel obstruction, trocar-site hernia, or recurrence. Chronic groin symptoms were assessed through direct questioning and the Carolinas Comfort Scale questionnaire, with chronic pain defined as groin pain lasting more than 3 months. Follow-up was performed at < 6 months and at or after 6 months using clinical assessment and inguinoscrotal ultrasonography. Computed tomography was used as supplementary imaging at the later assessment when feasible. Exact individual last follow-up dates were not available in a form that permitted calculation of mean or median follow-up duration. Recurrence, chronic groin symptoms, mesh displacement, abscess, and mesh-related infection were recorded.

2.3. Surgical technique

All operations were performed under general anesthesia by surgeons experienced in laparoscopic inguinal hernia repair. Patients received perioperative intravenous antibiotics according to the hospital protocol. Pneumoperitoneum was maintained at 12 - 14 mmHg. A 10-mm umbilical optical trocar was used for the 3D laparoscope and two 5-mm working trocars were placed laterally at the umbilical level.

After initial abdominal exploration, the hernia contents were reduced using gentle laparoscopic traction with external manual pressure when required. If reduction remained difficult, the defect was cautiously enlarged with electrocautery, avoiding the inferior epigastric vessels. Organ viability was assessed by color, peristalsis, and mesenteric pulsation. In equivocal cases, the organ was reassessed after 10 - 15 minutes, warm saline irrigation, and preperitoneal dissection. One patient required partial resection of nonviable omentum. No hollow-viscus resection or enteric spillage occurred in the analyzed cohort.

A side-specific 15 × 10 cm Parietex™ hydrophilic anatomical polyester mesh (Covidien/Medtronic) was positioned in the preperitoneal space to cover the myopectineal orifice. The same mesh platform and size were used throughout the study. Mesh fixation was performed using ProTack™, sutures, or no fixation according to the operative findings. The peritoneal flap was closed using ProTack™, absorbable sutures, Hem-o-lok clips, or a combination of these techniques. Mesh was not placed in an infected or contaminated field.

2.4. Statistical analysis

Data were analyzed using SPSS version 27.0. Continuous variables are presented as mean ± standard deviation and range. Categorical variables are presented as number and percentage. Exploratory comparisons between incarcerated and strangulated hernias, primary and recurrent hernias, and unilateral and bilateral repairs used the Mann-Whitney U test for continuous variables and Fisher exact test for categorical variables. Wilson 95% confidence intervals (CIs) were calculated for principal proportions. A two-sided $p < 0.05$ was considered statistically significant.

2.5. Ethics statement

The study protocol was approved by the Biomedical Research Ethics Committee (approval number H2024/605). Written informed consent was obtained from all participants. Patient information was anonymized and used solely for research purposes.

3. RESULTS

3.1. General characteristics

The final analysis included all 105 enrolled patients. The mean age was 57.1 ± 17.0 years and 101 patients (96.2%) were male. Sixty-eight patients (64.8%) had incarcerated hernias and underwent elective inpatient repair after preoperative assessment and optimization, whereas 37 patients (35.2%) had strangulated hernias and underwent emergency surgery. The mean admission-to-surgery interval was 4.09 ± 2.68 days for incarcerated hernias and 4.41 ± 1.09 hours for strangulated hernias. The longer interval in the incarcerated group reflected the planned elective inpatient pathway in clinically stable patients without evidence of vascular compromise or peritonitis. No patient had clinical signs of peritonitis.

Table 1. General characteristics of patients undergoing 3D laparoscopic inguinal hernia repair (n = 105)

Variable	Category	n	%
Age group	18 - < 40 years	19	18.1
	40 - 59 years	36	34.3
	≥ 60 years	50	47.6
	Mean ± SD (range), years	57.1 ± 17.0	21 - 89

Sex	Male	101	96.2
	Female	4	3.8
ASA class	I	44	41.9
	II	58	55.2
	III	3	2.9
Duration of hernia swelling	< 3 months	57	54.3
	3 - < 6 months	22	21.0
	6 - < 12 months	12	11.4
	≥ 12 months	14	13.3
Index complicated hernia side	Right	66	62.9
	Left	39	37.1
Anatomical type	Indirect	87	82.9
	Direct	18	17.1
Status	Primary	101	96.2
	Recurrent	4	3.8
Clinical classification	Incarcerated	68	64.8
	Strangulated	37	35.2
Surgical urgency	Elective	68	64.8
	Emergency	37	35.2
Previous surgery	Abdominal surgery	4	3.8
	Inguinal hernia surgery	7	6.7
Selected risk factors	Smoking	27	25.7
	Chronic constipation	4	3.8
	BPH/dysuria	11	10.5
	COPD/bronchiectasis	1	1.0

Seven patients had a history of previous inguinal hernia surgery, but only four index hernias were recurrent. Preoperative ultrasonography was performed in all patients. Doppler perfusion was preserved in the 68 incarcerated cases and absent in the 37 strangulated cases. The index complicated hernia was right-sided in 66 patients and left-sided in 39. Ten patients (9.5%) underwent bilateral TAPP repair after a contralateral hernia was identified intraoperatively, resulting in 115 repaired hernia sites.

3.2. Surgical Characteristics

Table 2. Surgical Characteristics (n = 105)

Variable		**Mean ± SD**	**Range (min-max)**
Overall operative time, min		82.6 ± 29.8	38 - 200
Reduction/dissection time, min		9.6 ± 6.8	2 - 40
Preperitoneal dissection time, min		19.6 ± 10.0	5 - 60
Intraoperative hernia contents		**n**	**%**
Repair laterality	Unilateral	95	90.5
	Bilateral	10	9.5
Hernia contents	Omentum	47	44.8
	Small bowel	29	27.6
	Small bowel and omentum	29	27.6
Organ preservation	Complete preservation	104	99.0
	Partial omentectomy	1	1.0

Variable		Mean ± SD	Range (min-max)
Mesh fixation	ProTack™	99	94.3
	Suture	5	4.8
	No fixation	1	1.0
Complication	Intraoperative	0	0.0

Mean operative time was 82.6 ± 29.8 minutes. Omentum was the most frequent hernia content. Complete preservation was achieved in 104 patients (99.0%, 95% CI, 94.8% - 99.8%). One patient underwent partial omentectomy for nonviable omentum. No patient required bowel resection or an alternative operative strategy. No intraoperative organ injury, conversion to open surgery, or intraoperative death occurred.

3.3. Postoperative and follow-up outcomes

Table 3. Postoperative and follow-up outcomes (n = 105)

Variable		Mean ± SD	Range (min-max)
Intravenous analgesic use, days		3.0 ± 1.4	1 - 7
VAS pain score at 24 - 48 h		3.48 ± 1.03	1 - 6
		n	**%**
Time to first flatus	< 12 h	18	17.1
	12 - 24 h	68	64.8
	24 - 48 h	19	18.1
Time to independent ambulation	< 12 h	8	7.6
	12 - 24 h	61	58.1
	24 - 48 h	36	34.3
Postoperative hospital stay, days	Mean ± SD (range)	3.50 ± 1.24	2 - 9
Patient-reported return to normal activities	1 - 7 days	25	23.8
	8 - 14 days	77	73.3
	15 - 21 days	3	2.9
Early postoperative complications during index hospitalization	Yes	3	2.9
	No	102	97.1
Clinical findings at < 6 months	Yes	4	3.8
	No	101	96.2
Hernia recurrence at protocol-defined assessment at or after 6 months	Yes	0	0.0
	No	105	100.0
Mesh-related infection at protocol-defined assessment at or after 6 months	Yes	0	0.0
	No	105	100.0

Within 24 hours after surgery, 86 patients (81.9%) passed flatus and 69 patients (65.7%) resumed independent ambulation. A total of 102 patients (97.1%) reported returning to normal activities within 14 days. Early complications occurred in 3 patients (2.9%, 95% CI, 1.0% - 8.1%), comprising two seromas and one hematoma. All were managed nonoperatively; one seroma required aspiration. No superficial or deep surgical-site infection and no early mesh infection occurred.

At < 6 months, four patients (3.8%) had minor clinical findings, predominantly seroma, and all were managed conservatively. At the protocol-defined assessment at or after 6 months, clinical examination and ultrasonography were completed in all 105 patients. Computed tomography was completed in 99 patients (94.3%). Six patients did not undergo computed tomography because they did not return for the scheduled examination. Recurrence assessment in these six patients was based on clinical

examination and ultrasonography. Exact individual follow-up duration could not be summarized because the dates of the last assessments were not available in a form suitable for calculation. No recurrence, abscess, mesh displacement, surgical-site infection, or mesh-related infection was identified. For zero observed mesh infections or recurrences, the upper bound of the 95% CI was 3.5%.

3.4. Exploratory subgroup analyses

Table 4. Comparison of outcomes between incarcerated and strangulated inguinal hernias

Outcome	Incarcerated (n = 68)	Strangulated (n = 37)	p
Operative time, min	83.3 ± 28.4	81.2 ± 32.6	0.489
Postoperative hospital stay, days	3.56 ± 1.21	3.41 ± 1.30	0.385
Complete preservation of hernia contents	68/68 (100%)	36/37 (97.3%)	0.352
Early postoperative complications	3/68 (4.4%)	0/37 (0%)	0.550

No statistically significant differences were observed between incarcerated and strangulated inguinal hernias in operative time, postoperative hospital stay, complete preservation of hernia contents, or early postoperative complications. Complete preservation of hernia contents was achieved in all incarcerated cases and in 97.3% of strangulated cases.

Table 5. Comparison of outcomes between primary and recurrent inguinal hernias

Outcome	Primary (n = 101)	Recurrent (n = 4)	p
Operative time, min	81.1 ± 27.9	120.0 ± 53.5	0.049
Postoperative hospital stay, days	3.46 ± 1.14	4.75 ± 2.87	0.442
Early postoperative complications	2/101 (2.0%)	1/4 (25.0%)	0.111

Operative time was significantly longer in recurrent hernias than in primary hernias (120.0 ± 53.5 versus 81.1 ± 27.9 minutes, p = 0.049). Postoperative hospital stay and early postoperative complication rates did not differ significantly between the two groups. These findings should be interpreted cautiously because only four patients had recurrent hernias.

Table 6. Comparison of outcomes between unilateral and bilateral repairs

Outcome	Unilateral repair (n = 95)	Bilateral repair (n = 10)	p
Operative time, min	80.4 ± 28.0	103.3 ± 39.4	0.034
Postoperative hospital stay, days	3.43 ± 1.15	4.20 ± 1.87	0.214
Early postoperative complications	3/95 (3.2%)	0/10 (0%)	1.000

Operative time was significantly longer for bilateral repairs than for unilateral repairs (103.3 ± 39.4 versus 80.4 ± 28.0 minutes, p = 0.034). No statistically significant differences were observed in postoperative hospital stay or early postoperative complication rates. The results should be interpreted cautiously because the bilateral repair group included only 10 patients.

4. DISCUSSION

This prospective single-center cohort evaluated 3D laparoscopic TAPP repair with anatomical mesh in 105 selected patients with incarcerated or strangulated inguinal hernias. The principal findings were a 99.0% organ-preservation rate, no bowel resection or conversion to open surgery, a 2.9% early complication rate, rapid postoperative recovery, and no recurrence or mesh-related infection detected at the protocol-defined assessment at or after 6 months. The results support the feasibility of the technique in appropriately selected patients, but do not establish superiority over open repair or conventional two-dimensional laparoscopy. The absence of observed late events should be interpreted in the context of limited follow-up and incomplete computed tomography assessment.

The cohort was predominantly male and nearly half of the patients were aged ≥60 years, consistent with the established epidemiology of inguinal hernia [1]. The study distinguishes clinical

urgency clearly. All 37 strangulated hernias were treated as emergencies, with a mean admission-to-surgery interval of 4.41 hours. The 68 incarcerated hernias represented clinically stable irreducible hernias without clinical or Doppler evidence of vascular compromise or peritonitis. These patients followed a planned elective inpatient pathway after preoperative assessment and optimization. Therefore, the mean interval of 4.09 days should not be interpreted as delayed treatment of suspected strangulation. Ten contralateral hernias were identified intraoperatively and repaired during the same procedure, illustrating an important diagnostic advantage of the transabdominal approach.

The mean operative time of 82.6 minutes was comparable with the 81.3 minutes reported by Mancini et al [7]. Reduction of incarcerated contents and dissection of a large or adherent sac are technically demanding steps [8,9]. Direct visualization enabled sequential reduction, reassessment of organ viability, and controlled enlargement of the defect when required. Complete organ preservation was achieved in all but one patient, who underwent partial omentectomy. Importantly, no patient in the analyzed cohort required bowel resection or an alternative operative strategy.

The use of synthetic mesh in strangulated hernias remains controversial because contamination and bowel resection increase concern for infection [10-13]. In the present study, a 15 × 10 cm anatomical polyester mesh was used only when there was no peritonitis, enteric spillage, or bowel necrosis requiring resection. No surgical-site or mesh-related infection was detected through ≥6 months. This finding is reassuring for the selected population studied, but it cannot be extrapolated to contaminated fields.

Postoperative recovery was favorable. Within 24 hours, 81.9% of patients passed flatus and 65.7% regained independent ambulation. The mean postoperative stay was 3.5 days, and 97.1% reported returning to normal activities within 14 days. Data on the return to normal activities were obtained at the first postoperative follow-up in person or by telephone and reflected resumption of usual self-care and routine daily activities without assistance. Exploratory analyses showed no significant difference in key outcomes between incarcerated and strangulated hernias. Longer operative times in recurrent and bilateral repairs are clinically plausible because previous surgery can alter tissue planes and bilateral repair requires wider dissection. However, the small recurrent and bilateral groups limit the precision of these comparisons.

The early complication rate was 2.9% and consisted only of seroma or hematoma. Four minor clinical findings were present at < 6 months. At the protocol-defined assessment at or after 6 months, clinical examination and ultrasonography were completed in all 105 patients, while computed tomography was completed in 99. Six patients did not return for scheduled computed tomography, and their recurrence assessment was based on clinical examination and ultrasonography. No recurrence, mesh displacement, abscess, or mesh infection was detected. Exact individual follow-up duration was not available for calculation. The 95% CI remains important because with no observed late mesh infections or recurrences, the true event rate could still be as high as approximately 3.5%. Therefore, zero observed events should not be interpreted as proof that the risks are absent.

This study has several limitations. It was conducted at a single center without a control group, preventing direct comparison with open surgery, TEP, or two-dimensional laparoscopy. A separate screening log was not maintained, so the total number of patients initially assessed and the reasons for non-enrollment could not be reconstructed. Strict selection excluded ASA IV-V patients, peritonitis, and bowel necrosis requiring resection. Consequently, the results apply to a selected population and not to all strangulated hernias. Exact individual last-follow-up dates were not available for calculation, so follow-up could only be described using protocol-defined categories. Six patients did not return for scheduled computed tomography. Although they completed clinical and ultrasonographic assessment, small or subclinical imaging findings cannot be fully excluded. Individual symptoms of bowel obstruction were not prospectively coded as separate variables, although irreducibility and perfusion were assessed clinically, by ultrasonography, and intraoperatively. The recurrent and bilateral subgroups were small, and the limited follow-up is insufficient to fully assess late recurrence, chronic postoperative inguinal pain, or delayed mesh complications. Larger multicenter comparative studies with longer and precisely documented follow-up periods are required.

5. CONCLUSIONS

In selected adults with incarcerated or strangulated inguinal hernias and without peritonitis or bowel necrosis requiring resection, 3D laparoscopic

TAPP repair using a pre-shaped anatomical polyester mesh was feasible and was associated with high organ preservation, few early complications, rapid recovery, and no detected recurrence or mesh-related infection during the protocol-defined limited follow-up. The procedure should be undertaken by experienced laparoscopic surgeons. These findings should not be generalized to contaminated surgical fields, advanced cases requiring bowel resection, or the broader population of acute irreducible groin hernias. The absence of observed recurrence or mesh-related infection should not be interpreted as proof that these risks are absent.

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