

2017 MID-ATLANTIC
CONFERENCE

7th ANNUAL CURRENT CONCEPTS IN
VASCULAR THERAPIES

2017



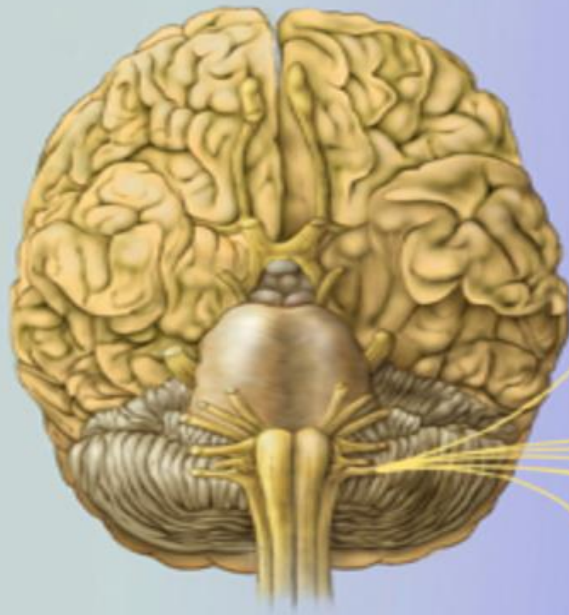
Michael E Landis
MD FACS

**Vagus Nerve Stimulation:
Indications and Technique**

Vagus Nerve

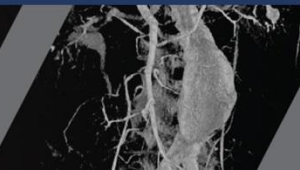
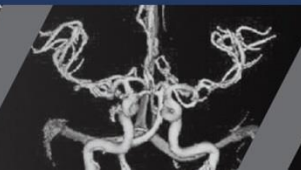
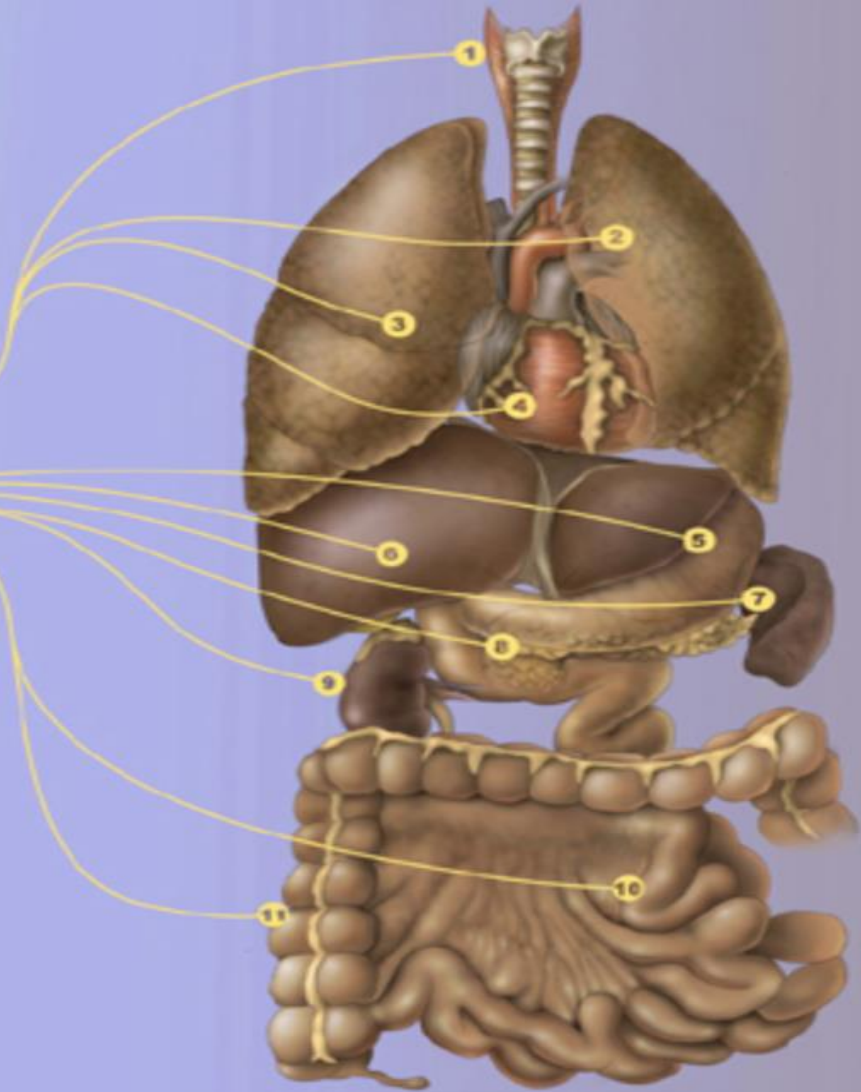
- Cranial nerve X
- Important regulator of the autonomic nervous system via parasympathetic and sympathetic function.
- Conveys most of the afferent nerves that provide sensory information for the body's organs to the CNS.





Vagus Nerve Innervation

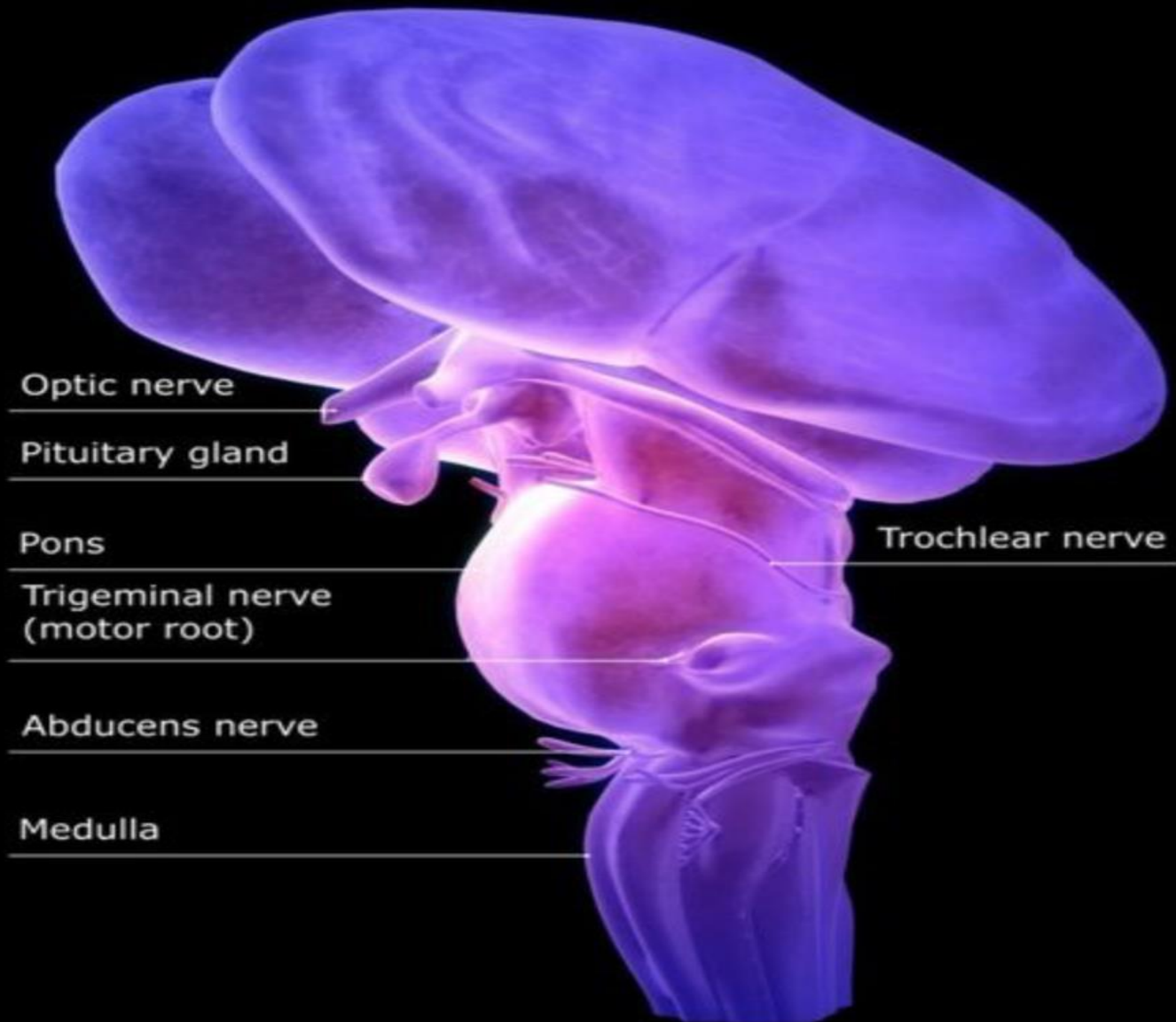
1. Pharynx
2. Left Lung
3. Right Lung
4. Heart
5. Stomach
6. Liver
7. Spleen
8. Pancreas
9. Right Kidney
10. Small Intestine
11. Large Intestine



Vagus Nerve

- Afferent fibers continue on as the Solitary tract, which terminates in the medulla.
- The medulla transfers information to various parts of the brain and spinal cord.
- Stimulates release of inhibitory neurotransmitters; GABA, serotonin, norepinephrine
- Regulates:
 - Control of autonomic function
 - Coordination of body movements
 - Regulates mood





Optic nerve

Pituitary gland

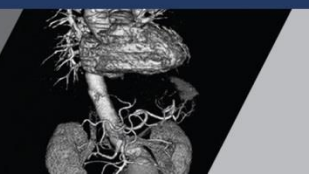
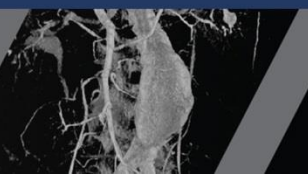
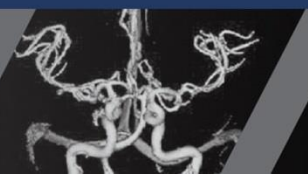
Pons

Trigeminal nerve
(motor root)

Abducens nerve

Medulla

Trochlear nerve



Vagal Nerve Stimulation

- Corning, New York neurologist, 1882. Carotid massage shown to be helpful in some epileptics. Hypothesized that electrical stimulation of the vagus may provide benefit.
- Effect initially thought to be secondary to regulation of cerebral blood flow; disproven in 1952 by Zanchetti.
- In 1997, Cyberonics received FDA approval for a surgically implantable VNS for the treatment of refractory epilepsy.



Vagal Nerve Stimulation

- Vagus nerve comprised of unmyelinated C-fibers (majority), and myelinated large A and small B fibers.
- Activation threshold much lower for A and B fibers, which explains lack of clinical side effects involving the gastrointestinal and cardiopulmonary system with nerve stimulation.

Woodbury, et al Epilepsia 1990



Vagal Nerve Stimulator

Indications for use

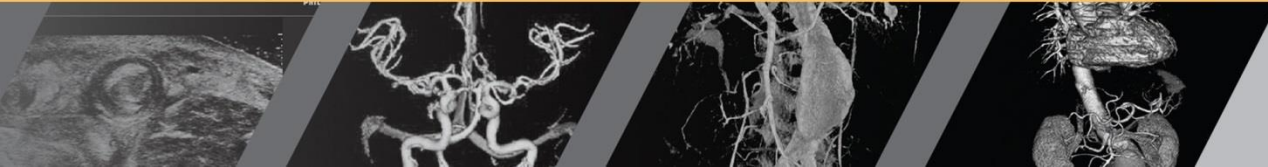
Epilepsy: The VNS Therapy System is indicated for use as an adjunctive therapy in reducing the frequency of seizures in adults and adolescents over 12 years of age with partial onset seizures that are refractory to antiepileptic medications (>2)



Vagal Nerve Stimulator

Indications for use

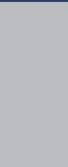
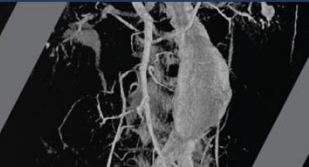
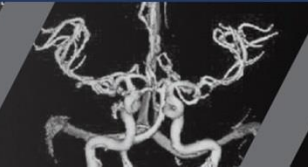
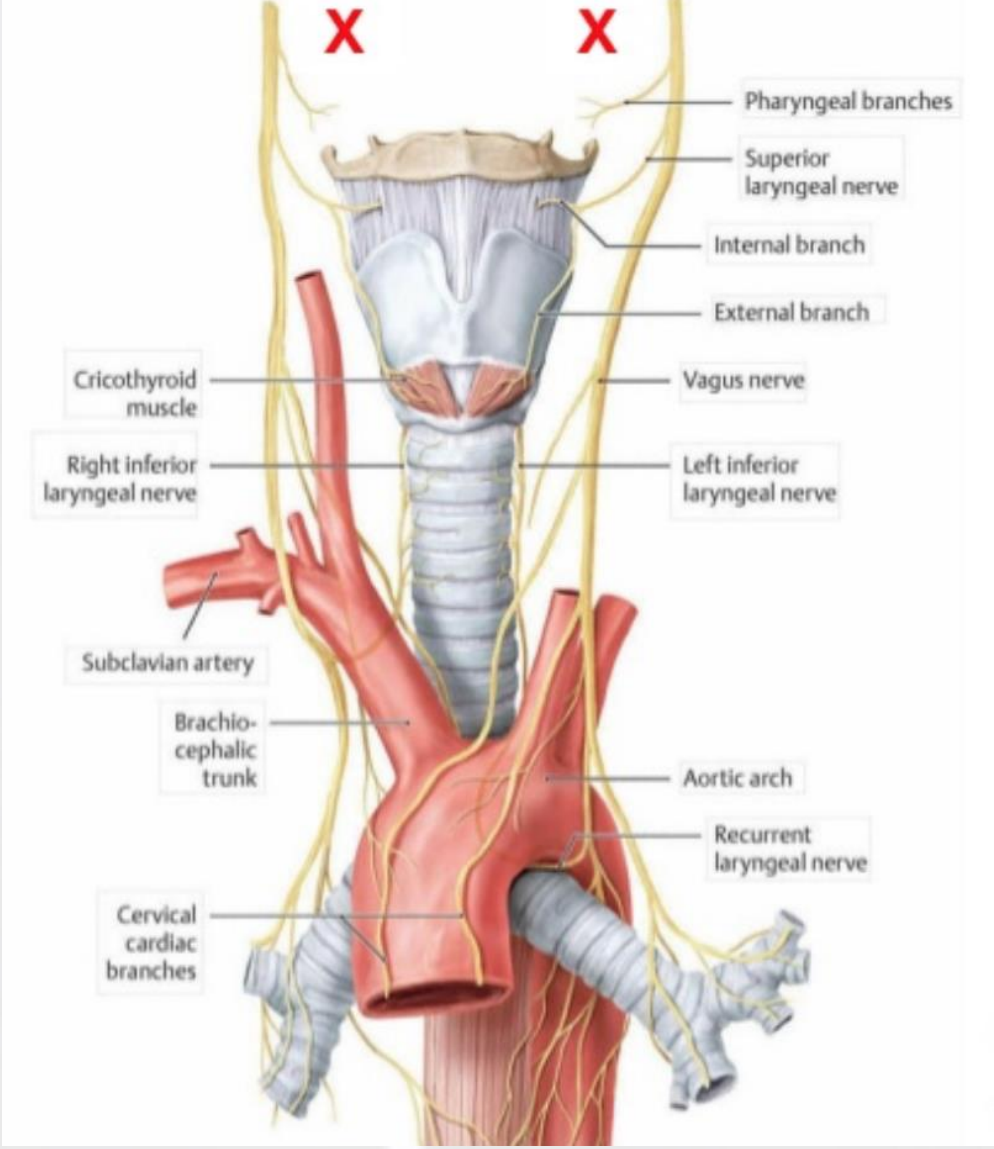
- Adjunctive therapy used **with** anti-epileptic drugs (AED's)
- Provides seizure control, but not relief from seizures.
- Can take up to 2 years to have an effect.



Vagal nerve stimulator - Contraindications

- One vagus nerve
- Receiving other concurrent forms of brain stimulation
- Heart arrhythmias or other heart abnormalities
- Dysautonomias (abnormal functioning of the autonomic nervous system)
- Lung diseases or disorders (shortness of breath, asthma, etc.)
- Ulcers (gastric, duodenal, etc.)
- Vasovagal syncope (fainting)
- Pre-existing hoarseness





Overview

- ❑ Approach similar to:
 - Carotid endarterectomy
 - Accepted practice for implanting a cardiac pacemaker with the exception of the placement of the electrodes and subcutaneous routing of the lead body

- ❑ **Approximately 1-1.5 hour** case for new implant

- ❑ Typically done under **general anesthesia**

- ❑ **Left neck incision** for electrodes and subcutaneous pocket incision in left upper chest or left axillary region for generator

- ❑ **Outpatient** or 23-hour overnight hospitalization

Preparing the Patient

- Pre-op antibiotics
- GETA
- Supine with head turned to the right
- Shoulder roll to improve exposure

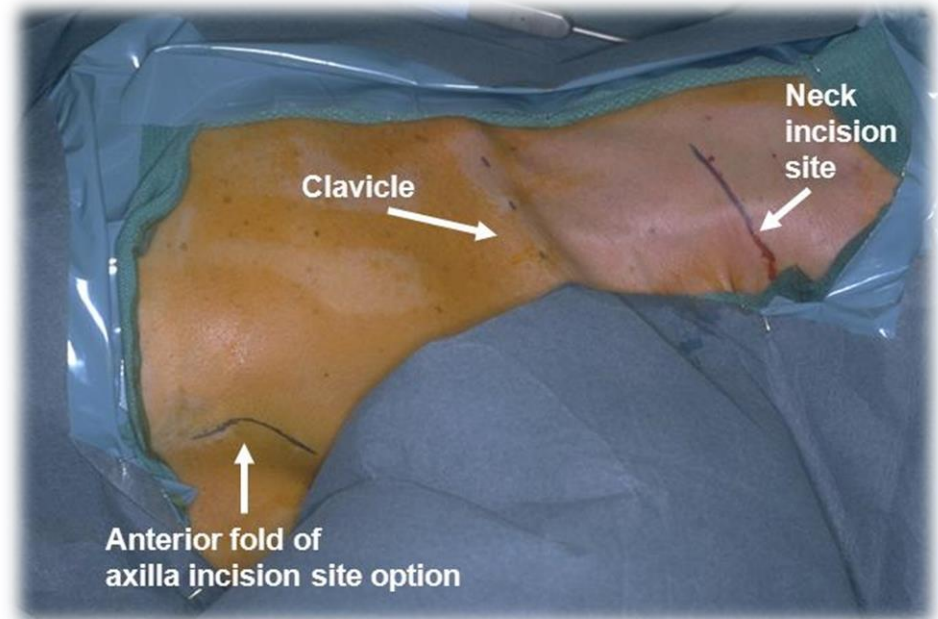


Preparing the Patient

Suggested placement for the lead is the area **half-way between the clavicle and the mastoid process**

Generator is usually implanted **just below the clavicle** in a subcutaneous pocket in the left upper chest

May be placed along the axillary border, as shown



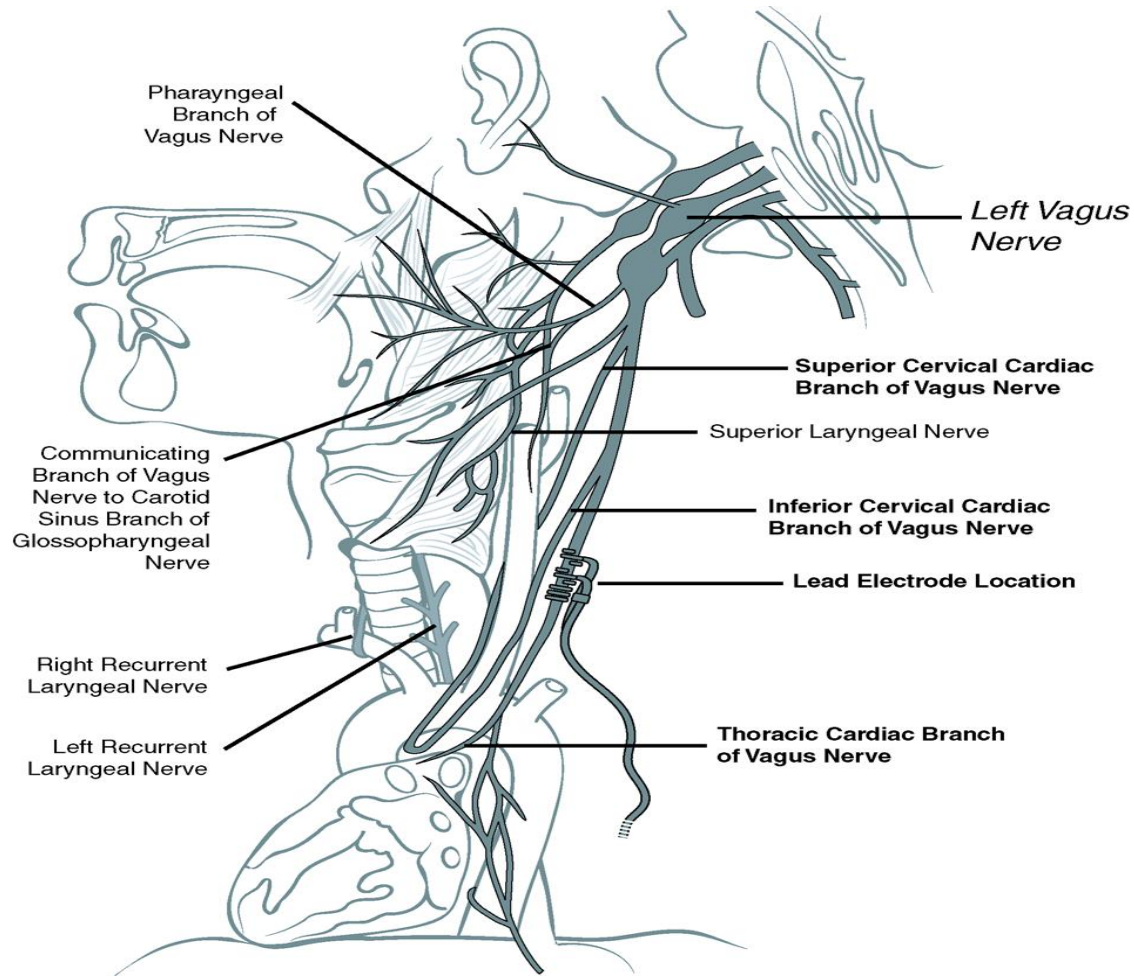
Access and Expose the Vagus Nerve

- ❑ **Expose the left carotid sheath** as it extends along the anterior border of the sternocleidomastoid muscle
- ❑ **Locate and expose at least 3 cm** of the left vagus nerve
- ❑ The recommended stimulation site is a **3 cm section of the vagus nerve**, approximately half-way up between the clavicle and the mastoid process, where the nerve is clear of branches

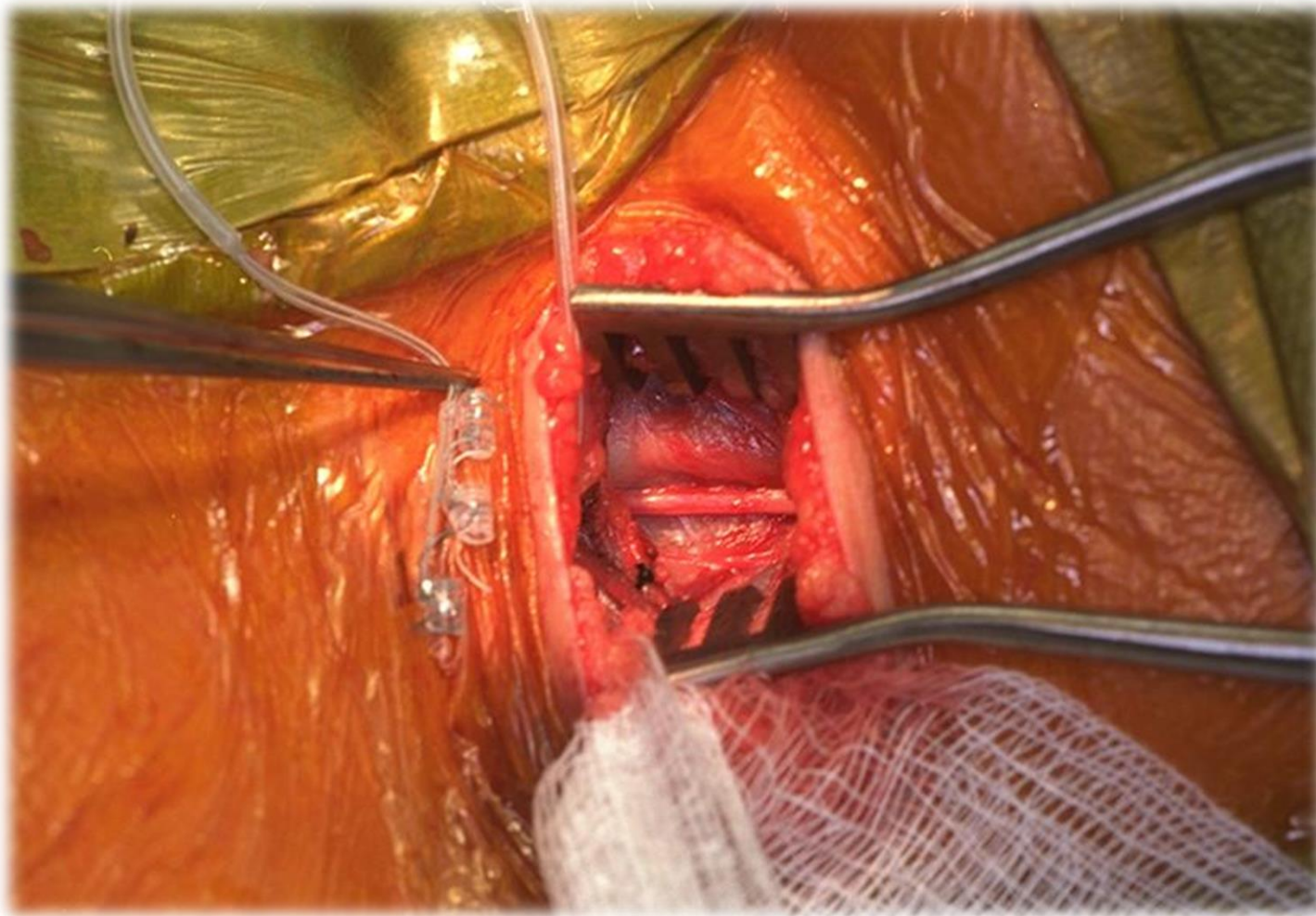
Below the superior and inferior cervical cardiac branches and above the left recurrent laryngeal nerve

- ❑ The **nerve usually lies in a posterior groove** between the carotid artery and internal jugular vein

Vagus nerve exposure



Carotid Sheath Exposed

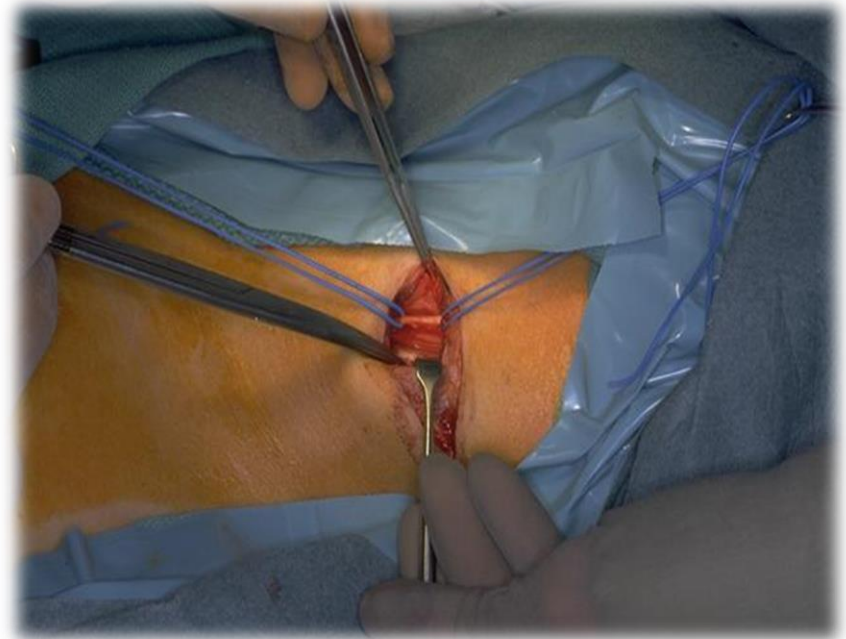


Isolating the Vagus Nerve

Expose ≥ 3 cm of nerve

- May use soft rubber vessel loops to raise or lift the nerve as necessary
- Ensure that the nerve is handled with care

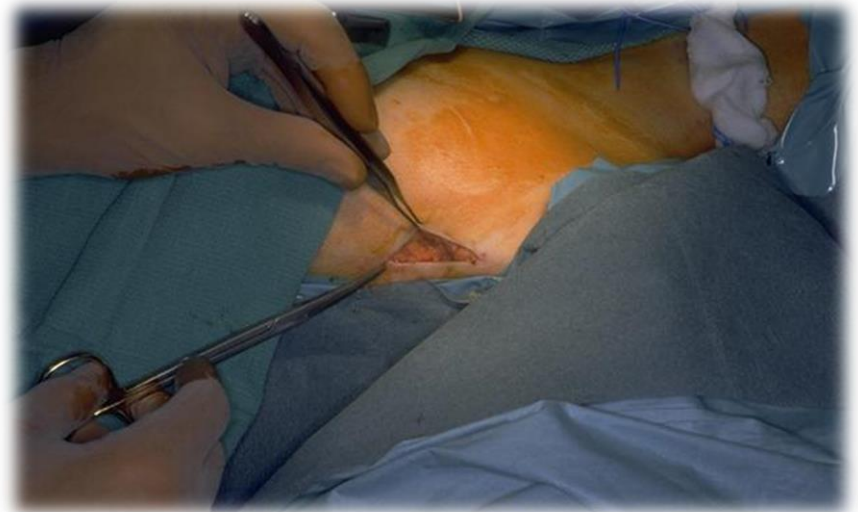
Avoid excessive handling of nerve to prevent injury and preserve branches off the vagus nerve



Creation of Generator Pocket

Create a subcutaneous pocket in either the left upper chest (below clavicle) or along the axillary border for the generator and excess lead

Successful communication is most likely if the surface of the programming wand head is within **1 inch** of the generator



Tunneling the Lead

Surgeons may choose the order in which they desire to tunnel the lead and place the electrodes:

Tunnel the lead subcutaneously, followed by **placement** of the electrodes and strain relief

OR

Place the electrodes on the vagus nerve, followed by placement of the strain relief, **concluding with** tunneling the lead to the chest pocket

Electrode Placement

Electrodes must be placed **only on the left vagus nerve**

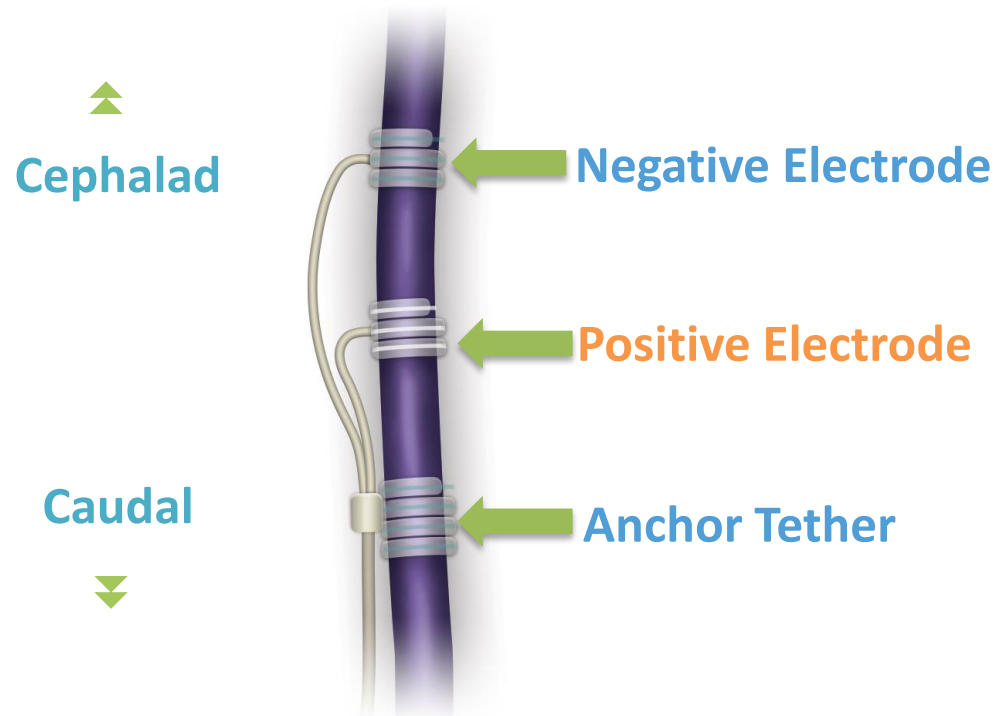
Electrodes should be placed below the cardiac branches of the vagus nerve and above the left recurrent laryngeal nerves

! Stimulation of either the superior or inferior cardiac branches may cause bradycardia or asystole during device testing and stimulation

Excessive manipulation of the vagus nerve during placement of the lead can result in noticeable post-operative hoarseness

Electrode Placement

The order of electrode placement depends upon the surgeon's preference

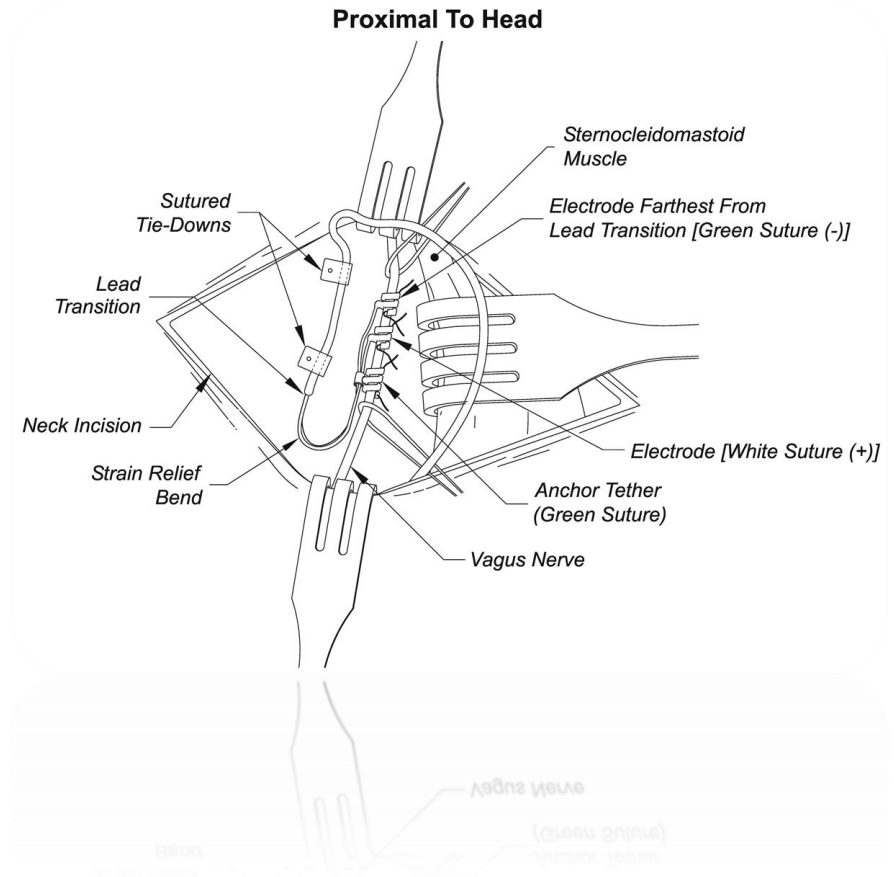


Note: Use of the integrated anchor tether helps prevent force transfer to the electrodes

Strain Relief Bend

1. Run **at least 1 cm** of lead parallel to the vagus nerve
2. Place **3 cm strain relief bend**
3. Place **first tie-down** opposite the anchor tether

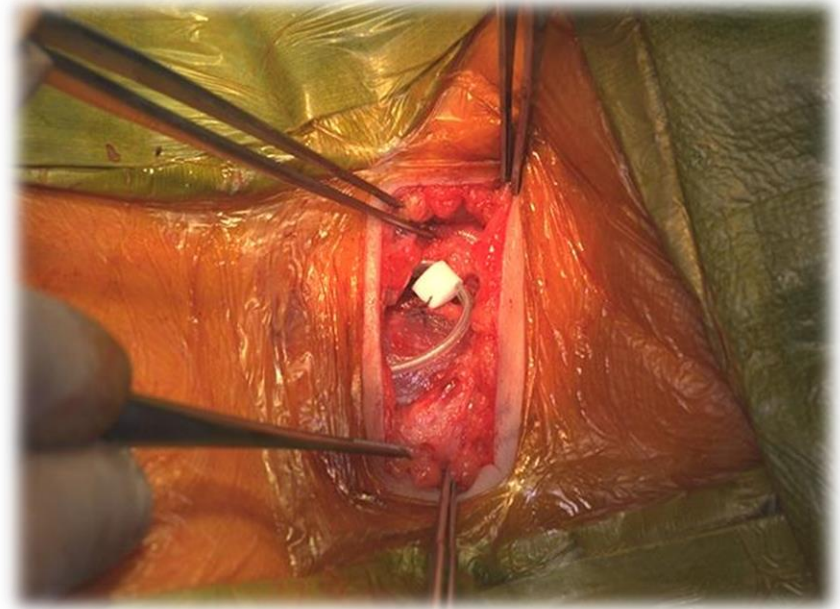
Note: Proper strain relief is critical to the long-term success of the implant. The lead wire has a potential for fracture if the recommended strain relief is not provided as described.



Use of Tie-Downs

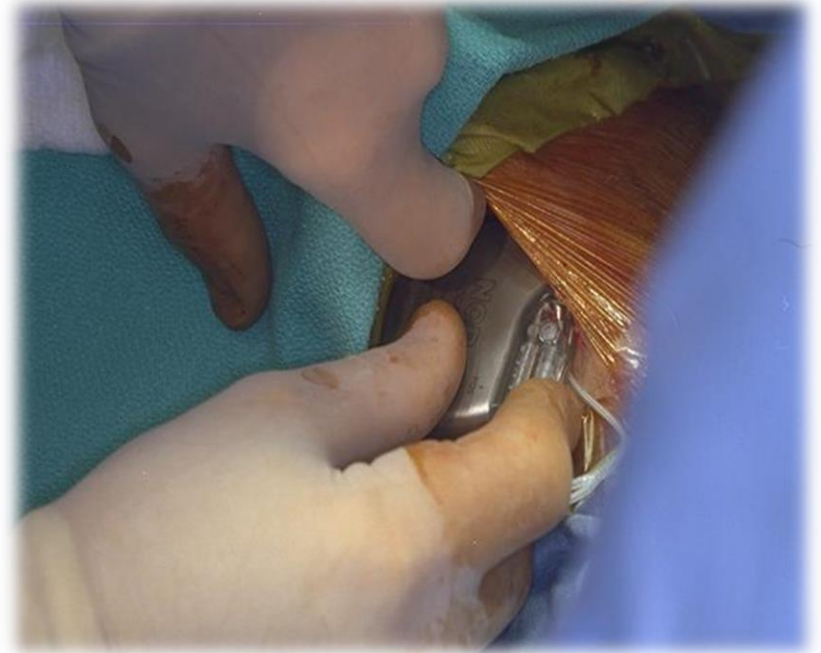
Secure strain relief with silastic tie-downs provided within lead package

Use non-absorbable sutures to **secure the tie-downs** to the fascia



Inserting the Generator

- ❑ Place generator in chest pocket
- ❑ **Coil the remaining lead** and place to the side of the generator
- ❑ Logo may face up or down
- ❑ **Secure generator** by placing suture through suture hole and attaching to fascia with non-absorbable suture



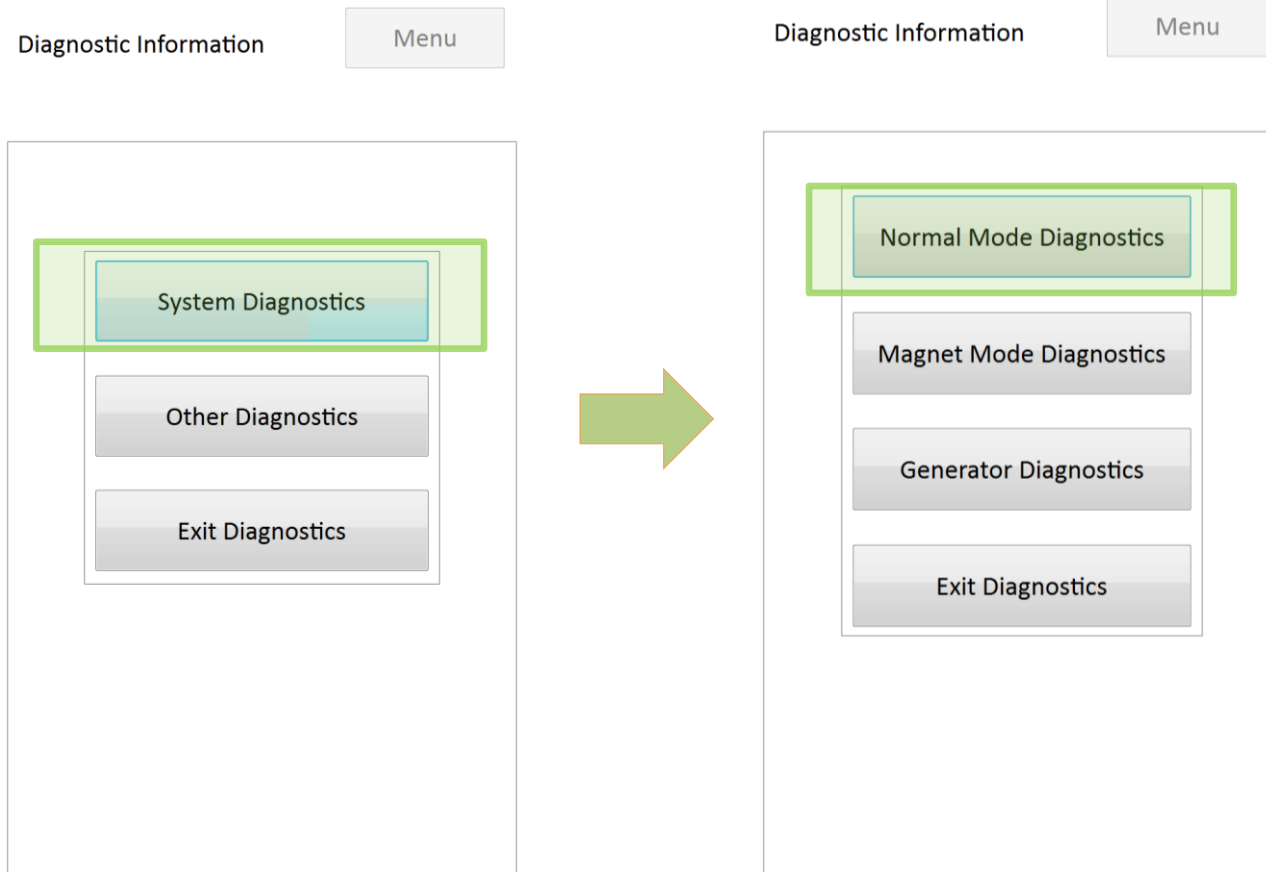
Preparation for System Diagnostic Test

The **programming wand** should be placed into a sterile laser arm bag, camera bag, or equivalent for entry into the sterile field

Handheld computer can remain outside the sterile field or can be passed through laser arm bag with programming wand if the surgeon will be performing the diagnostic tests



System Diagnostics: Models 102 and 102R



Assessing Lead Impedance

Diagnostic Information



Lead Impedance

DCDC Converter Code

Impedance OK

DCDC Converter 0-3

Impedance HIGH

DCDC Converter 4-6

Impedance HIGH

DCDC Converter 7

System Diagnostics Data 2013-10-29 9:04:58 AM	
Patient ID	VNS
Model ID	Pulse 102
Serial #	618
Implanted	2013-10-29
Communication	OK
Output Status	LIMIT
Output Current	1.00mA
Lead Impedance	HIGH
DCDC Converter	7
Near End of Service	NO

Assessing Output Current

Diagnostic Information



Output Current Status = **OK**
1.00 mA test current is being delivered

Output Current Status = **LIMIT**
1.00 mA test current is not being delivered

System Diagnostics Data 2013-10-29 9:04:58 AM	
Patient ID	VNS
Model ID	Pulse 102
Serial #	618
Implanted	2013-10-29
Communication	OK
Output Status	LIMIT
Output Current	1.00mA
Lead Impedance	HIGH
DCDC Converter	7
Near End of Service	NO

Using the stimulator

- Typically activated 2-4 weeks following implantation
- Programmed by treating neurologist. Stimulation starts slow and gradually increases.
- Periodic stimuli @ 20 – 30 Hz; 30 seconds on, 5 minutes off.
- Patient is given a hand held magnet, which can either pause (hold over generator) or augment (swipe across generator) treatment.



Results

- 20 -40% experience >50% reduction in seizure frequency.¹
- Number of responders increases with time.²
- Number of AED's required to maintain satisfactory seizure control decreases after VNS.^{3,4}

¹DiGiorgio, et al Epilepsia 2000

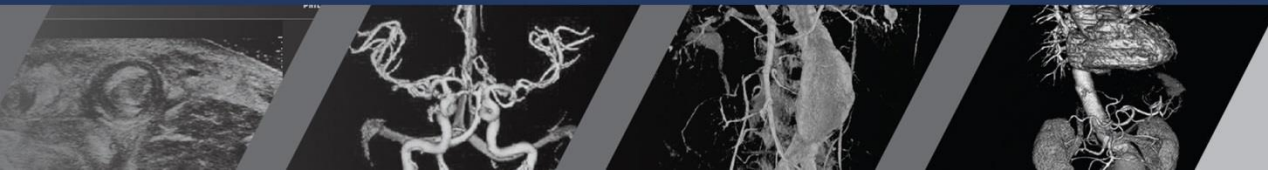
²Tatum, Neurology 2001

³NVSSG Neurology 1995



VNS – Side effects

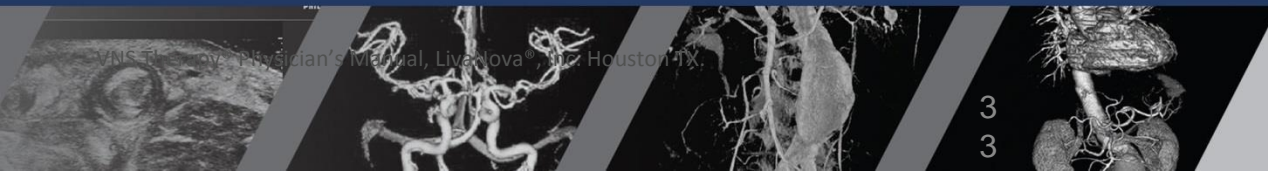
- **Hoarseness**
- **Increased coughing**
- **Changes in voice/speech**
- General pain
- Throat or neck pain
- Laryngospasm
- Headache
- Insomnia
- Indigestion
- Clonus/twitching
- Nausea or vomiting
- Impaired sense of touch
- Prickling or tingling of the skin



Complications of vagal nerve stimulation for drug-resistant epilepsy: a single center longitudinal study of 143 patients.

[Kahlow H¹](#), [Olivecrona M.](#)

- Single institution over 16 years; 143 pts with mean f/u 62 m.
- 16.8% surgical, and 16.8% hardware related complications
- Surgical complications significant in 4.2% (deep infection requiring explant, and permanent VC paralysis)
- Technical complications primarily related to lead fracture (11.9%).
- Similar results noted by Spruck, et al (5.7% surgical complication rate, and 15% related to hardware)²



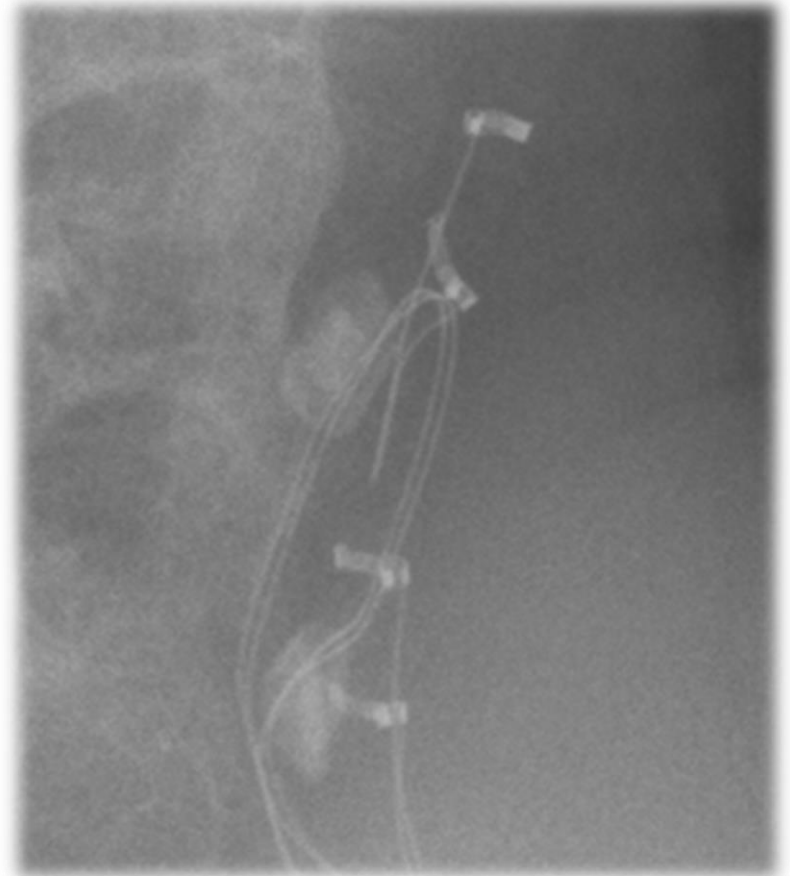
¹Seizure, Dec 2013

²Neurosurgery, 2010

Lead Revision Procedure

The replacement helices can be **placed above or below** existing helices if they remain

Follow remaining steps as explained in the *New Implant Procedure* section



Lead Removal: Case Study

- 10 Patients (Southern Illinois University Medical School)
 - First 3 cases: Removal of electrodes was unsuccessful
 - *New electrodes were placed cephalad to the old electrodes*
 - Last 7 cases: The VNS Therapy System, including the electrodes, was completely removed without difficulty

Mean duration of implant = 3.7 years (range 1.1 - 7.3)

Duration of surgical procedure was ~90 minutes on an outpatient basis

After removal of electrodes, the vagus nerve was “...without evidence of physical injury”

- Degree of fibrosis does not appear to have any correlation with duration of implant
- “...this procedure may be reversed with little difficulty”

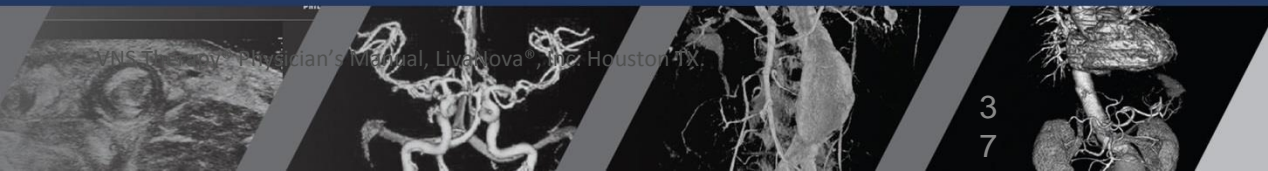
Risk of Asystole/Bradycardia

- Incidence of bradycardia and/or asystole during routine intra-operative lead test¹
 - Reported rates: bradycardia (0.07%) asystole (0.08%)
 - Full recovery for all patients
- Similar events are not reported in epilepsy clinical trials²
- Possible explanations include anatomic differences, lead placement, anesthesia, or collateral current spread^{1,3}

1. Data on file, LivaNova, Inc., Houston, TX; 2015. 2. Tatum WO, et al. *Neurology*. 1999;52:1267-1270. 3. Ascona JJ, et al. *Epilepsia*. 1999;40:1452-1454.

Magnetic Resonance Imaging

- Testing demonstrated the following generator and MRI procedures can be used safely without adverse events:
 - MRI compatible with all **1.5T and 3.0T** scanners
 - Head and extremity scans allowed using a **transmit and receive** type of RF coil
 - Generator output should be programmed to 0mA for the MRI procedure, and afterward, and afterwards reprogrammed to the original settings.

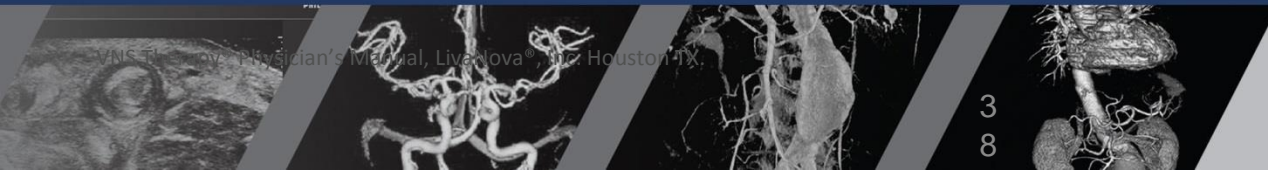


Precautions

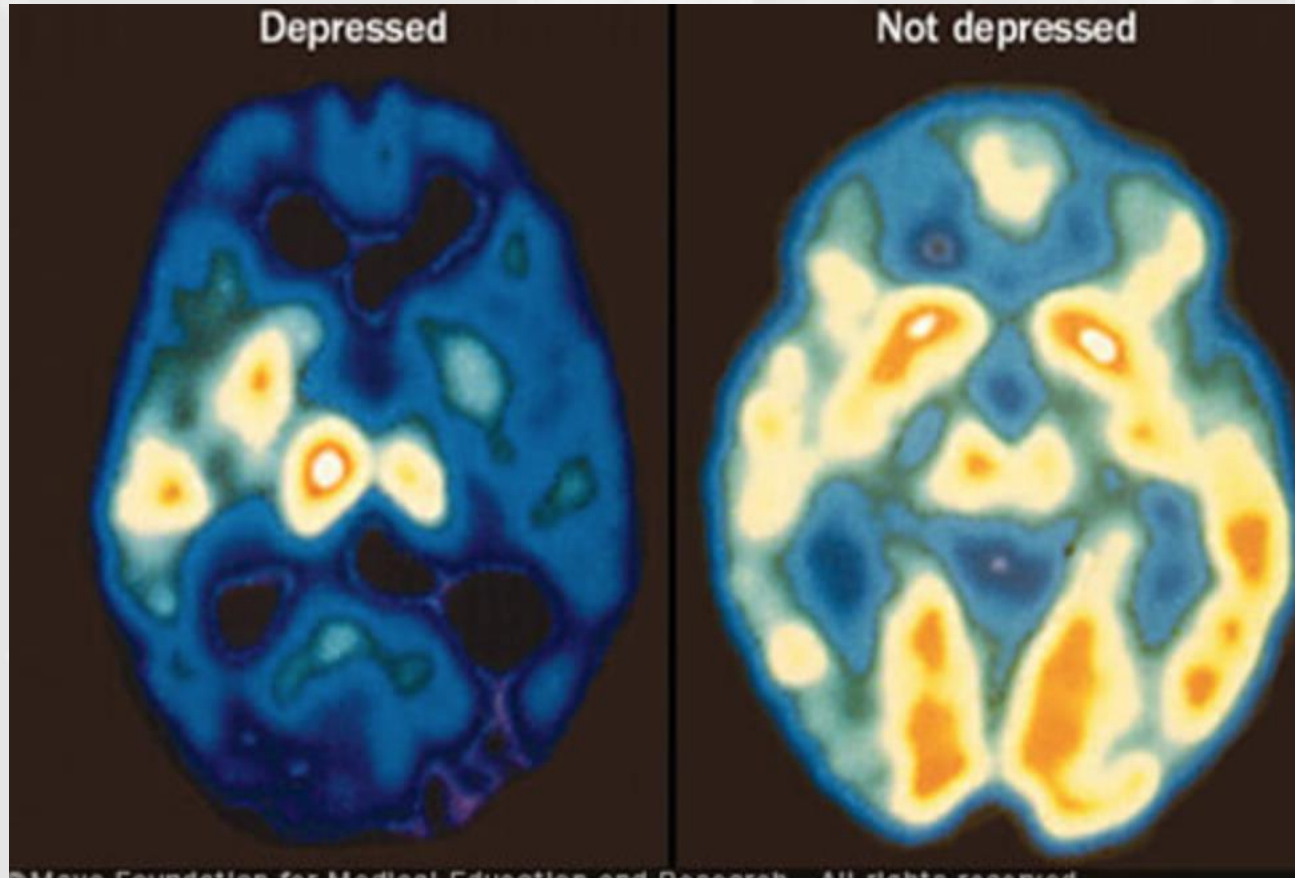
The following may damage the device and/or require additional precautions such as device disablement:

- electrosurgery/electrocautery
- electrostatic discharge
- external defibrillation
- extracorporeal shockwave lithotripsy
- therapeutic radiation
- therapeutic ultrasound
- TENS unit

VNS Therapy System operation **should always be checked** by performing device diagnostics after performing any of the above



VNS and Depression



VNS and Depression

- ECT currently mainstay of treatment resistant depression (TRD): Clinical response rates of 64%, remission in 47%.
- Stigmatized modality. Legitimate concerns regarding memory loss.
- Initial results with VNS showed improvement in patients who suffered from both depression and epilepsy.
 - Induction of frontal slow waves, and elevating levels of noradrenergic inhibitory neurotransmitters.



VNS and Depression

- 2 pilot studies led to FDA approval in 2005 as an acceptable treatment for TRD.
- Subsequent studies showed no benefit in the acute setting.
- 1 year response rates 20 – 30%, with remission in half.
- Poorer response in patients previously treated with ECT.
- 10% developed worsening depression, and comparative suicide rate increased from 2.9 to 3.5%.¹

¹Rudolph, FDA panel hearing 2005



VNS and Depression

Current recommendations

- Recommended for TRD with bipolar or unipolar depression.
- Failure to respond to ECT not a prerequisite
- ECT typically used in the acute setting, VNS for long term therapy.
- Historically difficult to obtain insurance coverage.



Future directions

- Right vagal nerve not used historically due to animal studies which showed a significant incidence in bradycardia (efferent stimulation of SA node)
- Canine and human vagal anatomy differ. Recent studies show safety and efficacy using right VN.¹
- Patients with lateralizing interdictional discharges may benefit from ipsilateral VNS.²

¹McGregor, Epilepsia 2005

²Janszky, JNNP 2005



Future directions



Gamma-core nVNS

Conclusions

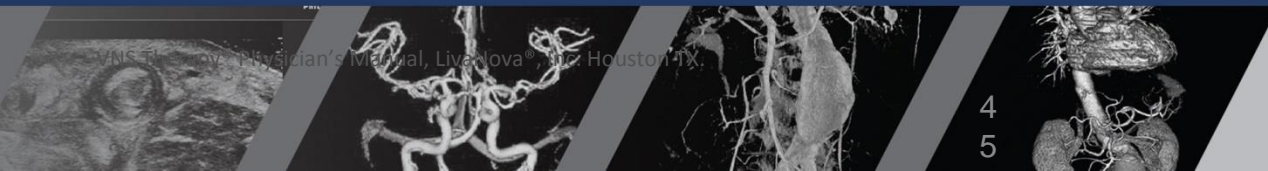
Vagal nerve stimulation is an accepted and appropriate treatment for Epilepsy and Treatment Resistant Depression in select patients that have failed conventional therapy.

Results may not be apparent for up to two years following surgery.

VNS is an adjunctive form of therapy, and does not replace standard medical therapy/medication.

Significant surgical complication rates are relatively low. Device related complications are more common, and typically involve lead fracture.

Future modalities may involve transdermal stimulation.



Thank you

