Intraoperative Neuromonitoring for Lateral Lumbar Interbody Fusion: An Intraoperative Protocol to Avoid Postoperative Neurologic Deficit

Nicole C. Record, DO, Alissa Carnelian, AuD, CNIM, Kristina Brady, AuD, CNIM, Stacie Tran, MPH, Daniel Thibaudeau, MD, Behrooz Akbarnia, MD, Robert K. Eastlack, MD, Gregory M. Mundis Jr., MD

San Diego Spine Foundation

Scripps Clinic, San Diego, CA, USA

Society for Minimally Invasive Spine Surgery

Las Vegas, NV

October 31-November 2, 2019

Disclosure: We received a Scripps Clinic Medical Group (SCMG) grant for this project

Background

- **Goals/Advantages**
  - Indirect decompression, deformity correction, interbody fusion
  - Avoid complications with other interbody approaches (ALIF, TLIF/PLIF)
- **Risk**-Neurologic Injury to individual nerves or nerve plexus
  - Anatomic studies (Moro et al 2003, Uribe et al, 2005, Park et al 2010)
  - Intra-operative neuromonitoring
    - EMG, SSEP (Silverstein et al, 2014), MEP (Block et al, 2015)

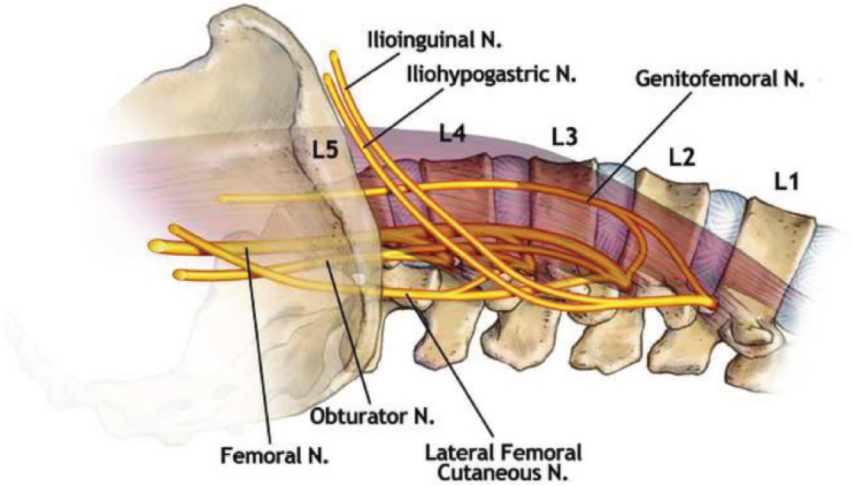


Figure 4. Illustration of the position of the nerves relevant to a lateral transpsoas approach.

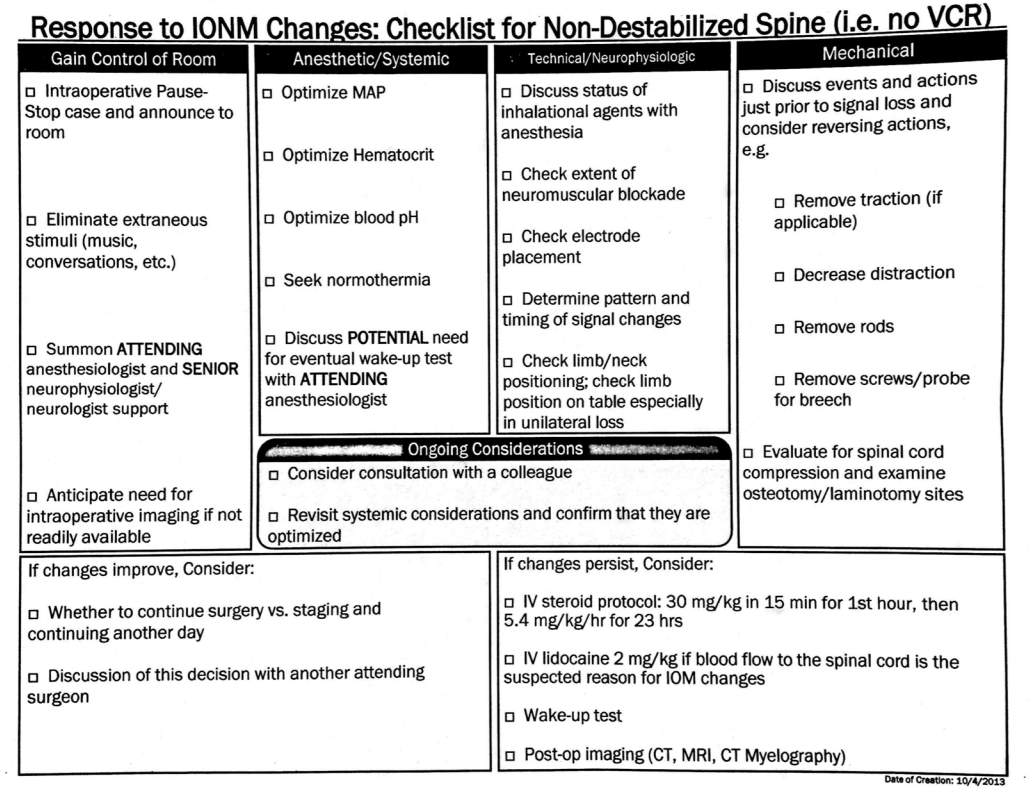
Uribe, Juan S., et al. *Spine*, vol. 35, no. Supplement, 2010.

San Diego Spine Foundation

Scripps

Background

- Intraoperative checklists have been studied and created for spine surgery when neuromonitoring is used (Vitale et al, 2014)
- LLIF is frequently performed with neuromonitoring
  - No consensus on extent of NM modalities
- No checklists or protocol exist for alerts that occur during LLIF procedures
  - Unique/additional potential causes from other surgical approaches



Response to IONM Changes: Checklist for Non-Destabilized Spine (i.e. no VCR)

Gain Control of Room	Anesthetic/Systemic	Technical/Neurophysiologic	Mechanical
☐ Intraoperative Pause-Stop case and announce to room	☐ Optimize MAP	☐ Discuss status of inhalational agents with anesthesia	☐ Discuss events and actions just prior to signal loss and consider reversing actions, e.g.
☐ Eliminate extraneous stimuli (music, conversations, etc.)	☐ Optimize Hematocrit	☐ Check extent of neuromuscular blockade	☐ Remove traction (if applicable)
☐ Summon **ATTENDING** anesthesiologist and **SENIOR** neurophysiologist/ neurologist support	☐ Optimize blood pH	☐ Check electrode placement	☐ Decrease distraction
☐ Anticipate need for intraoperative imaging if not readily available	☐ Seek normothermia	☐ Determine pattern and timing of signal changes	☐ Remove rods
	☐ Discuss **POTENTIAL** need for eventual wake-up test with **ATTENDING** anesthesiologist	☐ Check limb/neck positioning; check limb position on table especially in unilateral loss	☐ Remove screws/probe for breech
	Ongoing Considerations		☐ Evaluate for spinal cord compression and examine osteotomy/laminotomy sites
	☐ Consider consultation with a colleague		
	☐ Revisit systemic considerations and confirm that they are optimized		

If changes improve, Consider:	If changes persist, Consider:
☐ Whether to continue surgery vs. staging and continuing another day	☐ IV steroid protocol: 30 mg/kg in 15 min for 1st hour, then 5.4 mg/kg/hr for 23 hrs
☐ Discussion of this decision with another attending surgeon	☐ IV lidocaine 2 mg/kg if blood flow to the spinal cord is the suspected reason for IOM changes
	☐ Wake-up test
	☐ Post-op imaging (CT, MRI, CT Myelography)

Date of Creation: 10/4/2013

Vitale, Michael G., et al. *Spine Deformity*, vol. 2, no. 5, 2014, pp. 333–339

Purpose

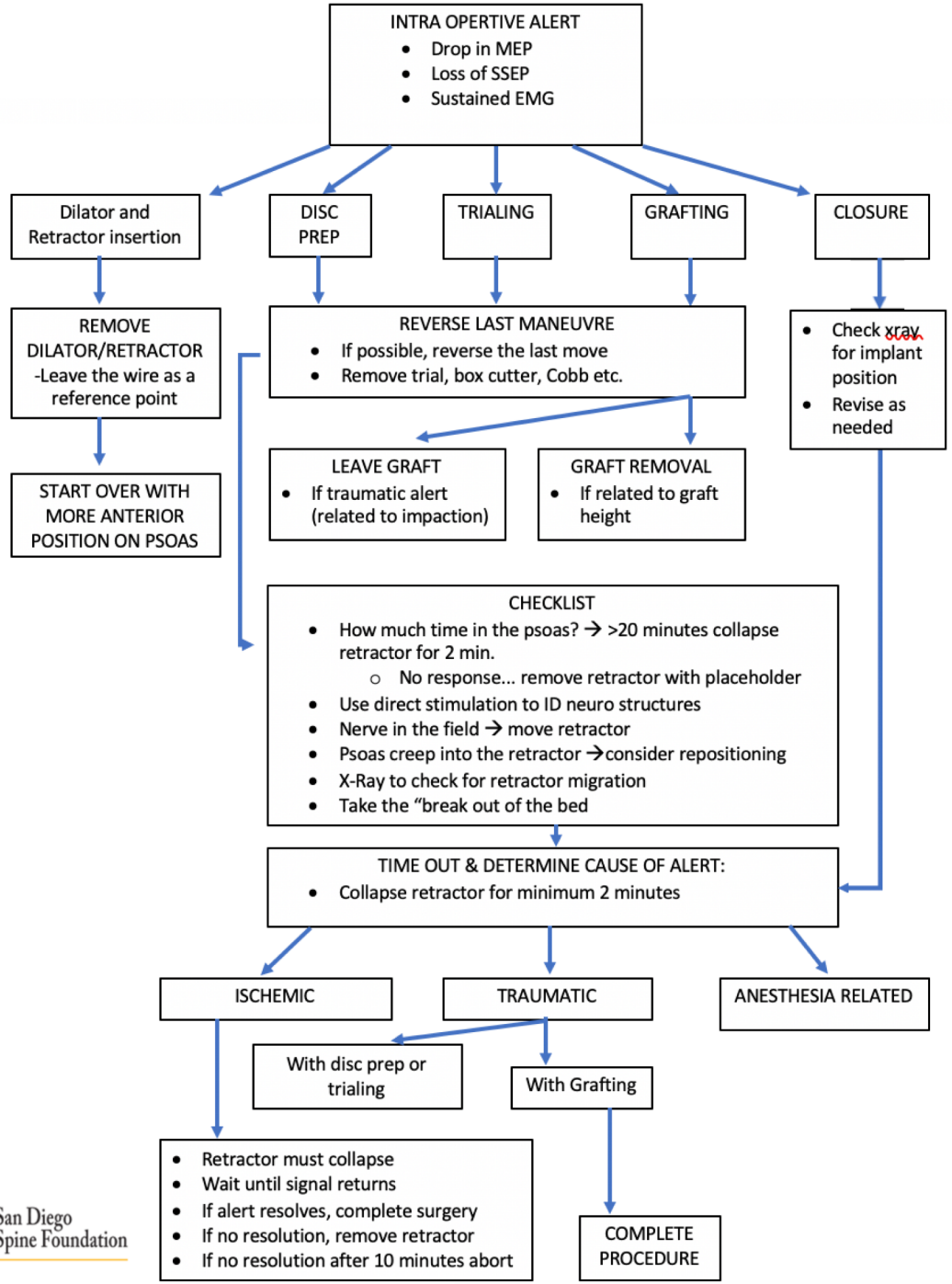
- **Primary purpose:** *To investigate the utility of neuromonitoring (NM) in LLIF and the development of an intra-operative protocol*

- Secondary purpose:
  - In depth evaluation of NM alerts: including timing, levels, diagnosis, association with dilator stim
  - Evaluation of Post op deficits (POD) and associated risks

Methods

- Retrospective review of all LLIF cases
  - Single institution
  - 2 experienced LLIF surgeons with 2 neurophysiologists
  - All indications for surgery (degenerative, deformity)
- Study Period: October 2014-October 2016
- Inclusion
  - At least 3 month follow-up
    - 2 year follow-up available
  - No concurrent Interbody (ALIF or PLIF/TLIF)
  - Complete neuromonitoring records
- Data Collection
  - Motor and sensory grading, clinical outcomes: Preop, 1 month and 3 months post op
  - Intra-operative: NM data, dilator stim alerts, Retractor timing (from time of insertion to time of removal from psoas)
- Neuromonitoring
  - **NVM5**
    - Proprietary monitoring system
    - Used for free run and triggered EMG
  - **Cadwell Cascade Pro**
    - SSEP
      - Saphenous as femoral nerve surrogate
      - posterior tibial, and ulnar nerve
    - TcMEP
      - adductor magnus, vastus medialis, vastus lateralis, tibialis anterior, and small muscles of the foot
      - Cremaster/mons for genitofemoral
  - **Alert = sustained EMG, ↓SSEP 50% and/or 10% latency increase, ↓MEP 50% from baseline**

INTRAOPERATIVE PROTOCOL



- **Evaluation**
  - During which part of the procedure
  - Type: ischemic, traumatic, anesthetic
- **Checklist:** Assess potential causes and solutions
  - Retractor time?
  - Nerve visualized in field?
  - Movement- retractor migration or muscle creep into field?
  - Tissue within disc space? (causing bouncing of retractor/instruments during insertion)
  - Trial or graft height-stretch
  - Bed break-prolonged time with stretch
- **Response**
  - Based on findings of evaluation and checklist

San Diego Spine Foundation

Scripps

Results- DEMOGRAPHICS and CLINICAL

- 83 patients were included with complete data
- 7 excluded for incomplete follow up
- 76 patients (123 levels) were studied

	N
Total Patients	76
Males	43
Females	33
Disease	
Degenerative	46
Deformity	30

Demographics

- M:F 43:33
- Mean age 67 ± 12.1
- Avg PSF levels: 2.3 ± 2.4
- Avg interbody levels was 1.6 ±0.9.
- Avg EBL: 193.2 ±312.6 cc
- Avg OR Time 204.2 ±109.2 min
- Diagnosis
  - Degenerative 46
  - Deformity 30

Clinical Outcomes

- At one month post op only NRS leg showed significant improvement
  - 6.8 → 4.4 (p=0.003)
- By 3 months all three outcome questions saw improvement
  - NRS Back: 7 → 4.7 (p<0.001)
  - NRS leg: 7.1 → 3.4 (p<0.001)
  - ODI: 45.3 → 30.8 (p<0.001)

San Diego Spine Foundation

Scripps

Results- ALERTS

- 14 (18.4%) had NM alerts triggering the protocol
  - 1 (7%) patient woke up with a POD (sensory and motor)
  - 9/14 (64.2%) had dilator stim threshold <10
- 62 (81.6%) had **no alert**
  - 37 (59.7%) had dilator stim <10 → 3 (4.8%) with POD (1 sens & 2 motor).
- 4/7 with lateral thigh numbness had alerts
- 5/12 with IP weakness had a NM alert
- Avg time to first alert → 13 min

	N	*p*
Neuromonitoring Alerts	14	
POD (both sensory + motor)	1	0.76
Dilator Stim		0.272
Dilator Stim <10	9	
Dilator Stim >10	3	
Dilator Stim No Data	2	

Type of Alerts	N
SSEP	3
MEP	6
EMG	9

Part where 1st alert occurred	N
Retractor insertion	4
Disc prep	3
Trial	2
Grafting	4
Closing	1

San Diego Spine Foundation

Results-DEFICITS

Only considered deficit if was **not** present preop

- **7 (10.9%) patients had POD** (3 sensory, 3 motor, 1 both)
  - 50% resolved by 1 month follow-up,
  - 85% resolved by 6 months
  - All resolved within 25 months
    - Patient with both sensory and motor deficit resolved by 25 month follow up
- 9 (11.8%) patients had ***lateral thigh numbness***
  - 78% resolved by 1 month
  - 89% resolved by 6 months
  - All resolved by 16 months
- 12 (15.8%) patients had ***psoas weakness***
  - 10 resolved by 1 month follow up visit (*9* resolved by discharge from hospital)
  - 1 lasted >12 weeks
  - 4 had an associated POD

	N	Type
POD	**7**	
Motor	3	1 Quad (4/5) 2 Tib Ant (4/5)
Sensory	3	1 L2 1 L2-L5 1 L4-S1
Both	1	L Quad (3/5) L IP (3/5) L3
NM Alert	**1**	Both
Lateral Thigh Numbness	**9**	
Psoas Weakness	**12**	
Assoc POD (P=0.001)	4	Both (M+S) Tib Ant (M) L2-L5 (S) L4-S1 (S)

Results: Diagnosis and Interbody Fusion

- **Diagnosis**
  - Patients carrying a ***deformity*** diagnosis were more likely to have a post operative ***sensory deficit***

	Degenerative	Deformity	*p*
N	46	30	
Postop Deficit	2	5	0.069
Sensory Deficit	0	4	0.011
Motor Deficit	2	2	0.658

- **Interbody Fusion (IBF)**
  - Number of IBF Levels
    - When comparing overall POD by level no significant difference was found
    - A multivariant logistic regression: **postoperative sensory deficit** was 15x more likely with 3 level IBF than in a single level (OR 15.67, CI 1.23, 199.92).
  - Location of IBF
    - No association with POD
    - **Most ALERTS at L3-4**
    - **ROC curve-Critical retractor time threshold 24.5 minutes**

Number	N	POD	Alerts	POD Sensory	POD Motor	Sensory Deficit OR (CI)
1 level IBF	48	2	10	1	2	1*
2 Level IBF	16	2	3	0	2	n/a
3 level IBF	7	2	1	2	0	**15.67 (1.23, 199.92)**
4 level IBF	5	1	0	1	0	11.75 (0.61, 225.35)
P-Value		0.183	0.676	**0.017**	0.424	

Location	#IBF levels	POD	P-Value	Total NM Alerts	P-Value	Retractor Time Mean (minutes)
Total	123	7	0.857	20	0.054	31.17 ± 24.35
T12-L1	3	0	n/a	0	n/a	61
L1-L2	13	0	n/a	0	n/a	27.17 ± 2.86
L2-L3	20	1	n/a	1	n/a	26.36 ± 15.76
L3-L4	34	2	0.955	10	**0.015**	29.24 ± 13.63
L4-L5	53	4	0.439	9	0.085	19.1 ± 6.36

Discussion- IOM LLIF PROTOCOL

1. IOM protocol was triggered in 14 patients with only 1 POD
2. Psoas weakness had an association with POD
    - Specifically sensory
3. Deformity cases were more likely to have a sensory deficit
    - 3+ IBF levels had increased risk of sensory deficit
4. No difference in POD by level
5. L3-L4 had higher risk of NM alert
6. Critical retractor time threshold 24.5 minutes for sensory

Conclusion

- Neuromonitoring can be used as an adjunct to help alert potential deficits to trigger an intraoperative checklist

- 6/7 POD were not associated with an alert highlighting the need to better understand the functional neuroanatomy