THE ROLE OF EFFECTIVE/SAFE NERVE ALLOGRAFTS

MR DETECTION IN THE DIAGNOSIS AND MANAGEMENT OF TRAUMATIC AND PLANNED TRIGEMINAL NERVE INJURIES

John R. Zuniga DMD, MS, PhD
Robert V. Walker DDS Chair in Oral and Maxillofacial Surgery
Professor, Departments of Surgery and Neurology & Neurotherapeutics
University of Texas Southwestern
Parkland Hospital
Children’s Medical Center
Dallas, Texas

FSOMS Mission
The mission of the Florida Society of Oral & Maxillofacial Surgeons is to improve the health of Florida residents through high practice standards, public and professional advocacy, ethical behavior, and to support its members through continuous professional education and advancement of the specialty.
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NERVE REPAIR PRINCIPLES/TECHNIQUES

- ACCESS PHASE
  - Goal: allow the ability to complete 2nd and 3rd phases (which affects outcome)
    - Exposure should always include normal nerve tissue on proximal and distal ends
    - Exposure of nerve length to allow preparation and mobilization (recommend 1 cm)
    - Provide unobstructed view by adequate retraction and retention of adjacent tissues
    - Ensure a surgical plane for the use of an operating microscope (or loupes)
- PREPARATION PHASE
  - Goal: identify normal nerve on the proximal and distal ends
    - Release mesoneurium from scar, etc. to explore the epineurial tissues for pathologic tissue (neuroma, scar, etc)
    - Identify normal fascicular pattern (fascicular patterns) from abnormal (intrafascicular scar, etc)
    - If abnormal, resect the ends till normal nerve fascicles identified (axon white, plump, protruding with interfascicular bleeding)
- MICROSURGERY PHASE
  - Goal: approximation of normal nerve tissues under no tension
    - If 5mm or less of nerve gap then direct neurorraphy
    - If >5mm of nerve gap then neurorraphy with nerve graft (autograft, allograft or conduit)

NERVE REPAIR PRINCIPLES/TECHNIQUES

- ACCESS PHASE OPTIONS
  - Transoral, buccal decortication
  - Extraoral, buccal decortication
  - Sagittal osteotomy

- PREPARATION PHASE OPTIONS
  - Loupes
  - Surgical microscope

- MICROSURGICAL PHASE OPTIONS
  - Direct neurorraphy with 8-0 nylon
  - Connector Assisted Repair (CAR)
  - Neurorraphy with autograft, allograft or conduit
IAN: ACCESS PHASE
1986-2008
IAN: ACCESS PHASE
1986-2008
IAN: PREPARATION AND MICROSURGERY PHASE
1986-2008
AVANCE Nerve Graft

Repairing Nerve with Nerve

ECM Maintained
Laminin Retained
Noncellular Inhibitors Cleared

Handles similar to autograft

Decellularized Nerve Graft
Does not cause Tissue Rejection

Ability to Match Nerve Stump Diameter
PROCESSED NERVE ALLOGRAFT

Human Peripheral Nerve Tissue (Avance® Nerve Graft, AxoGen, Inc)

- 3-Dimensional ECM scaffold
- Decellularized
- Pre-Degenerated
- Sterilized
- Preserved Architecture
  - Epineurium
  - Perineurium
  - Fascicles
  - Endoneural tubes
  - Microvasculature
Left proximal IAN

Left distal IAN at foramen

Right proximal IAN

Right distal IAN at foramen
Left proximal repair with AVANCE

Right AVANCE and Axoguard

Left AVANCE and Axoguard
AxoGen® Family of Products

**Avance® Nerve Graft**
- Bridge gaps up to 70mm
- Cable grafting (alone or in combination with autograft)
- Bridge a partially severed nerve

**AXOGRUARD™ Nerve Connector**
- Bridge gaps up to 5mm
- Coaptation aid for direct repair, grafting, or cable grafting
- Reinforce a coaptation site

**AXOGRUARD™ Nerve Protector**
- Wrap injured nerves up to 40mm
- Minimize risk of entrapment in compressed nerves
- Protect partially transected nerves
- Reinforce a coaptation site
AXOGUARD® NERVE PROTECTOR AND AXOGUARD® NERVE CONNECTOR

- Semi-Translucent
- Conformable to nerve
- Easily cut and sutured
AXOGUARD® NERVE PROTECTOR AND AXOGUARD® NERVE CONNECTOR

- Proprietary Processing & Terminal Sterilization
- Not reconstituted or chemically cross-linked
- 4 layers for added strength
- Semi-Translucent

Processing retains 3-D structure & composition of biological ECM
Forced misalignment and fascicular mismatch may occur when nerve stumps are repaired directly with suture.¹ ²

* Epineurium and connective tissue have been removed for illustration purposes.

Use of AxoGuard® Nerve Connector minimizes opportunity for fascicular mismatch and may improve outcomes.³ ⁴

*
OUTCOMES FOR RECONSTRUCTING THE TRIGEMINAL NERVE WITH AVANCE® NERVE GRAFT

- 20 nerve graft repairs in 18 patients from 2008 to 2012
- Follow up for minimum of 6 months
  - Useable data = 17
  - Lost to follow up or not completing 6 months = 3
- Sensory Analysis = NST Sensory Impairment Score
  - Both tests in level A within normative limits= Normal (0)
  - Level A abnormal, Level B & C normal = Mild (1)
  - Level A and B abnormal, Level C normal = Moderate (2)
  - Level A, B and C abnormal, but elevated = Severe (3)
  - Level A, B and C abnormal, and absent = Complete (4)
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<td>30-49</td>
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<td>Delayed (22-90)</td>
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OVERALL RECOVERY (N=17)

Pre op (2.54±1.3)  Post op (1.51±1.2)
83%  17%

Overall Recovery

Recovery (15)  No Recovery (3)
### OUTCOME RECOVERY RESPONSE TO AVANCE® NERVE GRAFT

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<td>n/a*</td>
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<tr>
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Recovery by Nerve Gap

Gap Length

- **0-5 mm**
  - Repair Number: Complete Impairment Score: 83%
  - Improvement: 17%
  - No Improvement: 83%

- **11-30 mm**
  - Repair Number: Complete Impairment Score: 82%
  - Improvement: 18%
  - No Improvement: 82%

- **31-70 mm**
  - Repair Number: Complete Impairment Score: 82%
  - Improvement: 18%
  - No Improvement: 82%
RECOVERY BY TIME TO REPAIR

Time to Repair

- **Complete**: 100%
- **Severe**: 0%
- **Moderate**: 100%
- **Mild**: 0%
- **Normal**: 67%

**Impairment Score**
- **Acute (< 22 days)**
  - Improvement: 100%
  - No Improvement: 0%
- **Delayed (22-90 days)**
  - Improvement: 100%
  - No Improvement: 0%
- **Chronic (> 90 days)**
  - Improvement: 33%
  - No Improvement: 67%

**Repair Number**
- **Acute (< 22 days)**
- **Delayed (22-90 days)**
- **Chronic (> 90 days)**
OUTCOMES FOR RECONSTRUCTING THE TRIGEMINAL NERVE WITH AVANCE® NERVE GRAFT

- **Safe**
  - No adverse events

- **Effective**
  - Sensory recovery in 83% of cases
    - Similar to historic outcomes for autogenous grafts
      - Lingual nerve = 90.5% FSR or USR
      - Inferior Alveolar Nerve = 87.3%
    - Independent of age, mechanism of injury, nerve type, gap length, and Sunderland class of injury*
    - Dependent upon time to repair (chronic >90d with higher impairment score)

- **Efficacy**
  - Better than historic outcomes for entubulation = 28% to 33% with some improvement
  - Autogenous - TBD
A Case Control, Multi-site, Positive Controlled, Prospective Study of the Safety and Effectiveness of Immediate Inferior Alveolar Nerve Processed Nerve Allograft Reconstruction with Ablation of the Mandible for Benign Pathology

John R. Zuniga DMD, MS, PhD
The University of Texas Southwestern

John Peter Smith Hospital, Fort Worth, Texas
Fayette Williams DDS, MD

OHSC, Portland Oregon
Dan Petrisor, DDS, MD
Ablation of the mandible for benign pathology requires resection of bone, teeth, soft tissue and inferior alveolar nerve (IAN). This study was designed to determine if the immediate reconstruction of the IAN with AVANCE allograft in conjunction with the simultaneous ablation and reconstruction of the mandible will be effective in restoring sensation of the lip and chin.

Options for IAN in large continuity defects
- Autograft
- Entubulation
- Allograft

Outcomes
- Safety
- Effectiveness
- Efficacy
RECONSTRUCTION: NERVE SPARING
NERVE SPARING
RECONSTRUCTION: AUTOGRRAFTING
IAN AUTOGRAFTING
RECONSTRUCTION:
NERVE SHARING
NERVE SHARING
NERVE SHARING (WITH THE TRIGEMINAL NERVE)
NERVE SHARING (WITH THE TRIGEMINAL NERVE)
NERVE SHARING (WITH THE TRIGEMINAL NERVE)
Nerve Allograft suspended to lateral flap using AXO GUARD
27 y/o female with large ameloblastoma

Step 1 = Intraoral surgical exposure at mental foramen

Step 2 = Extraoral surgical exposure and resection

Step 3 = Nerve allograft repair

Bilateral IAN allograft needed

Step 4 = Free flap including bone and soft tissue
Exposure – step 1

Resection – Step 2

Bone graft – Step 3

Nerve graft – Step 4
IMMEDIATE NERVE ALLOGRAFT RECONSTRUCTION WITH ABLATION OF MANDIBLE FOR BENIGN PATHOLOGY

INCLUSION CRITERIA

Patients (age 5-70) requiring the ablative resection of the unilateral or bilateral mandible for benign pathology which would include the continuity injury of the IAN were included.

The length of the graft must be between 4.5 and 7.0 cm.

Sensory values recorded before and at least twice with the last recording at 12 months postoperatively.

Safety data recorded during the immediate to 12 month postoperative times.
IMMEDIATE NERVE ALLOGRAFT RECONSTRUCTION WITH ABLATION OF MANDIBLE FOR BENIGN PATHOLOGY

- 26 patients from 2010 to 2016
- Follow up for minimum of 6 months
  - Usable data = 18
  - Lost to follow up or not completing 6 months = 5
- Screen Failures
  - 3 graft not possible (2 have served as positive control)
  - 1 case – failure to identify proximal end
  - 2 cases – decision to delay mandibular reconstruction

Sensory Analysis

- NST Sensory Score (MRSC)
  - S0 = No sensation
  - S1 = Deep cutaneous pain (severe sensory impairment)
  - S2 = Superficial pain and touch (moderate sensory impairment)
  - S3 = Superficial pain and touch without hyperesthesia and 2PDT >15mm (mild sensory impairment). Useful sensory recovery
  - S3+ = Same as S3 with good stimulus localization and 2PDT ~7 to 15mm (normal sensory impairment). Useful sensory recovery
  - S4 = same as S3 and 2PDT ~ 2 to 6mm Useful sensory recovery

Subjective Questionnaires

- DIRECT PATH (DP)
  - 15 questions on problems with unusual or altered feelings on face or mouth
- NUMERICAL RATING SCALE (NRS)
  - 12 questions rating intensity, unpleasantness and interference with daily activities by pain or altered sensations on face
- WORD CHOICES (WC)
  - 28 word list to indicate experienced any unusual or changed sensations on face in past week
Mean length of discontinuity = 59.75mm (45-70)
Mean length of allograft = 62.7mm (45-70 x 2 to 4mm)

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OVERALL NEUROSENSORY IMPAIRMENT SCORES

Anova = 0.003

T scores differences
a. group 1 v 2
b. group 2 v 4

8/18 USR at 3 months
15/18 USR at 6 months
16/18 USR at 12 months
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Direct Path – 15 questions on problems with unusual or altered feelings on face or mouth most affected and less likely to resolve at 1 year

- a. left over food in cheeks
- b. unusual feeling in face

Numerical Rating Scale – 12 questions rating intensity, unpleasantness and interference with daily activities by pain or altered sensations on face resolved and better than baseline at 1 year.

Word Choices - 28 word list to indicate experienced any unusual or changed sensations on face in past week
resolved and achieve baseline at 1 year

- a. numbness, tingling, tickling, swelling, cool, itching most frequent at 3 and 6 months
SAFETY DATA USING IMMEDIATE NERVE ALLOGRAFT RECONSTRUCTION WITH ABLATION OF MANDIBLE FOR BENIGN PATHOLOGY

- Infections – none
- Rejections - none
- Neuropathic pain - none
CONCLUSIONS

- Processed Nerve Allografts are safe and effective in restoring sensation to the lip and chin with 94% reaching useful and functional sensory recovery and >80% reporting similar sensations to preoperative subjective values.
Simulated Virtual Surgical Plan

Courtesy of Dr Thomas Schlieve

54 y/o male
Ameloblastoma left mandible
No sensory deficit
Simulated Virtual Surgical Plan

Courtesy of Dr. Thomas Schlieve
Mandible Marking Guide

Nerve Window Guide

Guide Fixation Holes

Nerve depth has been provided. All measurements are approximate.

Courtesy of Dr. Thomas Schlieve
Updated design of nerve window marking guide

Courtesy of Dr. Thomas Schlieve
Create channel with guide and remove guide

Widen with ultrasound device and expose proximal and distal 1cm from planned resection margins

Lateralize 1cm IAN distal and proximal

Courtesy of Dr. Thomas Schlieve
Place rigid plating system temporarily and assure no impingement on IAN

Complete planned resection

Place rigid plating system and bone graft

Insert nerve allograft with CAR

Prepare allograft for connector-assisted repair off table for insertion

AVANCE 2x3mm x 70mm
VSP® Reconstruction
Virtual Surgical Planning

Courtesy of Dr. Thomas Schlieve
WHAT'S NEW IN MICROSURGERY FOR TRIGEMINAL NERVE REPAIR

1. Pediatric Patients
2. Malignant Disease of Mandible
3. MRONJ
4. ORN
5. BMP

1. 3-D Microscopy
   Orb Eye

2. Navigational and Point Specific
   Synaptive
Proximal and Distal right lingual nerve isolation

Large amputation neuroma proximal end = Class V
Sonopet used for ostectomy to IAN
Uncovering IAN with sonopet

Class V injury right inferior alveolar nerve after exposure

3rd molar root socket

Distal IAN

Proximal IAN
Right lingual nerve

Neuroma – in-continuity
High magnification of Neuroma in continuity

93629807
DOS = 8/31/2018
orbeye used

12mm gap
BREAK TIME!!
MR DETECTION IN THE DIAGNOSIS AND MANAGEMENT OF TRAUMATIC AND PLANNED TRIGEMINAL NERVE INJURIES

John R. Zuniga DMD, MS, PhD
Robert V. Walker DDS Chair in Oral and Maxillofacial Surgery
Professor, Departments of Surgery and Neurology & Neurotherapeutics
University of Texas Southwestern
Parkland Hospital
Children’s Medical Center
Dallas, Texas

FSOMS Mission
The mission of the Florida Society of Oral & Maxillofacial Surgeons is to improve the health of Florida residents through high practice standards, public and professional advocacy, ethical behavior, and to support its members through continuous professional education and advancement of the specialty.
Misadventures in third molar surgery
1 wk (Nov 11, 2013)
Misadventures in implant surgery
8158 Closed Claims Through 2008

<table>
<thead>
<tr>
<th>Nerve damage cases</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental alveolar</td>
<td>704</td>
</tr>
<tr>
<td>Implants</td>
<td>114</td>
</tr>
<tr>
<td>Orthognathic</td>
<td>79</td>
</tr>
<tr>
<td>TMJ</td>
<td>30</td>
</tr>
<tr>
<td>Trauma</td>
<td>10</td>
</tr>
<tr>
<td>Cosmetic</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>938</strong></td>
</tr>
</tbody>
</table>
Incidence of Nerve Injury Consultation (by frequency)
- IAN (64%)
- LN (30%)
- Other (less significant)

Degree of Nerve Injury (by severity)
- LN
- IAN
- Other (less significant)

Etiology (by decreasing frequency)
- Odontectomy
- Orthognathic surgery
- Local anesthetic injection
- Implant surgery

Clinical Characteristics of Trigeminal Nerve (TN) Injury
Referrals to a University Centre

Nerve damage cases
- Dental alveolar: 704
- Implants: 114
- Orthognathic: 79
- TMJ: 30
- Trauma: 10
- Cosmetic: 1
- Total: 938

Odontectomy
- Most common procedure which led to referral
- Severe Impairment
  - 50% of LN
  - 25% of IAN
- Nerve Surgery was offered
  - 87% LN
  - 36% IAN

Implant Surgery
- Exclusively causes injury to only the IAN
- More common in females (6:1)
- Patients are generally much older (56 y/o)
- Impairment scores are less severe than odontectomy and orthognathic injuries to IAN
- No sensory impairment to moderate sensory impairment
Diagnosis
The Accuracy of Clinical Neurosensory Testing for Nerve Injury Diagnosis

John R. Zuniga, DMD, PHD, MS, Roger A. Meyer, DDS, MD, John M. Gregg, DDS, PHD, MS, Michael Miloro, DMD, MD, and Leon Davis DDS, MS, MD

A Contemporary Approach to the Clinical Evaluation of Trigeminal Nerve Injuries

John R. Zuniga DMD, MS, PhD, Greg K. Essig DDS, PhD


A. HISTORY AND PHYSICAL EXAMINATION

- Causes
  - Third molar
  - implant
- Time from injury
- Distribution
- Word choices
  - Normal
  - Paresthesia
  - dysesthesia
- Pain
  - Stimulus induced
  - spontaneous
- Functional deficits
  - Lip biting
  - Speech
  - taste
A. HISTORY AND PHYSICAL EXAMINATION

- Intraoral examination
- Self-injury
- Dystrophic changes
B. IMAGING OF NERVE INJURIES

- Dental radiology
- CT/Cone Beam
- MRN/MRI

Get back to this real soon!
C. CLINICAL NEUROSENSORY TESTING

- Sensory Impairment Score
  - Normal
  - Mild
  - Moderate
  - Severe
  - Complete

- Diagnosis
  - Seddon
  - Sunderland
Observe for Recovery
- Most Nerve Injuries Resolved by 6 months
- Rate of Regeneration in Man 1-2 mm/day

AGE
Location of Injury
Type of Injury
Time from the Injury*

Sensory Retraining
- Class 1 and 2
- Class 3
NERVE INJURY ASSOCIATED WITH THIRD MOLAR SURGERY

CONCLUSIONS (BEFORE 2017)

- Observation is indicated
  - For up to 3 months in unwitnessed injury
  - Hypoesthesia
  - Negative physical findings
  - No or mild sensory impairments
- Surgery treatment is indicated
  - Severe or complete sensory impairment up to or after 3 months (LN>IAN)
  - Negative word choices
  - Positive physical findings
- Treatment varies
  - Type of injury (class of injury)
  - Neuropathic pain
Determine the sensitivity, specificity and predictive values of the CNT using a 4-fold table with surgical findings as the “gold” standard

- Multisite, prospective, randomized, masked clinical trial
- Preoperative CNT and Sensory Impairment Score
- Postoperative surgical findings
NEUROSENSORY IMPAIRMENT SCORES

Patient Population

60 LN, 70 IAN

Male
IAN = 21
LN = 25

Female
IAN = 39
LN = 45

Duration of Injury (months)
Mean
IAN = 14.06±15.84
LN = 8.23±9.74

Range
IAN = 2-120
LN = 1-72

- More Diverse Distribution in IAN
- More homogenous in LN
NERVE INJURY SURGICAL FINDINGS

- Normal/Intact (N/I)
- Compressed/Intact (C/I)
- Neuroma-in-continuity (NIC)
- Partial Transection (PT)
- Complete Transection (CT)

More Diverse Distribution in IAN injuries

>80% of LN were Partial or Complete Transections
STATISTICAL RATES OF EFFICACY (%)

- **Sensitivity**
  - LN = 100
  - IAN = 85
- **Specificity**
  - LN = 62.5
  - IAN = 47
- **+Predictive**
  - LN = 95
  - IAN = 77
- **-Predictive**
  - LN = 100
  - IAN = 60
NOW WHAT?
TO DO OR NOT TO DO
CLINICAL NEUROSENSORY TEST

NST

- **Gold standard for diagnosis**
  - Inferior alveolar nerve (*IAN*)
    - PPV 77%, NPV 60%
  - Lingual nerve (*LN*)
    - PPV 95%, NPV 100%

- **Drawbacks to NST**
  - Delays treatment of higher class injury patients
  - Does not adequately delineate the anatomy and location of the injury
  - Can overestimate and underestimate the level of injury
Role of Magnetic Resonance Neurography in the Management of Peripheral Trigeminal Neuropathy

MR Neurography

- **Magnetic resonance neurography (MRN)** is the direct imaging of nerves in the body by optimizing selectivity for unique MRI water properties of nerves. It is a modification of magnetic resonance imaging.
- This technique yields a detailed image of a nerve from the resonance signal that arises from in the nerve itself rather than from surrounding tissues or from fat in the nerve lining.
- 3D, steady state and diffusion based, includes T2W

MRN Trigeminal Nerve

- Terumitsu et al. OOOO 111:95-102, 2011
  - T1W MR sequences in 2D
  - Endoneurial fluid alterations
  - Intra-neural edema
  - Mass lesions

Purpose: Evaluate a consecutive series of patients suspected of peripheral trigeminal neuropathy with MRN using a uniformed protocol to assess the correlation with surgical findings and impact of imaging in the clinical management.
MR IMAGING METHODS TO STUDY PERIPHERAL NERVE

- Anatomic MRN
  - 3 D reversed fast imaging with steady state precession (T2 PSIF)
  - Shows alterations of nerve caliber = quantitative criteria
  - Abnormal intraneural T2 signal intensity ratio (T2SIR) = qualitative criteria

- Diffusion-based Functional MRN
  - Diffusion Tension Imaging (DTI) shows alignment of water within nerve = tractometry
  - Shows functional evaluation of the intraneural pathophysiology
  - Altered diffusion characteristics correlate with axonal degeneration and regeneration
PERIPHERAL TRIGEMINAL MRN
NORMAL LEFT IAN
A, MIP coronal 3D PSIF image showing class II injury to the right IAN with mild increase in caliber (less than 50% of the left) and signal intensity of the right IAN (long arrow) in comparison with a normal left inferior alveolar nerve (short arrow). B, Sagittal reconstruction MIP 3D PSIF image showing increase in caliber and signal intensity of the right IAN (long arrow) proximal to injury site (arrowhead). C, Normal uniform caliber and signal intensity of the left IAN (short arrow).
A and B, MIP 3D coronal PSIF images show a hyperintense left LN (long arrow) with a 3-mm neuroma in continuity (demarcated by 3 arrowheads) compatible with class IV injury. C and D, Sagittal reconstructions show the abnormal left LN neuroma (demarcated by 3 arrowheads) compared with a normal right LN (short arrow).
Coronal 3D PSIF images showing A, localization of the site of the LN and IAN (short and long arrows, respectively) and B, signal intensity measurements on both sides.
METHODS

Patient Pool

- Retrospective
  - 20 months (2013 – 2014)
- 17 patients
  - 10♂; 7♀
  - 43.4 ± 18.7 years
  - Symptoms = 2.2 ± 4 years (2 weeks to 17 years)
- 2 surgeons
  - OMS and PRS
- TN distribution
  - IAN = 13
  - LN = 2
  - Both = 7

Imaging

- 1.5 Tesla Scanner
  - Siemens, avanto, erlanger
- No contrast
  - 1 exception (mass effect)
- Duration = 45 minutes
- Evaluations
  - 3D manuevers
    - Axial, longitudinal, coronal
  - Thick slab max intensity projection
  - 2 readers, blinded
  - CISS 3D sequences
    - T1W & T2W SPAIR sequences STIR SPACE (non-vessel suppressed) and DW PSIF (vessel-suppressed nerve selective)
  - Corpus collosum to chin
<table>
<thead>
<tr>
<th>Image Results</th>
<th>Impact on Management</th>
<th>Surgical Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>None</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>no change in diagnosis</td>
<td>No correlation</td>
</tr>
<tr>
<td></td>
<td>no change in nerve involved</td>
<td></td>
</tr>
<tr>
<td></td>
<td>no change in treatment strategy</td>
<td></td>
</tr>
<tr>
<td>Entrapment</td>
<td>Mild</td>
<td>Moderate</td>
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<tr>
<td></td>
<td>change in diagnosis or nerve involved</td>
<td>Partial correlation</td>
</tr>
<tr>
<td></td>
<td>no change in treatment strategy</td>
<td></td>
</tr>
<tr>
<td>Injury</td>
<td>Substantial</td>
<td>Excellent</td>
</tr>
<tr>
<td></td>
<td>change in diagnosis or nerve involved</td>
<td>Full correlation</td>
</tr>
<tr>
<td></td>
<td>change in treatment strategy</td>
<td></td>
</tr>
</tbody>
</table>
PATIENT #11
62 Y/O FEMALE 2.5 MONTHS WITH PAINFUL NEUROPATHY LEFT IAN

Axial T1W – perineural fibrosis

Coronal 3D DW PSIF – thickening and hyperintense with mild contour changes due to entrapment

Same in DTI

Left inferior alveolar nerve
PATIENT #9
26 Y/O FEMALE WITH PAINFUL NEUROPATHY RIGHT IAN AND NON-PAINFUL NEUROPATHY RIGHT LN

Axial T2 SPAIR – thickening and hyperintensity right IAN and LN with small NIC (arrow)
Axial T1 – perineural fibrosis and thickening of IAN
Axial DTI - confirms

3D DW PSIF -NIC of LN
LN surgical findings
IAN surgical findings
PATIENT #2
48 Y/O FEMALE, 1.5 MONTHS INJURY NON-PAINFUL NEUROPATHY LEFT LN

Coronal 3D DW PSIF – enlarged thickened and discontinuous with nerve gap = 8.5mm

Coronal 3D STIR SPACE – hyperintensity left submandibular gland (arrow)

LN surgical findings = 12mm
45 y/o Female s/p 2 months #17 extraction with severe sensory impairment, positive trigger, dystrophic ageusia and burning, consistent with Class IV injury left lingual nerve
25 year old 17 months s/p right lingual nerve repair with allograft
Normal S4 outcomes
"85% back but worried about possible neuroma coming back"

IMPRESSIONS: MR Neurography
11/30/2015

The right lingual nerve is mildly prominent with adjacent susceptibility artifacts reflecting postoperative changes. No focal neuroma identified.
## Results

<table>
<thead>
<tr>
<th>Imaging Results</th>
<th>Impact on Management</th>
<th>Surgical Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse nerve thickening 12/17</td>
<td>None = 5/17</td>
<td>Moderate/Excellent = 7/17</td>
</tr>
<tr>
<td>Focal Mass = 4/17</td>
<td>Mild = 6/17</td>
<td>False Positive = 1</td>
</tr>
<tr>
<td>Perineural fibrosis = 7/17</td>
<td>Substantial = 6/17</td>
<td></td>
</tr>
</tbody>
</table>

### Diagnosis
- normal = 3/17
- neuritis = 4/17
- scar entrapment = 3/17
- neuroma IC = 2/17
- transection = 1/17

- No pathology on contralateral side
- Submandibular & sublingual gland – edema


A, MIP 3D PSIF coronal image shows class IV/V injury of the left LN with excessive granulation and possible discontinuity of its distal end (long arrow). B, On surgery, it was also called class IV/V injury (arrow) with excessive scarring and granulation tissue and was resected. The final gap was 16 mm (C) and an allograft was placed for nerve reconstruction.
MRN – IAN AND LN INJURY IN THIRD MOLAR EXTRactions

- 42 patients (24 cases, 18 controls)
  - 35.8±10.2 years
  - ♂ to ♀ =1:1.4

Nerve injury demographics
- 25 injuries found
- 18 LN/7 IAN
- NST = class II (2); Class III (4); Class IV (4); Class V (1)
- 13 had surgery performed

Imaging
- T2 PSIF and DTI on 1.5 and 3.0 T

Interpretation and analysis on T2 PSIF
- Readers blinded
- Nerve thickness = max transverse of IAN in midcanal, LN in midcourse
- Signal intensity = same area ROI at most visible abnormality
- T2SIR = SI nerve / \sqrt{SI nerve} and CNR (SI nerve — SI pterygoid muscle/\sqrt{SI nerve})
- Fisher exact and Wilcoxon rank sum test for demographic values
- AUC – using receiver operating characteristics of MRN accuracy in detection of neuropathy
- \kappa analysis to test correlation of Sunderland classification on NST, MRN and Surgical findings
- Pearson correlation coefficient for differences in thickness between normal and abnormal nerve
- Intraclass correlation coefficients to assess interobserver performance
### Sunderland Nerve Classification

**By NST, Surgical Findings and MRN Imaging**

<table>
<thead>
<tr>
<th>Sunderland Classification</th>
<th>Clinical NST Level and MRCS Grade Description</th>
<th>Surgical by Direct inspection</th>
<th>MR Neurography</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal (4)/S3+ or S4 by 3 months</td>
<td>Intact with no internal or external fibrosis, normal mobility and neuroarchitecture (visualized fascicles and fanconi bands)</td>
<td>Anatomic: Homogenous increased T2 signal of nerve. Diffusion: Normal FA and ADC. Tractography: Symmetrical and normal tracts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anatomic: Homogenous increased T2 signal of nerve and mild nerve thickening or constriction. Perineural fibrosis</td>
<td>Diffusion: Decreased FA and increased ADC. Tractography: Normal or mild asymmetry of tracts</td>
</tr>
<tr>
<td>II</td>
<td>Normal (4)/S3+ or S4 by 6 months</td>
<td>Intact with no internal fibrosis. External fibrosis, restricted mobility but neuroarchitecture intact (visualized fascicles and fanconi bands once external scar removed</td>
<td>Anatomic: Homogenous increased T2 signal of nerve and mild nerve thickening or constriction. Perineural fibrosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diffusion: Decreased FA and increased ADC. Tractography: Partially disrupted tracts</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Mild (3) or Moderate (2)/S2, S2+, S3 by 6 months or more</td>
<td>Intact with both internal and external fibrosis, restricted mobility and disturbance of neuroarchitecture (abnormal fascicle patterns and/or fanconi bands not visible)</td>
<td>Anatomic: Homogenous increased T2 signal of nerve and moderate thickening or constriction. Perineural fibrosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diffusion: Decreased FA and increased ADC. Tractography: Partially disrupted and disorganized tracts</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Moderate (2) or Severe (1)/S1, S2, S2+ by 6 months or more</td>
<td>Partial transected nerve but some amount of distal nerve present with or without neuroma in continuity</td>
<td>Anatomic: Heterogeneous T2 signal of nerve and neuroma in continuity. Perineural and intrafascicular fibrosis. Diffusion: Decreased FA and increased ADC. Tractography: Partially disrupted and disorganized tracts</td>
</tr>
<tr>
<td>V</td>
<td>Severe (1) or Complete (0)/S0, S1 by 6 months or more</td>
<td>Complete transected nerve with or without amputation neuroma</td>
<td>Anatomic: Discontinuous nerve with end-bulb neuroma. Diffusion: Decreased FA and increased ADC. Tractography: Completely disrupted tracts</td>
</tr>
</tbody>
</table>
Differences in thickness, T2SIR, and CNR among the case and control groups.

κ correlations for A, MRN versus NST and B, MRN versus surgical classifications.

κ = 0.57
κ = 0.4

P = 0.1  both
P = 0.12  IAN
P = 0.005  LN
P = 0.01  IAN
P = 0.0001  LN

Differences in thickness, T2SIR, and CNR among the case and control groups.
ROC curves for A, IAN and B, LN.

Accuracy of:
CNR = 0.83
T2 SIR = 0.84
Thickness = 0.99

Correlations between differences in nerve thickness on MRN versus NST (A) and surgery (B).

PCC = 0.68
PCC = 0.81
NOT TO SCARE- BUT THIS IS HOW SUBTLE THESE LESIONS CAN BE..

Young female

Right lingual nerve, third molar extraction injury >8 months
Neurosensory testing=Moderate impairment/ S2 = Class III or IV injury
92832114
DOS = 7/21/17

DTI
3D shows it better

92832114
DOS = 7/21/17
Lingual nerve
Class IV injury following molar tooth extraction
Neuroma in continuity

Post nerve reconstruction
Young Female with 3 months s/p extraction third molar

PREV CT- MAY- ABSCESS

1 month s/p I&D left mandible with numbness lip/chin and tongue
MRN IN JULY- SEE SOMETHING?
DTI
IAN AND LN– DIAG?

Diag- Class IV injury IAN
LN- Class IV/V- meaning bad neuroma
Molar tooth extraction injury - MR neurography and surgical correlation

Left - inferior alveolar nerve class IV injury

Right - lingual nerve class IV/V injury
8 MONTHS POST MOLAR TOOTH EXTRACTION - TONGUE PAIN AND DYSFUNCTION LEFT LINGUAL NERVE IN 64 Y/O MALE 90397190, DOS= 8/4/17
CAN YOU FIND THE LESION- UNFORTUNATELY PATIENT MOVED AND METAL IN ORAL CAVITY
HERE IT IS - PATIENT MOVED - SO IT IS CHALLENGING
INFERIOR ALVEOLAR NERVES - NORMAL
LINGUAL NERVE- NOTICE LATERAL NEUROMA IN CONTINUITY

Sag recons- the lingual nerve neuromas are really well seen on Sag
Lateral neuroma in continuity
MAGNETIC RESONANCE NEUROGRAPHY (MRN) OF TRAUMATIC AND NON-TRAUMATIC PERIPHERAL TRIGEMINAL NEUROPATHIES (PTN)

• Inclusion Criteria
  • Patients seen at UTSW OMFS with neurosensory complaint who underwent clinical NST and consented to MRN evaluation for a suspected PTN in the second or third division of the trigeminal nerve.

• Exclusion Criteria
  • History of pre-existing bilateral IAN or LN pathology

• Demographics:
  • 60 patients (40 IAN and 20 LN)
  • Age 43 +/- 15 years (12-75 years old)
  • Numbness (25), pain (16), diminished/lost taste (19)

Distribution of Traumatic Peripheral Trigeminal Neuropathies by Nerve and Etiology

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Third Molar</th>
<th>Dental Implant</th>
<th>Benign Pathology</th>
<th>Orthognathic</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAN</td>
<td>10</td>
<td>11</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>LN</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Distribution of Non-Traumatic Peripheral Trigeminal Neuropathies by Nerve and Etiology

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Dental injection</th>
<th>Non-invasive Endodontics</th>
<th>unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAN</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>LN</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

MAGNETIC RESONANCE NEUROGRAPHY (MRN) OF TRAUMATIC AND NON-TRAUMATIC PERIPHERAL TRIGEMINAL NEUROPATHIES (PTN)

Traumatic (n=48)
- IAN=28
  - 79% grade S3 to S4
  - NST – Sunderland III or IV
  - Neuropathic = 45%
  - Duration of sx = 13.61 months
- LN=19
  - 79% grade S0 to S2
  - NST – Sunderland IV and V
  - Neuropathic = 15%
  - Duration of sx = 5.5 months

Non-Traumatic (n=12)
- IAN = 11
  - 100% grade S3 to S4
  - NST = Sunderland < III
  - Neuropathic pain = 50%
  - Duration of sx = 4.87 months
- LN = 1
  - S4
  - Sunderland 1
  - Neuropathic pain present
  - Duration of sx = 24 months
MRN correlation with NST

- Kappa 0.60
- PCC 0.66
- Accuracy 77%
- Sensitivity 90%
- Specificity 70%

MRN correlation with surgery

- Kappa 0.74
- PCC 0.90
- Accuracy 84%
- Sensitivity 93%
- Specificity 100%
CONCLUSIONS

• MRN provides non-invasive information of the IAN and LN. Allows to map PTN injury and stratify nerve injury in traumatic and non-traumatic conditions
  • Non-traumatic = lower Sunderland levels, pain predominant symptom, MRN ranged from normal to Sunderland Class III with perineural fibrosis, mild thickening, entrapment or compression
  • Traumatic = higher Sunderland levels, sensory complaints with or without pain, MRN findings ranged from Sunderland Class III to V with no normals
• MRN has moderate to strong correlations with the NST levels/MRCS grading scores and the surgical findings.
  • Matched surgical findings 58%
  • Overestimated 4%
  • Underestimated 37%
WHAT’S NEXT IN MRN STUDIES???
OUTCOMES!!!!!
Post-op Imaging- Nerve Regeneration- sequential scans over 6 months.. showing ulnar nerve fascicular growth.
Follow-up- ulnar nerve functional
Post-op failure - fluid filled nerve tubes

Re-exploration operative image

No nerve connection - post op neuromas
YOUNG FEMALE 1-1/2 YR S/P INJURY RIGHT INFERIOR ALVEOLAR NERVE

Molar tooth again
Right IAN low mag at 3\textsuperscript{rd} molar site

Right IAN high mag at 3\textsuperscript{rd} molar site with injury

Site of injury

After resection of neuroma-in-continuity, 8mm gap
Connector attached to proximal end

Graft insert and attached to distal end for best alignment of fascicles

Completed case with axoguard protectors/connectors
Postop nerve regeneration - 
Right IAN partial regeneration.
Left normal IAN in face

Diffusion Tension Imaging
September, 2018

Regenerating through Allograft
a. haphazard sprouting
b. anisotropy present
c. double back?
d. reduced volume
e. no neuroma
Many Thanks!

2018 Annual Meeting
Florida Society of Oral and Maxillofacial Surgeons