Groin anatomy, preoperative pain, and compression neuropathy in primary inguinal hernia: What really matters

Robert Wright[*], Troy Salisbury, Jordan Landes

Cascade Hernia Institute, USA

ABSTRACT

Introduction: Enlargement of the ilioinguinal nerve distal to the inguinal ring is common in primary open inguinal herniorrhaphy and is histologically consistent with compression neuropathy. However, the origin of this neuropathy has not been thoroughly studied in primary inguinal hernia.

Methods: In this prospective study, 143 primary inguinal herniorrhaphies were performed. Prior to surgery, all patients completed a preoperative pain questionnaire from the Carolina Comfort Scale and Visual Analog Scale—evaluating pain with various activities. Pain scores were statistically compared with several different anatomical surgical observations.

Results: When each variable is individually compared with pain scores, a significant positive correlation exists between nerve enlargement and increased pain compared to those without enlargement for preoperative "most of the time pain" ($P < 0.0017$). There is also a statistically significant positive correlation between nerve enlargement and external ring fibrosis ($P < 0.001$). 81% of patients with enlargement have histological abnormalities.

Conclusion: Preoperative pain in primary inguinal hernia is correlated with ilioinguinal nerve enlargement, which is also correlated with fibrosis of the external oblique fascia at the external ring.

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1. Introduction

Nerve enlargement in primary inguinal hernia was first described as occurring in 34% of patients, most commonly occurring with the ilioinguinal nerve at the external inguinal ring. These nerves were histologically confirmed to be abnormal.[1] (see Figs. 1 and 2)

This abnormality was further confirmed by histological analysis in a smaller series where 35 primary inguinal hernia patients were prospectively studied using a preoperative pain scale and H&E histological examination of ilioinguinal nerve samples taken near the external inguinal ring. Histological analysis revealed that this gross enlargement is due to an increase in true nerve diameter and an expansion of the epineurium. Patients with visibly enlarged ilioinguinal nerves were found to have significantly increased preoperative pain.[2] Furthermore, known histologic changes of compression neuropathy were present, such as increased myeloid in the perineurium and epineurium, and these changes correlate with increased preoperative pain.[3]

In recurrent inguinal hernia, the presence of nerve enlargement follows a similar distribution involving the ilioinguinal nerve in 69% of cases and most commonly occurs also at the external inguinal ring.[4] These results suggest there is an intrinsic correlation between some aspect of anatomy of the herniated inguinal canal and nerve enlargement leading to a common pathway of compression neuropathy in some patients.

We have undertaken a larger study to confirm early findings and expand this search into the underlying anatomic alignment in order to evaluate what factors might contribute to compression neuropathy and preoperative pain in primary inguinal hernia. This current study investigates anatomical and operative hernia observations including method of hernia diagnosis, incarceration status of the hernia, medial vs. lateral hernia type, hernia size, degree of fibrosis at the external inguinal ring, as well as ilioinguinal nerve, genital branch nerve and iliohypogastric nerve trajectories in relation to preoperative pain and enlargement of the ilioinguinal nerve. Histology of the enlarged nerves is also examined.

* Corresponding author.
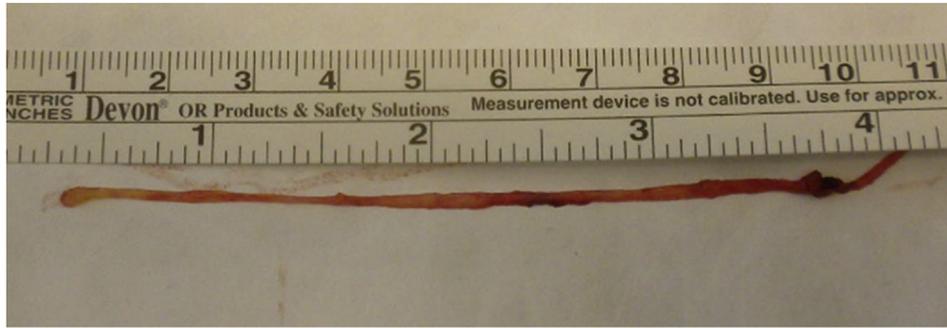 *E-mail address:* Bob@meridiansurgerycenterwa.com (R. Wright).

Fig. 1. Not enlarged ilioinguinal nerve.

2. Materials and methods

A prospective study of 143 primary outpatient inguinal hernia repairs was carried out on males over the age of 22 during 2017 and 2018 in a private practice setting using open Lichtenstein technique. The study design was reviewed, approved, and monitored by a hospital institutional review board. All patients gave consent for nerve resection if identified during surgery. These patients were assigned study identification numbers to allow a blinded study and underwent preoperative history and physical examination, as well as routine preoperative pain score testing with a validated hernia-specific pain measure—the Carolina Comfort Scale (CCS) and 3 additional visual analog scale (VAS) questions. CCS is a visual analog graphic scaled response (Likert Scale) survey where patients rate common hernia-related symptoms during 8 activities of varying intensity: laying down, bending over, sitting up, activities of daily living, coughing or deep breathing, walking, stairs, and exercise.[5,6] VAS questions were formatted similarly—asking maximum pain level, pain most of the time, and pain while at rest. Exclusion criteria for enrollment in this study included women, men under the age 23, patients with recurrent hernias, persons with incomplete data, and those who refused consent.

During Lichtenstein repair, routine neurectomy of the entire visible segment of the ilioinguinal nerve was carried out. Transection was done beyond the external inguinal ring and the nerve was mobilized proximally to its penetration point through the internal oblique muscle. Depo-Medrol (40 mg) was injected in the muscle adjacent to the nerve. The nerve was then put under tension and transected at the muscle with scissors and allowed to retract into the muscle. If bleeding occurred, the site was packed for 5 min rather than cauterized. Nerves were excised and grossly inspected by the surgeon. Nerves with no gross evidence of enlargement at

the external ring, or neuroperforatum were designated as not enlarged. Ilioinguinal nerves that exhibited any enlargement at and beyond the external inguinal ring were labeled enlarged. We compared patients with enlarged nerves versus patients with un-enlarged nerves for statistical evaluation. Enlarged nerves were sent for routine H&E sectioning and, the results were tabulated.

Hernia anatomy was evaluated using the European Hernia Society classification: hernia size (no hernia detected, <1.5 cm, <3 cm, >3 cm) and hernia type (direct or indirect) were documented. Additionally, the hernia incarceration status (incarcerated or not), degree of fibrosis of the external oblique fascia at the external ring (none, very thin fascia, mild to moderate adhesions/fibrosis, dense fibrosis, fibrosis involving nerve), the method of hernia determination (visible, palpable, determined by imaging), status of genital branch nerve (not seen, enlarged, not enlarged), ilioinguinal nerve trajectory (no nerve seen, follows cord to external ring, medial neuroperforatum at an angle <40°, medial neuroperforatum at an angle >40°, bifurcated), and iliohypogastric nerve course (not seen, low course, high course) were recorded.

The resulting data was then evaluated by a statistician to determine if there were any statistically significant findings between the intraoperative anatomical information and the preoperative pain and patient classification information. Anatomical variations between patients with enlarged and un-enlarged nerves were examined as well as preoperative pain levels between patients with enlarged and un-enlarged nerves for each anatomical category. Group means between categories were compared using independent samples t-tests for independent measures utilizing robust sandwich variance estimator to account for multiple observations per patient. Due to the high number of dependent variables examined, our calculated p-values were adjusted to Holm-Bonferroni p-values, in order to reduce the likelihood of type 1

Fig. 2. Enlarged ilioinguinal nerve.

statistical error in our results. Confidence intervals were calculated as well to increase our confidence that any difference or lack thereof between groups is true and not due to random variance.

3. Results

One hundred forty-three men, aged 23–88, were prospectively enrolled who underwent open inguinal hernia by Lichtenstein repair. All patients completed preoperative expanded CCS pain score surveys. Twenty patients were found not to have a visible ilioinguinal nerve (14%). Of the patients who had a visible ilioinguinal nerve, all were resected. One hundred four patients who had visible ilioinguinal nerves had also completed all survey questions for pain. Of those, forty were found to have grossly uniform diameter of the ilioinguinal nerve and were therefore categorized as having unenlarged nerves (38%). The remaining 64 patients had size disparity of the nerves and were therefore categorized as having enlarged nerves (62%). ANOVA analysis between patients classified as having no enlarged nerves, at least one enlarged nerve and an unknown number of enlarged nerves indicates that these three groups are not significantly different from each other on the basis of both age and BMI (Table 1). Of the 64 patients with the noted enlarged nerves, 58 had nerve segments sent for routine H&E sectioning. Of those sectioned nerve segments, 81% were described as having features consistent with compression neuropathy: increased myxoid/edema, perineural fibrosis, neuroma or traumatic neuroma.

Comparison of the preoperative pain of patients with enlarged and un-enlarged ilioinguinal nerves demonstrates a statistically significant increase in pain for patients with enlarged nerves in five out of ten survey questions for pain: most intense pain (P < 0.006), most of the time pain (P < 0.0002), cough/deep breathing pain (P < 0.017), walking pain (P < 0.016), and walking-up-stairs pain (P < 0.022) (Table 2). For all five of these pain criteria, the difference in mean pain scores does not contain zero at a 95% confidence interval. After correcting for multiple comparisons and protecting against the inflation of type I error using the Holm-Bonferroni method, most of the time pain (P = 0.0017) remains statistically significant and most intense pain (P = 0.051) is just above the significance cut-off (Table 2).

Further comparison of the anatomical variations of patients with enlarged or unenlarged ilioinguinal nerves demonstrated a statistically significant trend that nerve enlargement is uncommon if the external oblique fascia is very thin, but correlates with thicker fibrosis of the external inguinal ring (P < 0.001) (Table 3). Also, fibrosis involving the ilioinguinal nerve was found solely in patients with enlarged nerves (P < 0.001) (Table 3).

When each other variable is individually compared with preoperative pain scores, there is little to no significant correlation between preoperative pain and operative findings of: method of hernia diagnosis, hernia size, whether the hernia was medial or lateral, incarceration of the hernia, fibrosis of the external oblique, ilioinguinal nerve trajectory, iliohypogastric nerve course, and

genital branch nerve course. For both the comparison of pain scores to incarceration status and whether the hernia was medial or lateral, the mean pain score difference for all ten pain criteria at a 95% confidence interval includes zero. This further supports that there is no evidence of a significant difference in preoperative pain for these two anatomical variables. When each anatomical finding is individually compared between patients with unenlarged and enlarged ilioinguinal nerves at the external inguinal ring, there is no significant difference between the anatomical variations in those with enlarged nerves and those with unenlarged nerves in operative findings of: hernia size, whether the hernia was medial or lateral, incarceration status, status of the genital branch nerve, ilioinguinal nerve trajectory, iliohypogastric nerve course, nor the method of hernia diagnosis prior to surgery (Table 3).

4. Discussion

We found that 62% of patients undergoing primary inguinal hernia repairs using open Lichtenstein technique have grossly visible enlargement of the illioinguinal nerve distal to the external inguinal ring. In 81% of these patients the enlargement was confirmed to be consistent with entrapment neuropathy or "neuroma." If a patient's ilioinguinal nerve is grossly enlarged, our analyses demonstrate a statistically significant increase in the preoperative pain most of the time (P < 0.0017). One other study, to our knowledge, has examined this relationship between ilioinguinal nerve enlargement and preoperative hernia pain, and found very similar results.[2] In that previous study, 63% of patients undergoing primary inguinal hernia repairs were shown to have grossly visible enlargement of the illioinguinal nerve distal to the inguinal ring. Also, that previous study demonstrated that increased preoperative pain "most of the time", among multiple other pain categories, was correlated with ilioinguinal nerve enlargement (P < 0.05). Nearly identical findings in the only other study to inquire into this suggests that ilioinguinal nerve enlargement may be a sign of entrapment neuropathy and ongoing preoperative pain in primary inguinal hernia.

Another major finding of our study is that nerve enlargement is uncommon if the external oblique is very thin, but correlates with thicker fibrosis of the external inguinal ring (P < 0.001) and that fibrosis involving the ilioinguinal nerve was found solely in patients with enlarged nerves (P < 0.001). The only anatomical variation that differed between patients with enlarged and un-enlarged nerves was the fibrosis; this suggests that fibrosis of the external inguinal ring and the ilioinguinal nerve is the only finding that correlates with of nerve enlargement. This is noteworthy since our data suggests ilioinguinal nerve enlargement may be a source of constant pain in primary inguinal hernia and fibrosis of the external ring and ilioinguinal nerve is a possible contributor to nerve enlargement.

Our results support previous hypotheses suggesting the external oblique fascia edge can create a constriction site as it intersects with the ilioinguinal nerve leading to this nerve enlargement and increased pain consistent with compression neuropathy.[3] The fascial edge at the external inguinal ring can act as a friction point involving the ilioinguinal nerve as the hernia exerts force, which compresses the nerve. The inguinal hernia repeatedly results in passage of preperitoneal and intraabdominal contents beyond the external inguinal ring and this mushrooming of material under pressure through the external ring can exert force repeatedly on the ilioinguinal nerve. This could result in the constriction required to initiate compression neuropathy as we have confirmed histologically. It could be the case that when a patient has waited until they are in pain "most of the time" before surgery, enough pressure has been exerted on the nerve to allow nerve damage—resulting in

Table 1
Pain scores by patient demographics.

	no enlarged nerves (n = 31)		at least one enlarged nerve (n = 62)		unknown number of enlarged nerves (n = 34)		p-value
	mean	sd	mean	sd	mean	sd	
Age	51.3	16.7	53.6	13.8	52.2	16.1	0.8
BMI	27.9	4.0	27.1	4.2	27.9	5.5	0.6

Table 2
Pain scores by enlargement or No enlargement.

	Nerve enlargement at neuroperforatum/external ring (n = 64)		No enlargement (n = 40)		Difference (enlarged - not)	95% confidence interval		p-value	Holm-Bonferroni p-value
	Mean	Standard Deviation	Mean	Standard Deviation					
Most intense pain	**2.9**	1.5	**2.0**	1.8	−1.0	−1.6	−0.3	0.0057	0.051
Most of the time pain	**1.7**	1.2	**0.9**	1.0	−0.8	−1.3	−0.4	0.00017	0.0017
Laying Down Pain	0.9	1.1	0.6	1.0	−0.3	−0.8	0.1	0.1	NS
Bending Over Pain	1.5	1.6	1.1	1.4	−0.4	−1.0	0.2	0.2	NS
Sitting Up Pain	1.2	1.2	0.8	1.2	−0.3	−0.8	0.1	0.15	NS
Daily Living Activities Pain	1.6	1.5	1.1	1.5	−0.5	−1.1	0.0	0.07	NS
Cough/Deep Breathing Pain	1.8	1.6	1.1	1.4	−0.7	−1.2	−0.1	0.02	NS
Walking Pain	1.5	1.4	0.9	1.3	−0.6	−1.1	−0.1	0.02	NS
Walking Up Stairs Pain	1.5	1.5	0.9	1.3	−0.6	−1.2	−0.1	0.02	NS
Exercising Pain	1.7	1.7	1.2	1.5	−0.6	−1.2	0.1	0.08	NS

compression neuropathy.

Compression neuropathy is characterized by measurable enlargement of a peripheral nerve near anatomical constriction sites and pain.[7–9] Previous research has shown that ilioinguinal nerves that are grossly enlarged at the external inguinal ring constriction site are histologically consistent with nerves with effected by compression neuropathy elsewhere in the body.[3] These enlarged nerves were shown to be demonstrate increased nerve diameter, increased fascicle count, and increased myxoid material both within the perineurium and endoneurium, which all were in turn associated with increased preoperative pain: characteristic findings of compression neuropathy.[3] This suggests that when the ilioinguinal nerve is grossly enlarged and causing pain, it is

evidence of compression neuropathy in this nerve. Our current research supports these previous findings because in our larger series, ilioinguinal nerve enlargement was correlated with increased preoperative pain as well histological abnormalities.

Our results indicate that there is no relationship between preoperative pain in primary inguinal hernia and the method of hernia determination, hernia size, whether the hernia is direct or indirect, whether the hernia is incarcerated or not, fibrosis of the external oblique fascia, ilioinguinal nerve trajectory, iliohypogastric nerve course, enlargement of the genital branch nerve, nor patient age and BMI. This is surprising since many of these findings are often associated with increased severity of hernias and naturally assumed to be contributors of increased pain. Therefore, many of

Table 3
Nerve Enlargement/Uniformity vs Hernia Variations.

		Nerve Enlargement at Neuroperforatum/External Ring				p-value
		enlarged		not enlarged		
		n	%	n	%	
Hernia Size	no hernia detectable	1	20%	4	80%	0.3
	<1.5 cm	33	63%	19	37%	
	<3 cm	23	64%	13	36%	
	>3 cm	4	67%	2	33%	
Hernia Type: Medial or Indirect	lateral/indirect hernia	**43**	70%	**18**	30%	0.08
	medial/direct hernia	**16**	52%	**15**	48%	
Incarceration Status	incarcerated	42	58%	30	42%	0.4
	not incarcerated	21	68%	10	32%	
Fibrosis of External Ring	none	**3**	43%	**4**	57%	0.001
	very thin fascia	**17**	49%	**18**	51%	
	mild to moderate adhesions/fibrosis	**22**	63%	**13**	37%	
	dense fibrosis	**7**	54%	**6**	46%	
	fibrosis involving nerve	**15**	100%	**0**	0%	
Fibrosis Involving Nerve	no fibrosis or fibrosis not involving nerve	**49**	54%	**41**	46%	0.001
	fibrosis involving nerve	**15**	100%	**0**	0%	
Status of Genital Branch Nerve (Condensed)	not seen	19	70%	8	30%	0.5
	not enlarged	44	58%	32	42%	
	enlarged	2	67%	1	33%	
Ilioinguinal Nerve Trajectory (Condensed)**	follows cord to external ring	36	62%	22	38%	0.9
	medial neuroperforatum at an angle <40°	8	57%	6	43%	
	medial neuroperforatum at an angle >40°	13	65%	7	35%	
Iliohypogastric Nerve (Condensed)	not seen	13	62%	8	38%	0.9
	high course	34	61%	22	39%	
	low course	17	65%	9	35%	
Hernia Determination	visible	48	66%	25	34%	0.4
	palpable	10	50%	10	50%	
	determined by imaging	7	54%	6	46%	

the factors that have been thought to contribute to pain do so to a similar degree in primary inguinal hernia, and actually do not stand out as factors associated with more pain, as our confidence intervals support.

These findings could potentially have a significant impact in the recommendations regarding the timing of surgery for primary inguinal hernia. The "watchful waiting" approach is commonly recommended in regards to the treatment of primary inguinal hernia, such that no immediate action is taken.[10] In our study, nerve enlargement was found to be correlated with constant pain in primary inguinal hernia, and fibrosis of the external ring and ilioinguinal nerve from frictioned sliding was found to be correlated with this nerve enlargement. If the goal of the general surgeon—as it pertains to primary inguinal hernia—is to diminish the potential for chronic postoperative pain, perhaps the intervention needed is early surgery before compression neuropathy is allowed to occur.[11] Several studies have demonstrated that preoperative pain scores correlate well with chronic postoperative pain.[12—14] There are many studies demonstrating that the rate of postoperative pain varies between 3 and 12%, and this is not changing despite numerous attempts to change our operative approach.[11,12,14] Perhaps the natural biology of compression neuropathy is one of the underlying causes of this postoperative pain status. Certainly, this is well known in compression neuropathy associated with carpal tunnel syndrome, where 6—25% of patients have persistent neurologic symptoms, despite adequate nerve decompression.[9,15—17] If compression neuropathy were part of inguinal hernia pathology and natural history, it would be expected that a certain percentage of patients would experience residual pain after repair by any technique due to permanent pre-repair nerve damage.

Although this study had a substantial amount of patients enrolled, it is limited by being a single surgeon series with the uncertainty of subjective pain scales. Trends toward significance that could be better understood with a larger sample. There is a need for other research to go beyond this study and examine the molecular changes to the enlarged nerves. We identified how an enlarged ilioinguinal nerve affects patients, but we did not examine what is different about that nerve and its neurons on a cellular level. One study researched the tissue-level histological changes,[3] but there is still no published research to our knowledge on how enlarged nerves may be affected in regards to demyelination, edema, and Wallerian degeneration. Research into this area would provide further clarification into whether what appears to be compression neuropathy in the ilioinguinal nerve in primary inguinal hernia is identical to compression neuropathy elsewhere in the body.

5. Conclusion

Gross enlargement of the ilioinguinal nerve just distal the external inguinal ring occurs in 62% of patients undergoing primary inguinal hernia repair, and 81% of these patients had abnormal histology consistent with compression neuropathy or "neuroma." Patients with enlarged nerves experienced increased preoperative pain compared to those with unenlarged nerves reported by Likert pain surveys. Nerve enlargement is uncommon if the external oblique is very thin, but correlates with thicker fibrosis of the external inguinal ring and fibrosis involving the ilioinguinal nerve was found solely in patients with enlarged nerves. Nerve enlargement at fascial constriction sites and associated pain are characteristic for compression neuropathy. We conclude that in primary inguinal hernia, patients whose ilioinguinal nerve courses past a firm external oblique fascia are at risk for compression neuropathy.

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