A Single Surgeon Surgical Learning Curve for Unilateral Biportal Endoscopic Spine Surgery

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INTRODUCTION: Minimally invasive surgical methods incorporate muscle-preserving techniques for spinal access, preserving the central support structures that serves to reduce both intraoperative blood loss and postoperative pain. Microscopic decompression (MD) and percutaneous endoscopic transforaminal discectomy approaches present challenges related to steep learning curves. To address these limitations, the technique known as unilateral biportal endoscopy (UBE) is introduced. This study aims to characterize an experienced single-surgeon learning curve for UBE spine surgery.

METHODS: Patients undergoing UBE were retrospectively identified. The cumulative sum (CUSUM) of operative time separated cases into three phases: learning, practicing, and mastery. A polynomial function was fitted to identify these phases. Demographics, perioperative characteristics, complications, patient-reported outcomes (PROMs), were collected and included Patient-Reported Outcomes Measurement Information System-Physical Function (PROMIS-PF), visual analog scale (VAS) Leg/Back, and Oswestry Disability Index (ODI). Minimum clinically important difference (MCID) achievement was determined, and inferential statistics compared the phases.

RESULTS: Of 91 total cases, there were 16 patients in the learning phase, 27 in the practicing, and 48 in the mastery. The mean postoperative follow-up time was 3.10±1.82 months. A significantly greater percentage of patients had central stenosis in the practicing phase, and operative times were greatest in the mastery phase ($p < 0.05$, all). No significant intraoperative complications occurred, but postoperative adverse events included one dural tear repaired with lumbar blood patch and one case of endoscopic fluid-induced meningitis treated conservatively with complete resolution. Intercohort MCID rates did not differ, and there were no differences between learning phases for PROMs.

DISCUSSION AND CONCLUSION: For an experienced minimally invasive spine surgeon, the learning phase for UBE was estimated to span 14-43 cases. Our database demonstrated three phases: cases 1-14 in the learning phase, 14-43 in the practicing, and 44-91 in the mastery. This single-surgeon learning curve demonstrates that UBE may be performed safely and with comparable outcomes by experienced spine surgeons.

Figure 1. Cumulative sum of operative time against case number. The phases were separated from inflection points defined through the polynomial function that fit the data and are represented through the dashed lines for the Learning Phase (n=14), Practicing Phase (16)(n=43), and Mastery Phase (n=43).

Table 1. Patient Demographics

Characteristic	Total (n=91)	Learning (n=16)	Practicing (n=27)	Mastery (n=48)	*p-value
Age (mean ± SD, years)	66.03±13.8	60.5±12.2	64.9±12.8	68.2±14.4	0.081
Gender					0.917
Female	54.1(56) (35)	31.3% (5)	57.0% (18)	55.3% (34)	
Male	45.9% (60)	68.8% (11)	43.0% (17)	66.7% (32)	
Ethnicity					0.985
White	75.3% (87)	75.3% (11)	70.4% (19)	78.7% (57)	
African American	4.60% (4)	6.67% (1)	7.41% (2)	2.13% (1)	
Hispanic	11.2% (10)	6.00% (1)	14.8% (4)	9.09% (4)	
Asian	4.60% (4)	6.67% (1)	3.70% (1)	4.26% (2)	
BMI (mean ± SD, kg/m²)	29.1±5.41	28.7±3.21	28.4±3.77	29.1±5.58	0.938
Comorbidities					
Smoker	10.4% (9)	0.0% (0)	11.1% (3)	12.8% (6)	0.338
Hypertension	13.7% (14)	12.5% (2)	18.2% (5)	14.9% (7)	0.822
Diabetes	3.38% (3)	6.25% (1)	3.70% (1)	2.08% (1)	0.714
ASA Classification					0.846
1/2	90.4% (83)	87.5% (14)	92.6% (25)	89.4% (42)	
3/4	10.4% (9)	12.5% (2)	7.41% (2)	10.6% (5)	
CCI Score (Mean ± SD)	1.06±1.52	0.53±1.09	0.86±1.24	1.17±1.69	0.285

BMI = body mass index; CCI = Charlson Comorbidity Index; ASA = American Society of Anesthesiologists; SD= standard deviation
*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables

Table 2. Perioperative Characteristics

Characteristic	Total (n=91)	Learning (n=16)	Practicing (n=27)	Mastery (n=48)	*p-value
Spinal Pathology					
Herniated Nucleus Pulposus	84.6% (77)	93.8% (15)	81.5% (22)	83.3% (40)	0.525
Central Stenosis	54.0% (72)	93.8% (15)	96.3% (26)	75.0% (36)	**0.026**
Foraminal Stenosis	70.3% (64)	87.5% (14)	70.4% (19)	64.6% (31)	0.221
Number of levels Decompressed					0.451
One	53.1% (59)	93.3% (14)	85.3% (20)	59.5% (25)	
Two	46.9% (52)	6.67% (1)	14.7% (4)	21.5% (5)	
Spinal Levels					0.312
L3-4	2.20% (2)	6.25% (1)	0.0.0%	2.08% (1)	
L4-5	39.6% (28)	25.0% (4)	25.2% (6)	37.5 (10)	
L5-S1	46.2% (42)	87.5% (14)	55.6% (15)	35.4% (17)	
Operative Time (minutes to Skin Closure) (Mean ± SD, min)	51.7±20.7	34.4±26.8	53.9±9.1	56.3±16.5	**<0.001**
Estimated Blood Loss (Mean ± SD, mL)	24.6±2.55	26.4±2.5	25.8±8.0	24.4±3.38	0.645
Length of Stay (Mean ± SD, hours)	2.84±0.61	1.92±0.65	1.89±0.42	2.09±0.68	0.331
Postoperative Vas pain (Mean ± SD)	3.89±2.84	4.14±1.58	3.63±1.55	3.95±2.24	0.765
Postoperative Narcotic Consumption (OME) (SD)	14.0±5.48	11.7±4.72	13.4±5.89	14.8±5.33	0.123

PHD = postoperative day; mL = milliliters; SD = standard deviation; OME = oral morphine equivalents
*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables
Bolding denotes statistical significance ($p < 0.05$)

Table 3. Post-Surgical Complications*

Complication	Total (n=91)	Learning (n=16)	Practicing (n=27)	Mastery (n=48)
Acute Renal Failure	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Altered Mental Status	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Anemia, postoperative	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Arrhythmia	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Aspiration/Re-intubation	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Atelectasis	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Dysphagia	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Dural Tear	3.70% (1)	0.0% (0)	0.0% (0)	3.70% (1)
Epidural Hematoma	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Fever of Unknown Origin	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Ileus	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Incontinence, urinary	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Meningitis (endoscopic fluid induced)	3.70% (1)	0.0% (0)	0.0% (0)	3.70% (1)
Narcan/Vomiting	2.22% (2)	0.0% (0)	3.70% (1)	2.13% (1)
Pleural effusion	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Pneumonia	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Pulmonary Embolism	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Urinary Retention	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Urinary Tract Infection	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
Venous Thromboembolism	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

* Complication without return to the operating room

Table 4. Patient-reported outcomes

	Learning	Practicing	Mastery	p-value
Pre-Op				
PROMIS-PF	36.7±9.22	37.7±5.91	37.1±6.03	0.927
VAS Back	5.88±3.04	6.32±1.52	5.43±2.34	0.397
VAS Leg	6.38±1.85	5.68±2.07	5.35±2.75	0.613
ODI	23.3±11.9	20.4±8.95	18.8±7.29	0.417
6-week Post-Op				
PROMIS-PF	42.9±6.40	44.7±7.91	44.5±7.21	0.877
VAS Back	2.2±2.68	2.32±2.54	2.17±2.24	0.979
VAS Leg	2.6±3.21	1.89±2.40	2.13±2.09	0.829
ODI	8.62±5.21	11.9±10.4	12.1±8.10	0.625
Final Post-Op				
PROMIS-PF	48.3±8.37	45.4±13.1	48.0±9.22	0.650
VAS Back	2.38±2.50	2.24±2.30	2.11±2.38	0.955
VAS Leg	2.25±3.15	1.90±2.26	1.89±2.06	0.923
ODI	6.45±5.67	11.4±9.60	10.4±9.18	0.342
Δ Pre-Op to 6-week Post-Op				
PROMIS-PF	5.46±6.99	7.30±7.64	7.30±7.64	0.914
VAS Back	4.0±3.65	3.5±2.98	3.53±2.94	0.956
VAS Leg	2.87±2.35	3.23±3.18	2.75±2.70	0.807
ODI	11.4±13.3	7.74±9.54	9.23±8.41	0.737
Δ Pre-Op to Final Post-Op				
PROMIS-PF	12.5±15.5	8.88±8.15	9.96±8.87	0.735
VAS Back	3.4±2.97	3.36±2.62	3.39±2.89	0.999
VAS Leg	2.0±3.81	3.29±2.81	3.94±2.46	0.384
ODI	12.7±15.8	7.02±8.22	9.92±8.36	0.449
MCID Achievement				
PROMIS-PF	62.5% (5)	69.2% (9)	77.8% (14)	0.704
VAS Back	75.0% (3)	66.67% (10)	80.0% (10)	0.689
VAS Leg	60.% (3)	71.4% (10)	72.2% (13)	0.863
ODI	28.6% (2)	21.4% (3)	30.0% (6)	0.852

*p-value calculated using ANOVA for continuous variables and chi-square analysis for categorical variables