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Original Article

Transient Femoral Nerve Dysfunction During Open Lichtenstein Repair Under Local Anesthesia: A Retrospective Cohort Study

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ABSTRACT

Background: Transient femoral nerve dysfunction (TFND) following inguinal hernia repair under local anesthesia is likely underrecognized because symptoms are typically self-limited. This study evaluated the incidence, clinical presentation, and factors associated with TFND after open inguinal hernia repair under local anesthesia.

Methods: A retrospective cohort study was conducted in 636 consecutive patients undergoing open Lichtenstein inguinal hernia repair under local anesthesia between March 2018 and March 2026. TFND was defined as transient postoperative sensory disturbance over the femoral dermatome and/or motor weakness impairing knee extension or weight-bearing ambulation. Patients were assessed postoperatively until symptom resolution and discharge. Univariable and multivariable logistic regression analyses were performed to identify factors associated with TFND.

Results: TFND occurred in 74 patients (11.6%), including 26 (4.1%) with isolated sensory dysfunction and 48 (7.6%) with motor weakness. All neurological deficits resolved spontaneously within 1.5 – 6 hours without permanent sequelae or unplanned admission. Multivariable analysis identified complex hernia (adjusted odds ratio [aOR] 5.93, $p < 0.001$), advanced operative phase (phase 2: aOR 6.78, $p = 0.001$; phase 3: aOR 13.65, $p < 0.001$), female sex (male sex: aOR 0.30, 95% CI 0.13–0.66; $p = 0.017$), and left-sided hernia (right-sided hernia: aOR 0.45, 95% CI 0.29–0.83; $p = 0.004$) as independent factors associated with TFND. Outpatient day surgery was independently associated with lower TFND risk (aOR 0.41, $p = 0.006$). The composite case-mix index increased progressively across phases ($p < 0.001$).

Conclusions: TFND after open inguinal hernia repair under local anesthesia occurred in 11.6% of patients but was uniformly transient and self-limited, resolving spontaneously within 1.5 to 6 hours without permanent neurological sequelae or unplanned hospital admission. Multivariable analysis

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identified complex hernia (aOR 5.93), advanced operative phase (phase 2: aOR 6.78; phase 3: aOR 13.65), female sex, and left-sided hernia as independent risk factors for TFND, while ODS was independently protective (aOR 0.41). These findings indicate that TFND is predominantly associated with operative complexity and evolving anesthetic infiltration behavior across the surgeon experience trajectory, rather than a simple dose-dependent effect of local anesthetics. The composite case-mix index demonstrated progressive increase in operative burden across phases supporting the multidimensional nature of TFND risk in this setting. Refinement of infiltration technique, including ultrasound guidance in complex cases, may improve perioperative safety.

Keywords: Transient femoral nerve dysfunction (TFND), Lichtenstein hernia repair, Local anesthesia, Inguinal hernia, One-day surgery (ODS)

Introduction

Inguinal hernia repair is one of the most frequently performed surgical procedures globally, with an estimated 20 million operations conducted annually.[1] While surgical approaches have evolved to include laparoscopic (TEP, TAPP) and robotic-assisted techniques, open mesh repair remains the gold standard, particularly the Lichtenstein tension-free technique.[1,2] Due to its shorter learning curve, cost-effectiveness, and low complication rates, it is highly recommended by the HerniaSurge Guidelines (2018, 2023). Specifically, performing this procedure under local anesthesia (LA) is strongly recommended as the first-line choice for elderly and frail patients with significant comorbidities.[1,3] This approach facilitates rapid recovery, minimizes the risk of urinary retention and is a cornerstone of Ambulatory or One Day Surgery (ODS) programs, which have been a national healthcare priority in Thailand since 2019.[4]

Despite its high safety profile, regional anesthesia in the inguinal area is not without challenges. Beyond systemic toxicity (LAST), Transient Femoral Nerve Dysfunction (TFND) is a clinical concern. The femoral nerve (L2–L4) lies posterior to the transversalis fascia and enters the thigh beneath the inguinal ligament within the femoral sheath, potentially placing it at particular risk of involvement during inguinal field infiltration.[5,6] Reported TFND incidence ranges from 3% to 8.8% across prior studies.[8,9,10] These rates likely underestimate the true incidence because most previous reports did not employ systematic postoperative neurological assessment and primarily captured motor deficits, potentially overlooking transient sensory disturbances. Furthermore, existing evidence is limited to small



case series (n = 10–54)[8,9,10] and has not examined independent risk factors using multivariable analysis, nor characterized how operative case-mix evolves across the surgeon experience continuum. To provide a biological rationale for TFND, additional anatomical background from Gray's Anatomy and Skandalakis' Surgical Anatomy was incorporated, highlighting the anatomical relationship between the deep inguinal ring, iliopubic tract, femoral canal, and femoral nerve, and supporting a potential pathway for local anesthetic spread from the inguinal region to the femoral compartment.[5,6]

Although temporary, TFND carries meaningful clinical consequences in the ODS setting. Impaired weight-bearing ambulation from quadriceps weakness substantially increases the risk of postoperative falls during early mobilization — a critical patient safety concern for same-day discharge. Unexpected neurological symptoms may necessitate prolonged recovery room observation and may ultimately precipitate unplanned hospital admission or delayed discharge.

Previous studies have suggested several potential mechanisms for transient femoral nerve dysfunction (TFND). Higher local anesthetic doses may increase the likelihood of anesthetic spread beyond the intended tissue planes, potentially resulting in transient femoral nerve blockade.[10] Complex hernias often require broader dissection and hydrodissection, which may facilitate anesthetic spread toward the femoral compartment.[8] Surgeon experience may also influence anesthetic infiltration behavior and case selection, thereby modifying TFND risk.[9] However, the relative contribution and independence of these factors remain unclear.

Therefore, this study aimed to evaluate the incidence, clinical characteristics, and independent factors associated with TFND following open Lichtenstein inguinal hernia repair under local anesthesia in a large consecutive single-surgeon cohort spanning an eight-year period, and to characterize the evolution of operative case-mix across surgeon experience phases.

Materials and Methods

Study Design and Population

This study was a retrospective cohort analysis conducted at Phatthalung Hospital, Thailand. We included all adult patients who underwent inguinal hernia repair under local anesthesia over an 8-year period (March 2018 to March 2026).

Participants

Inclusion Criteria: All adult patients who underwent open inguinal hernia repair under local anesthesia performed by a single surgeon (the author).

Exclusion Criteria: Patients with pre-existing neurological deficits of the lower extremities, incomplete medical records, or those whose anesthesia plan was converted to general or spinal anesthesia intraoperatively.

All procedures were performed by a single experienced general surgeon (>600 inguinal hernia cases) using a standardized operative and anesthetic protocol, thereby reducing variability related to different operators.

Based on previous reports of femoral nerve palsy following ilioinguinal-iliohypogastric block and established groin anatomy, we hypothesized that TFND may result from local anesthetic spread through deep tissue planes toward the femoral compartment. Surgeon experience was considered an indirect determinant through evolving case selection, operative complexity, and infiltration behavior. The proposed conceptual framework is illustrated in Figure 1.

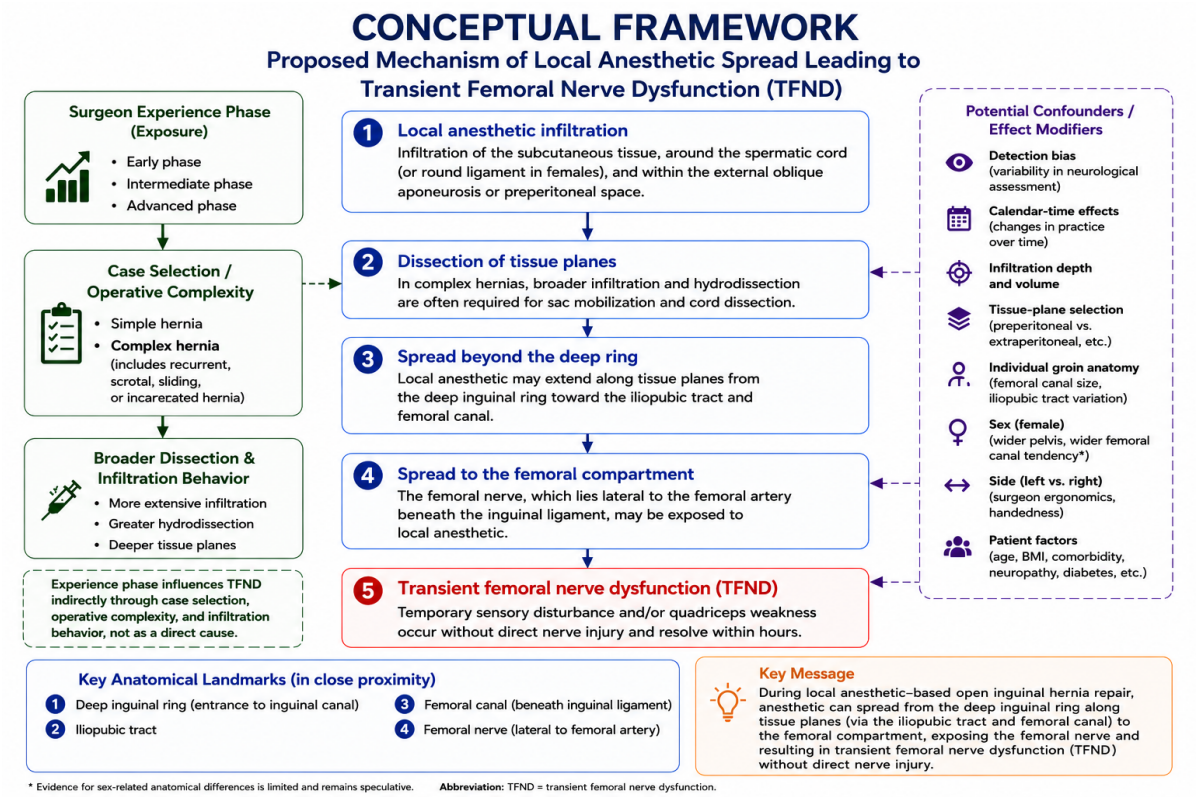


Figure 1 Proposed conceptual framework of factors associated with transient femoral nerve dysfunction (TFND).

Author- generated conceptual framework. The framework illustrates the hypothesized relationship between surgeon experience, operative complexity, anesthetic infiltration behavior, and subsequent local anesthetic spread toward the femoral compartment leading to transient femoral nerve dysfunction. The model was developed a priori to guide variable selection and interpretation of study findings.

Surgical Procedure

Open Lichtenstein tension-free mesh repair was performed under local anesthesia with monitored anesthesia care (MAC). Stepwise ilioinguinal and iliohypogastric nerve blocks, followed by layered local infiltration using diluted Lidocaine and Bupivacaine solutions, were applied according to a standardized institutional protocol.[13,14,15,16] Supplemental infiltration was administered intraoperatively as required according to operative complexity and patient discomfort. (Figure 2)

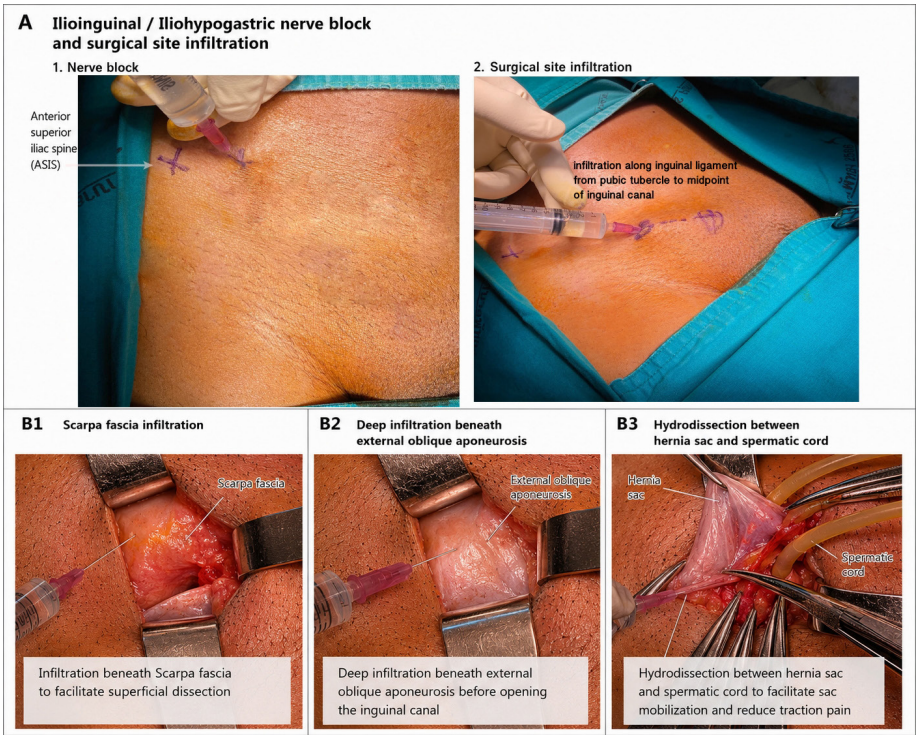


Figure 2 Operative technique of inguinal hernia repair under local anesthesia.
(A) Ilioinguinal and iliohypogastric nerve block followed by local infiltration at incision site (level of internal inguinal ring to external inguinal ring at pubic tubercle)
(B1) Infiltration beneath Scarpa fascia during early dissection.
(B2) Deep infiltration beneath the external oblique aponeurosis before opening the inguinal canal.
(B3) Hydrodissection between the hernia sac and spermatic cord facilitating sac mobilization and reducing traction pain.



Outcome Measures and Variables

The primary outcome was transient femoral nerve dysfunction (TFND), defined as transient postoperative sensory disturbance and/or motor weakness within the femoral nerve distribution identified immediately after surgery and resolving completely within 24 hours (pre-specified outer limit for outcome ascertainment). In this cohort, all observed deficits resolved within 1.5–6 hours; no case required reclassification as a non-transient deficit.Variable

Postoperative neurological assessment was performed by the operating surgeon (T.P.) immediately following emergence from monitored anesthesia care (MAC), prior to discharge from the recovery area. All 636 consecutive cases underwent a standardized two-component protocol. Sensory function was evaluated using pin-prick testing with an unfolded paper clip applied to the anterior thigh and the medial aspect of the knee on the operative side, with direct comparison to the contralateral side; asymmetric or diminished pain perception constituted a positive sensory finding. Motor function was assessed in two sequential steps: first, active knee extension against gravity compared with the contralateral limb; second, surgeon-assisted standing with full weight-bearing on the operative limb — inability to extend the knee, asymmetric weakness on comparison, failure to bear full weight unassisted, or tendency to fall was recorded as motor weakness. TFND was diagnosed when either component was positive. In patients with confirmed TFND, repeated assessments were performed at regular intervals until complete symptom resolution; discharge was permitted only after full neurological recovery was confirmed on repeat examination. For ODS patients, postoperative telephone follow-up was performed according to the institutional ODS protocol by ODS nurses at 24 hours, 2 days, and 3 days after surgery to assess symptom resolution and detect any delayed or persistent neurological deficits. Inpatients with confirmed TFND underwent serial bedside neurological reassessment until complete resolution was documented prior to ward discharge. All patients — both ODS and inpatients — attended a scheduled one-month outpatient follow-up, at which wound healing, general recovery, and neurological status were formally evaluated.

Definitions and Consolidation

To ensure statistical robustness and prevent model overfitting, primary predictors were categorized and consolidated based on clinical relevance:

Hernia complexity was classified according to the Nyhus classification system[17,18]. For statistical analysis, Nyhus type I hernias were categorized as “simple,” whereas Nyhus types II–IV, including wide neck indirect, direct, pantaloon, femoral, and recurrent hernias, were categorized as “complex”



to improve statistical robustness and maintain an adequate events-per-variable ratio.

Surgeon experience was categorized into three operative phases according to cumulative case volume: phase 1 (cases 1–200), phase 2 (201–400), and phase 3 (> 400 cases).

Surgical Setting: Patients were grouped into One Day Surgery (ODS) or Inpatient care models.

Total dosages of Bupivacaine and Lidocaine were calculated as mg/kg to evaluate their association with TFND.

Outcome: The primary outcome was the incidence of Transient Femoral Nerve Dysfunction (TFND)

Data Quality Control

All data were extracted by the primary investigator (T.P.) from original medical records using a standardized data extraction form. Data completeness and consistency were verified before statistical analysis.

Statistical Analysis

Continuous variables were summarized as mean ± standard deviation or median (interquartile range), while categorical variables were expressed as frequencies and percentages. Univariable logistic regression analysis was initially performed to identify variables associated with TFND.

Clinically relevant variables, including operative complexity, surgeon experience phase, operative setting (ODS versus inpatient), operative duration, anesthetic dosage per body weight, sex, and operative side, were entered into multivariable logistic regression models regardless of univariable statistical significance. A reduced final model was presented to preserve model stability and events-per-variable adequacy. Model discrimination was assessed using receiver operating characteristic (ROC) analysis and area under the curve (AUC). Multicollinearity was evaluated using variance inflation factors (VIF).

Composite case-mix index.

To quantify the evolution of operative burden across surgeon experience phases independently of phase itself, a composite case-mix index was constructed for each patient. The index was the individual predicted probability of TFND from: $\text{logit}(P[\text{TFND}]) = \beta 0 + \beta 1(\text{complexity}) + \beta 2(\text{bupivacaine mg/kg})$, with complexity coded 0/1 (Nyhus I vs. II–IV) incorporating hernia complexity (simple vs. complex) and bupivacaine dose per body weight (mg/kg) as sole predictors, with operative experience phase intentionally excluded. This approach isolates the contribution of anatomical complexity and anesthetic utilization two factors independently associated with TFND from the phase variable under investigation. The resulting index provides a continuous, patient-level, phase-independent estimate of operative burden, ranging from 0 to 1. Mean case-mix index values were compared across experience phases using the Kruskal Wallis test, with post-hoc pairwise Mann–Whitney U tests corrected by the Bonferroni



method. A linear trend across ordered phases was evaluated by linear regression of the index on phase number (1, 2, 3). Statistical significance was defined as $p < 0.05$ for all analyses. All statistical analyses were performed using R version 4.5.3 (R Foundation for Statistical Computing, Vienna, Austria).

A reduced final model was derived using backward elimination guided by Akaike Information Criterion (AIC) minimization. Variables were retained if their removal increased AIC or if they were deemed clinically essential, with a minimum events-per-variable ratio of ≥10 maintained throughout.

The analytic dataset was complete for all study variables. Patients with incomplete medical records had been excluded according to the pre-specified exclusion criteria, and no missing data imputation was required. Univariable analyses in Table 2 were performed solely for the purpose of variable selection and descriptive characterization of individual associations, and not as hypothesis-testing procedures in their own right. Correction for multiple comparisons was deliberately not applied to these 13 univariable tests, consistent with standard practice in logistic regression model building, in which such correction would inappropriately restrict variable entry and risk excluding clinically important predictors. The multivariable model, which accounts for the simultaneous interplay of all predictors, provides the primary adjusted estimates and constitutes the confirmatory analysis.

This study was approved by the Institutional Review Board (IRB) of Phatthalung Hospital (Approval No. 13-2569). Informed consent was waived owing to the retrospective nature of the study and the use of de-identified patient data.

Results

A total of 636 patients were enrolled in the study. The study population was predominantly male (94.5%) with a mean age of 62.5 ± 15.1 years. Right-sided hernias were more frequent, occurring in 57.2% of cases. The mean operative time was 48.55 ± 11.55 minutes. Regarding anesthesia, the mean dosages for Lidocaine and Bupivacaine were 5.11 ± 0.9 mg/kg and 1.63 ± 0.29 mg/kg, respectively. According to the Nyhus classification, 39.3% of hernias were classified as simple (Type I), whereas 60.7% were categorized as complex (Types II–IV). Within the complex group, Nyhus Type II (23.6%) and Type IIIa (21.9%) were the most common. Postoperatively, Transient Femoral Nerve Dysfunction (TFND) was observed in 74 patients (11.6%), comprising 26 cases (4.1%) of pure sensory dysfunction and 48 cases (7.6%) of motor weakness. Transient femoral nerve dysfunction (TFND) was uniformly self-limited. Most symptoms resolved spontaneously within approximately 2 hours postoperatively (range 1.5–6 hours), with no persistent neurological deficits or unplanned conversion from outpatient day surgery to inpatient admission.

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Table 1 Baseline demographic and operative characteristics of the study population

Characteristic	Value
Total cases	636
Age, years	62.54 ± 15.06
BMI, kg/m²	22.20 ± 2.93
Operative time, min	48.55 ± 11.55
Lidocaine dose (mg/kg)	5.11 ± 0.98
Bupivacaine (mg/kg)	1.63 ± 0.29
ASA class, n (%)	
ASA 1	114 (17.9)
ASA 2	398 (62.6)
ASA 3	124 (19.5)
Diagnosis complexity, n (%)	
Simple hernia	250 (39.3)
Complex hernia	386 (60.7)
Nyhus II	150 (23.6)
Nyhus IIIa	139 (21.9)
Nyhus IIIb	78 (12.3)
Nyhus IIIc	6 (0.9)
Nyhus IV (recurrent)	13 (2.0)
Care setting, n (%)	
ODS	338 (53.1)
Inpatient	298 (46.9)
Side, n (%)	
Right	364 (57.2)
Left	272 (42.8)
Sex, n (%)	
Male	601 (94.5)
Female	35 (5.5)
Intraoperative sedation, n (%)	
No	583 (91.7)
Yes	53 (8.3)
Outcome, TFND, n (%)	74 (11.6)
Sensory dysfunction	26 (4.1)
Motor dysfunction	48 (7.6)
Operative phase, n (%)	
Phase 1 Early	200 (31.4)
Phase 2 Middle	200 (31.4)
Phase 3 Late	236 (37.1)

Values are mean ± SD or n (%)



Univariable logistic regression analysis was performed to evaluate factors associated with TFND. Variables with $p < 0.10$ in univariable analysis or considered clinically relevant were subsequently entered into the multivariable logistic regression model.

Table 2 Univariable analysis of factors associated with TFND

Variable	Univariable OR	95% CI	*P* value
Age (per year)	1.02	1.00 -1.03	0.075
ASA class			
ASA 1	Reference		
ASA 2	1.16	0.58 - 2.33	0.669
ASA 3	1.69	0.77 - 3.74	0.191
BMI	1.01	0.93 - 1.10	0.78
Male sex	0.30	0.14 - 0.65	0.002
Right-sided hernia	0.50	0.30 - 0.81	0.005
Operative time	1.00	0.98 - 1.02	0.87
Lidocaine dose (mg/kg)	0.98	0.77 - 1.26	0.82
Bupivacaine dose (mg/kg)	1.72	1.17 - 2.53	0.006
Complex hernia	5.43	2.68 - 11	<0.001
Intraoperative sedation	1.63	0.72 - 3.35	0.209
Experience phase 2	4.82	1.85 - 12.5	0.001
Experience phase 3	11.3	4.62 - 27.4	<0.001
ODS vs IPD	0.59	0.33 - 1.04	0.069

OR, odds ratio; CI, confidence interval; TFND, transient femoral nerve dysfunction.



Based on these univariable logistic regression analysis results, variables with $p < 0.10$ (age, sex, operative side, Bupivacaine dose, hernia complexity, experience phase, and operative setting) were entered into the multivariable logistic regression model. This approach was used to evaluate the independent association of each factor while accounting for the interplay between surgical experience, operative selection patterns, and hernia complexity.

Table 3 Multivariable analysis of factors associated with TFND

Variable	Adjusted OR	95% CI	*P* value
ODS vs IPD	0.41	0.22-0.78	0.006
Male sex	0.30	0.13-0.66	0.017
Right-sided hernia	0.45	0.29-0.83	0.004
Complex hernia	5.93	2.80-12.55	<0.001
Experience phase 2	6.78	2.39-18.4	0.001
Experience phase 3	13.65	4.17-28.87	<0.001

OR, odds ratio; CI, confidence interval; TFND, transient femoral nerve dysfunction. The final reduced model showed AUROC 0.81 and no substantial multicollinearity (all VIFs < 1.5).

Multivariable analysis identified operative complexity and advanced operative phase as the strongest independent predictors of TFND. ODS remained independently associated with lower odds of TFND after adjustment for operative complexity, operative duration, surgeon experience phase, sex, and operative side.

Given the observed differences in operative characteristics across experience phases, multivariable adjustment was performed to reduce potential confounding related to operative selection patterns and hernia complexity.

Although Bupivacaine dose per body weight was associated with TFND in univariable analysis, the association was attenuated after multivariable adjustment and was not retained in the final reduced model.

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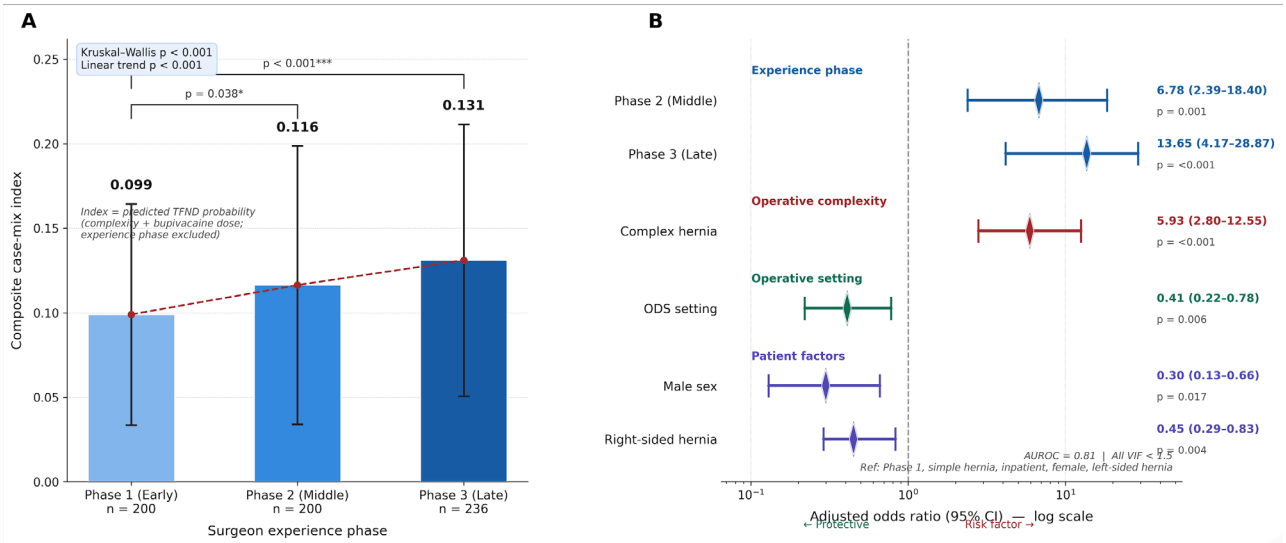


Figure 3 Composite case-mix index and adjusted predictors of TFND across surgeon experience phases. Composite case-mix index across surgeon experience phases. Error bars represent +1 standard deviation. Significance brackets indicate Bonferroni-corrected Mann-Whitney U pairwise comparisons. The dashed line indicates the linear trend across ordered phases (A). Forest plot of adjusted odds ratios (aOR) from the final reduced multivariable logistic regression model for transient femoral nerve dysfunction (TFND) (B).

Diamond markers indicate point estimates; horizontal lines indicate 95% confidence intervals. aOR, adjusted odds ratio; CI, confidence interval; ODS, outpatient day surgery; TFND, transient femoral nerve dysfunction.

The composite case-mix index represents a patient-level score of operative difficulty — derived from hernia complexity and bupivacaine dose, independent of experience phase — enabling phase-neutral comparison of operative burden across the experience continuum.

The composite case-mix index increased significantly and progressively across experience phases (Phase 1: 0.099 ± 0.065; Phase 2: 0.116 ± 0.082; Phase 3: 0.131 ± 0.080; Kruskal–Wallis $p < 0.001$; linear trend $p < 0.001$). Pairwise comparisons using Bonferroni-corrected Mann–Whitney U tests demonstrated significant differences between Phase 1 and Phase 2 ($p = 0.038$) and between Phase 1 and Phase 3 ($p < 0.001$), while the difference between Phase 2 and Phase 3 did not reach significance after correction ($p = 0.329$), indicating that the principal shift in operative burden occurred between the early and subsequent phases.

Notably, although the proportion of complex hernias did not increase monotonically across



phases (63.5%, 52.5%, and 65.3% in phases 1–3, respectively), the composite index rose consistently. This apparent discrepancy reflects the concurrent and substantial evolution in bupivacaine utilization (Phase 1: 1.46 ± 0.30 mg/kg; Phase 2: 1.72 ± 0.24 mg/kg; Phase 3: 1.69 ± 0.25 mg/kg; $p < 0.001$), which offset the relatively lower proportion of complex hernias in Phase 2, collectively elevating the composite operative burden beyond what hernia classification alone could capture.

TFND incidence increased progressively and significantly across phases: 2.5% in Phase 1, 11.0% in Phase 2, and 19.9% in Phase 3 ($p < 0.001$). Pairwise comparisons demonstrated stepwise increases between all phase pairs: Phase 1 versus Phase 2 (OR 4.82, 95% CI 1.85–12.54; $p = 0.001$), Phase 2 versus Phase 3 (OR 2.01, 95% CI 1.16–3.50; $p = 0.012$), and Phase 1 versus Phase 3 (OR 9.70, 95% CI 3.78–24.91; $p < 0.001$). Operative characteristics across experience phases are summarized in Table 4.



Table 4 Operative case-mix, perioperative characteristics, and clinical outcomes across surgeon experience phases

Variable	Phase 1 (Early) n = 200	Phase 2 (Middle) n = 200	Phase 3 (Late) n = 236	*p* value
Hernia complexity, n (%)				
Simple (Nyhus I)	73 (36.5)	95 (47.5)	82 (34.7)	0.015
Complex (Nyhus II–IV)	127 (63.5)	105 (52.5)	154 (65.3)	
Nyhus II	47 (23.5)	42 (21.0)	61 (25.8)	
Nyhus IIIa	57 (28.5)	30 (15.0)	52 (22.0)	
Nyhus IIIb	18 (9.0)	29 (14.5)	31 (13.1)	
Nyhus IIIc	1 (0.5)	2 (1.0)	3 (1.3)	
Nyhus IV (recurrent)	4 (2.0)	2 (1.0)	7 (3.0)	
Sex, n (%)				
Male	191 (95.5)	195 (97.5)	215 (91.1)	0.011
Female	9 (4.5)	5 (2.5)	21 (8.9)	
Surgical care setting, n (%)				
Outpatient day surgery (ODS)	96 (48.0)	104 (52.0)	138 (58.5)	0.085
Inpatient admission (IPD)	104 (52.0)	96 (48.0)	98 (41.5)	
Anesthetic dose, mean ± SD				
Bupivacaine dose (mg/kg)	1.46 ± 0.30	1.72 ± 0.24	1.69 ± 0.25	< 0.001
Lidocaine dose (mg/kg)	5.40 ± 1.27	5.07 ± 0.79	4.91 ± 0.76	< 0.001
Operative outcomes				
Operative time (min)	52.41 ± 9.99	48.51 ± 11.32	45.32 ± 12.02	< 0.001
Sedation used, n (%)	23 (11.5)	18 (9.0)	12 (5.1)	0.050
Composite case-mix index†, mean ± SD				
Case-mix index	0.099 ± 0.065	0.116 ± 0.082	0.131 ± 0.080	< 0.001
Clinical outcome, n (%)				
TFND (any)#	5 (2.5)	22 (11.0)	47 (19.9)	< 0.001
Sensory dysfunction	2 (1.0)	3 (1.5)	21 (8.9)	
Motor weakness	3 (1.5)	19 (9.5)	26 (11.0)	

Values are n (%) or mean ± SD. ODS, outpatient day surgery; IPD, inpatient admission.

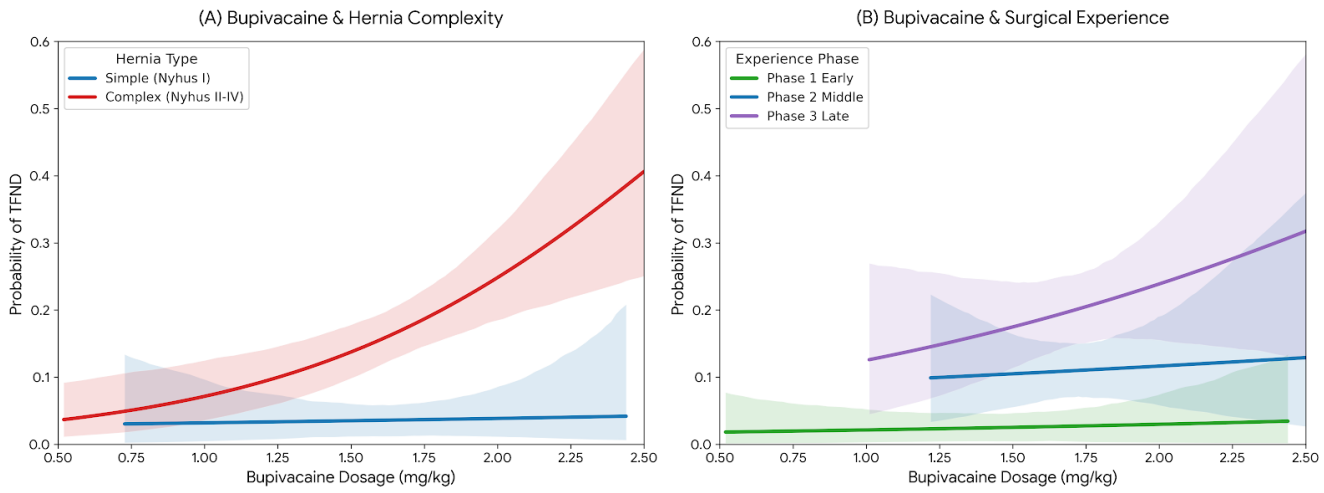


Figure 4 Exploratory relationship between hernia complexity (A), surgeon experience phase (B), and Bupivacaine dose in relation to TFND probability. Exploratory relationship between hernia complexity (A), surgeon experience phase (B), and Bupivacaine dose in relation to TFND probability.

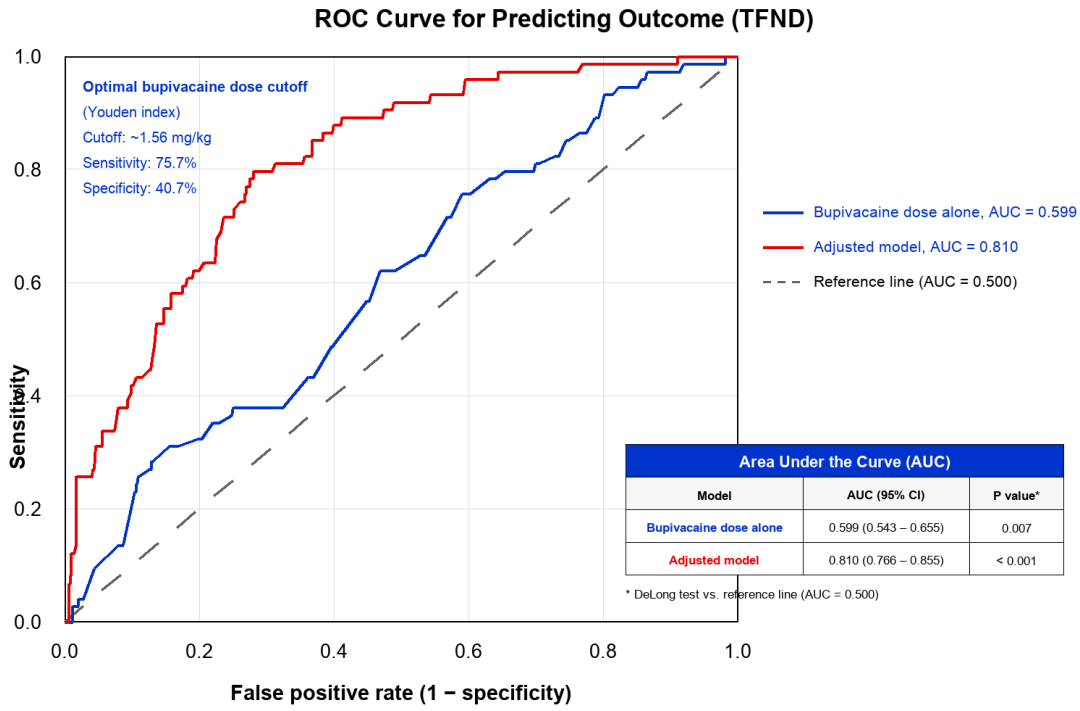


Figure 5 ROC curve comparing predictive performance of Bupivacaine dose alone versus the adjusted multivariable model for TFND prediction

Predicted TFND probability according to bupivacaine dose, stratified by hernia complexity and surgeon experience phase. Higher predicted TFND probability was observed mainly in complex hernias and later operative phases.

Bupivacaine dose alone showed limited discrimination (AUROC 0.599), whereas the adjusted model showed better discrimination (AUROC 0.810). The Youden-derived bupivacaine cutoff was 1.56 mg/kg.

Discussion

The present study demonstrates that TFND following open Lichtenstein repair under local anesthesia occurs in 11.6% of patients higher than previously reported rates of 3%–8.8%[8,9,10] but is uniformly transient and self-limited. The absence of permanent neurological deficits or unplanned admissions in this cohort supports the characterization of TFND as a reversible conduction-block or pressure-related phenomenon rather than structural femoral nerve injury.[19,20,21] The higher observed incidence likely reflects systematic postoperative neurological assessment, capturing transient sensory symptoms that are frequently omitted in routine clinical documentation.

Operative complexity and advanced surgeon experience phase emerged as the dominant independent predictors. Complex hernias were associated with an approximately six-fold increase in TFND risk, consistent with the hypothesis that technically demanding groin dissection, broader tissue-plane infiltration, and extensive preperitoneal manipulation may facilitate anesthetic spread toward the femoral compartment.[11,21] Importantly, operative phase remained an independent predictor after adjustment for hernia complexity, indicating that the phase effect is not explained by case-mix differences alone.

Collectively, these findings support the conceptual framework proposed in Figure 1, suggesting that TFND is mediated by operative complexity and anesthetic infiltration behavior rather than anesthetic dose alone.

The counterintuitive phase–TFND association reflects two concurrent behavioral changes: progressive dose escalation (1.46 → 1.72 → 1.69 mg/kg across phases; $p < 0.001$) and expansion to higher-complexity cases, including incarcerated hernias and emergency presentations, that were previously more often managed under general anesthesia. Both factors may increase the likelihood of anesthetic spread toward the femoral compartment. The identical anesthetic formulation across phases supports a behavioral rather than pharmacological explanation for this association.

The composite case-mix index reveals that overall operative burden increased progressively across the experience trajectory — even when hernia complexity alone did not increase



monotonically — by capturing both complexity and anesthetic utilization in a single phase-neutral metric. The apparent paradox of a rising case-mix index in Phase 2 despite lower complex hernia proportions is explained by substantially increased bupivacaine utilization (1.72 vs. 1.46 mg/kg), reflecting broader anesthetic infiltration strategies employed during technically demanding cases. Operative burden in this setting is thus multidimensional, encompassing hernia anatomy, infiltration extent, and anesthetic utilization.

Several anatomical mechanisms may explain femoral nerve vulnerability during inguinal field block. The femoral nerve traverses the iliopsoas compartment posterior to the transversalis fascia, in close proximity to the deep tissue planes accessed during Lichtenstein repair.[5,6,11,12,21] Anesthetic spread along the iliac fascia toward the femoral sheath has been demonstrated in cadaveric studies, particularly during percutaneous ilioinguinal-iliohypogastric block or preperitoneal infiltration.[21] The transient and fully reversible character of TFND in this cohort is consistent with a temporary conduction block rather than axonal injury.

Between the inguinal ligament and the iliopectineal line, the subinguinal space is divided into three compartments: the lateral neuromuscular compartment containing the iliopsoas muscle, femoral nerve, and lateral femoral cutaneous nerve; the vascular compartment containing the femoral artery and vein; and the femoral canal.[5,6] The femoral sheath — a prolongation of the transversalis fascia into the thigh — envelops the femoral vessels and canal, and is embryologically and anatomically a specialization of the transversalis fascia and transversus abdominis aponeurosis.[5,6] During layered local infiltration for inguinal hernia repair, anesthetic agents infiltrated along the posterior wall of the inguinal canal or deep to the transversalis fascia may track within these fascial planes toward the lateral neuromuscular compartment, placing the femoral nerve at risk of transient conduction block.

The association of female sex with TFND warrants consideration. Female patients typically demonstrate a broader gynecoid pelvic configuration, wider subpubic angle, and greater femoral triangle dimensions compared with males — anatomical features documented in systematic reviews of inguinal-pubic anatomy.[25] Cadaveric morphometric studies further confirm that the femoral neurovascular bundle lies significantly closer to the inguinal canal in female specimens compared with males (2.02 ± 0.44 cm vs. 2.63 ± 0.38 cm; $p < 0.001$; Cohen's d = 1.48),[26] and that the deep inguinal ring is significantly smaller and more slit-like in female specimens, with proportionally wider femoral canal dimensions.[24,25] These anatomical differences collectively provide a plausible mechanistic basis for the



higher TFND risk observed in female patients, as anesthetic spread along fascial planes toward the femoral compartment is more likely when the neurovascular bundle lies in closer proximity to the inguinal field.[21] However, it should be noted that female patients comprised only 5.5% of the present cohort (n = 35), and the wide confidence interval of the sex-related estimate (aOR 0.30 for male sex, 95% CI 0.13–0.66) reflects this limited sample size. This finding should be interpreted as hypothesis-generating pending prospective confirmation with greater female representation.

The independent association of left-sided hernia with higher TFND risk is an additional observation of clinical interest. Although the precise mechanism remains uncertain, potential explanations include asymmetrical groin anatomy between sides, differences in surgeon ergonomics and operative positioning during right-handed dissection of the left groin — a phenomenon supported by evidence that surgeon handedness introduces operative asymmetry between dominant and non-dominant sides across multiple surgical disciplines[27] — altered tissue traction vectors, or differences in infiltration angulation relative to the femoral nerve axis. This observation is hypothesis-generating and warrants further investigation.

The independently associated lower risk of TFND observed in ODS patients is clinically important. Although this finding may partly reflect selective allocation of lower-risk patients to outpatient settings, it persisted after multivariable adjustment for complexity, phase, and other covariates. The progressive ODS expansion across phases (48.0% to 58.5%) supports its safety even as operative complexity increased.

Bupivacaine dose was significantly associated with TFND in univariable analysis but was attenuated and not retained after multivariable adjustment. Exploratory analyses demonstrated that bupivacaine dose alone provided limited discriminative performance (AUROC 0.599), and higher predicted TFND probability was concentrated in complex hernias and advanced operative phases rather than distributed by dose alone. These findings suggest that bupivacaine utilization primarily serves as a surrogate marker of operative complexity and tissue-plane exposure, rather than an independent neurotoxic agent at the doses employed in this cohort.

This study has several limitations. The retrospective single-center design limits causal inference and generalizability. TFND was clinically diagnosed without electrophysiological confirmation; however, given the uniformly transient and self-limited course, formal electro-diagnostic testing was neither warranted nor feasible. The study reflects outcomes from a single experienced surgeon; findings may not be directly applicable to surgeons at different stages of their learning curve or to laparoscopic



techniques. Unmeasured technical variables including infiltration depth, tissue-plane targeting, and patient-specific groin anatomy could not be fully characterized.

Despite these limitations, this study provides one of the largest analyses of TFND after open local-anesthesia hernia repair (PubMed search May 2026; no larger single-surgeon series identified), with a novel framework for characterizing operative burden evolution. The findings have direct implications for operator training, patient counseling, and infiltration technique refinement. Furthermore, the proportion of female patients was small (5.5%, n = 35), limiting the precision of sex-related odds ratio estimates and warranting cautious interpretation; this finding should be considered hypothesis-generating pending confirmation in prospective studies with greater female representation. The experience phases defined herein are specific to the cumulative caseload of a single surgeon and cannot be directly extrapolated to other practitioners without knowledge of their individual operative volumes. Additionally, increasing clinical awareness of TFND across later phases may have contributed to higher detection rates — an ascertainment bias inherent to retrospective design that cannot be fully excluded.

The three experience phases span a calendar period from 2018 to 2026. During COVID-19 (2020–2021), elective cases were curtailed to urgent and selected ODS only, shifting Phase 2 toward lower-complexity presentations; pharmaceutical confounding is limited as anesthetic protocol was unchanged.

The surgeon experience phase captures simultaneously evolving behaviors that cannot be disentangled retrospectively: case-complexity expansion, increasing anesthetic volumes, and potentially greater detection vigilance. Early-phase redirection of higher-complexity cases to general anesthesia likely underestimates Phase 1 TFND risk. Identical anesthetic formulation throughout partially mitigates pharmaceutical confounding.

Conclusion

TFND following open Lichtenstein repair under local anesthesia occurred in 11.6% of patients but was uniformly transient and self-limited, with complete spontaneous resolution within 1.5–6 hours and no permanent neurological sequelae. Multivariable analysis identified complex hernia (aOR 5.93), advanced operative phase (phase 2: aOR 6.78; phase 3: aOR 13.65), female sex, and left-sided hernia as independent risk factors for TFND, while ODS was independently associated with lower odds of TFND (aOR 0.41). These findings suggest that TFND risk is more strongly associated with operative complexity and evolving anesthetic infiltration behavior across the surgeon experience continuum, rather than anesthetic dose alone.

The composite case-mix index provided a



novel and preliminary framework for quantifying operative burden evolution across experience phases, demonstrating that increasing TFND incidence parallels a progressive rise in the composite operative challenge rather than hernia classification alone.

The lower TFND risk observed among outpatient day surgery patients, persisting after multivariable adjustment, suggests that ambulatory inguinal hernia repair under local anesthesia can be safely performed in appropriately selected patients, even as operative complexity increases across a surgeon's experience trajectory.

These findings have practical implications for perioperative counseling and operative planning, particularly in complex cases and for female or left-sided presentations. Refinement of local-anesthesia infiltration techniques — including potential adoption of ultrasound guidance to improve tissue-plane precision and minimize inadvertent femoral nerve exposure — warrants prospective evaluation.[22,23] Future studies with standardized neurological outcome assessments and imaging correlation are needed to further characterize the anatomical determinants of TFND and validate strategies for its prevention.

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