



SPINAL CORD STIMULATION

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HISTORY

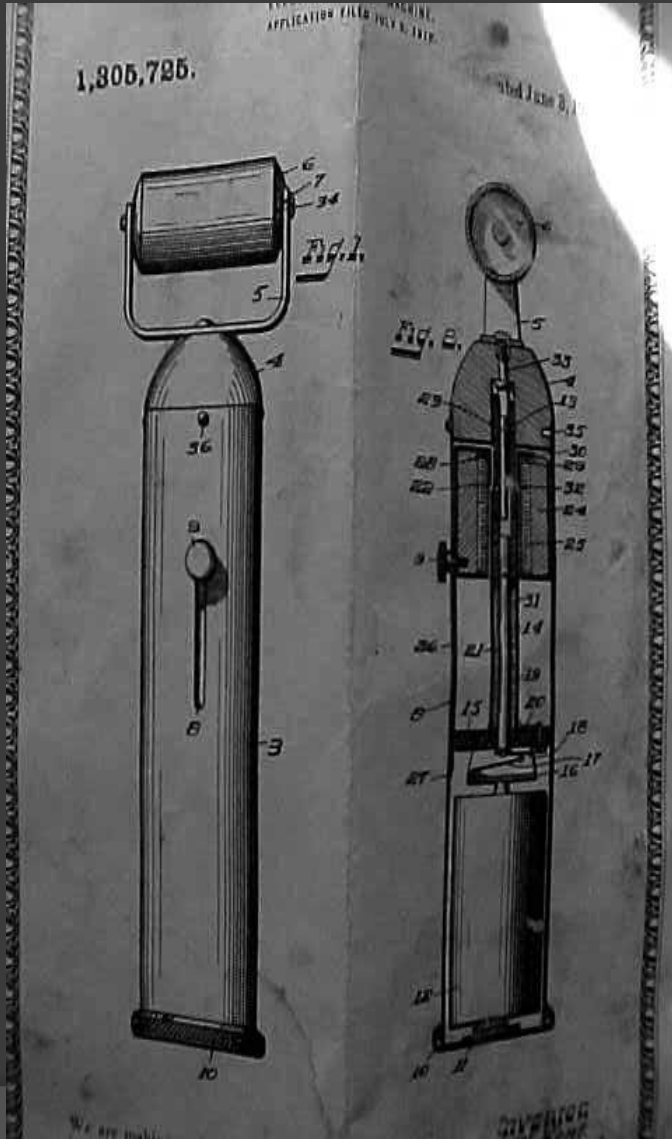
- ⦿ Ancient Egyptians used Black torpedo fish 4500 yrs ago.
- ⦿ The live fish was placed over the painful site
- ⦿ Electrical discharge endured until pain reduced
- ⦿ 1st modern app in 1874 when exposed brain was electrically stimulated
- ⦿ 1948 1st electrodes implanted in brain

Various Electrical Generators

Black Torpedo Fish



Electrostat



Massage and Muscle Development

GUARANTEE

Every ELECTRAPLY is guaranteed to be mechanically and electrically perfect; to be free from defects of workmanship or material; and to be in perfect working order. If properly taken care of it should last an ordinary lifetime. We agree to replace with a new machine or repair any defect free of cost within one year from date of purchase.

ELECTRAPLY LABORATORIES, INC.
PHILADELPHIA, PENNA.

REPAIR SERVICE

Proficient handily ELECTRAPLY needs no soldering or repairs, and will last an ordinary lifetime. However, it should not be tampered with, and, if through accident or misuse repairs are required, it should be done at our factory. Repairs of this character will be done at once, plus return postage.

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Batteries for ELECTRAPLY may be purchased from electrical shops, hardware stores, drugstores, department stores and dealers generally everywhere. Any make single cell standard size may be used. The price is from 10 to 25 cents.

When buying new batteries, we suggest your taking the machine with you, try the new battery for strength, for very often the dealer's stock has deteriorated from standing so long on the shelf. Batteries one year old are worthless, even though they have never been used.

PRICE LIST EXTRA PARTS (POSTPAID)

Battery single cell (used 10 cents extra for postage)	10 to 25
Absorbent applicator pads (each pad for 20)	20
Card with open	25

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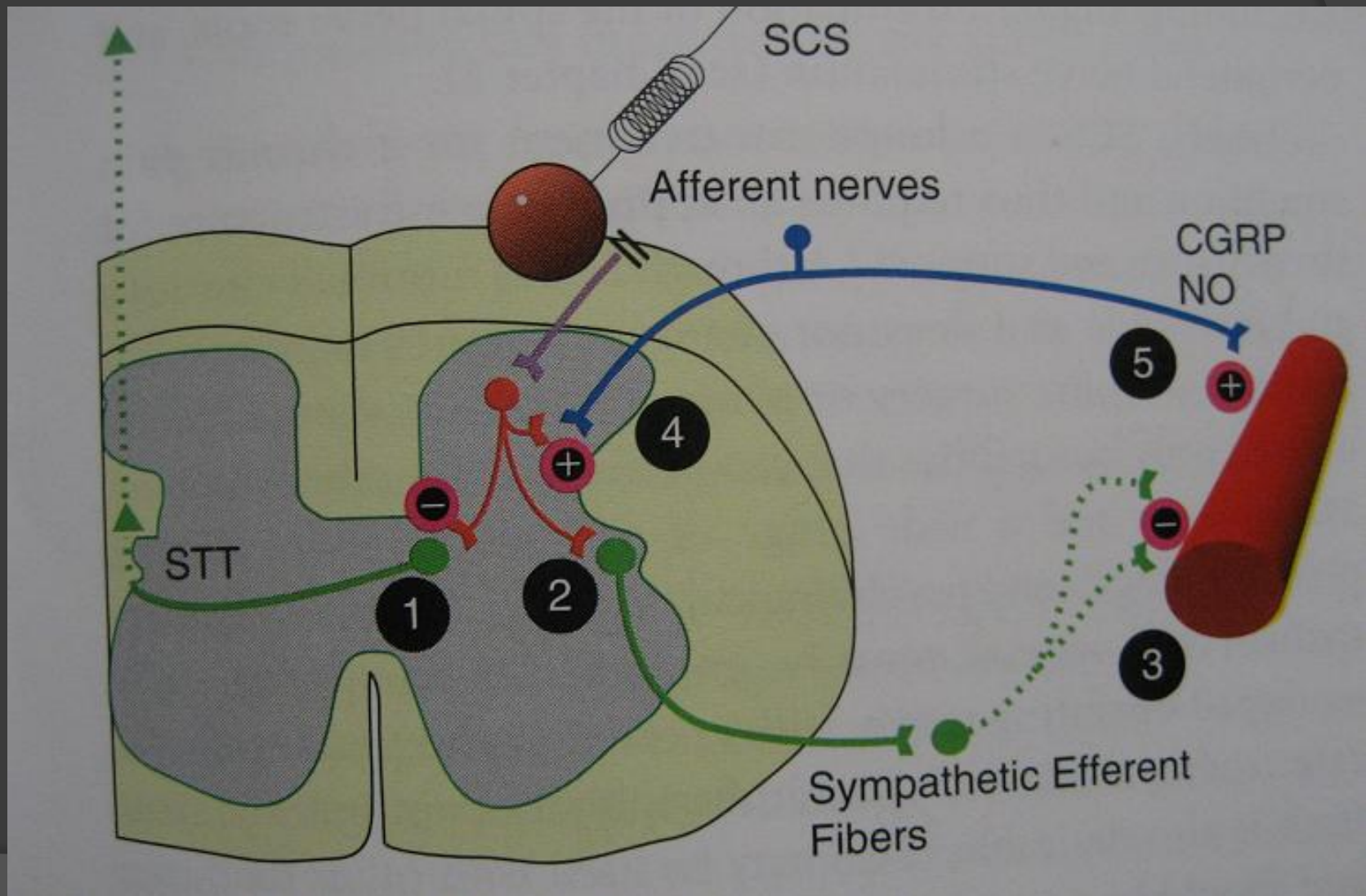
MADE IN U.S.A.



Gate Theory

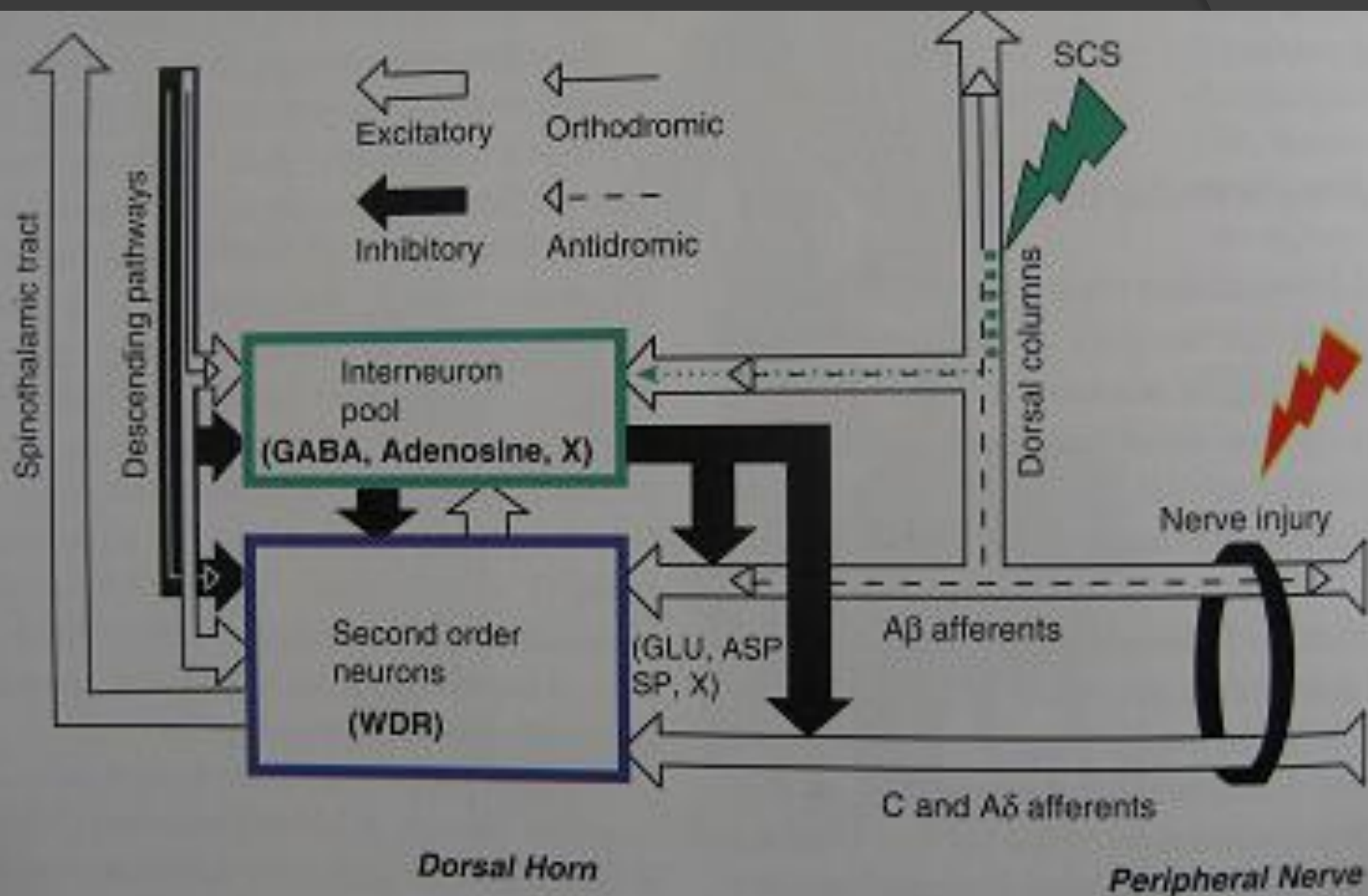
- Melzack and wall in the 60's
- Good basic framework but now pain transmission is understood to be more complex.
- Basic theory used to develop SCS
- Concept is that both large myelinated fibers and small pain fibers synapse at dorsal horn and stimulation of one type of fiber causing pleasant sensation can override an unpleasant sensation letting only the pleasant sensation pass through the "gate"
- example- rubbing a painful area after injury

Effects Of SCS on L1 DC



Mechanisms

- SCS mechanisms still not fully understood
- SCS attenuates the response of WDR neurons in the dorsal horn to injury in which they become hyperexcitable to decreasing GABA and increasing Glutamate
- SCS appears to be segmental, although supratentorial descending inhibitory mechanisms may become activated increasing noradrenalin and serotonin
- GABA b activation leads to Glutamate reduction in dorsal horn of rats
- SCS is not reversed by naloxone, suggesting no opiod receptor involvement



Cont...

- ① SCS occurs by platinum alloy contacts in epidural space
- ① The contacts are attached to a pulse generator
- ① The pulse generator creates a voltage potential
- ① This transmits to the dorsal column and dorsal roots
- ① Creates a paresthesia in stimulated area

Dorsal Column Anatomy

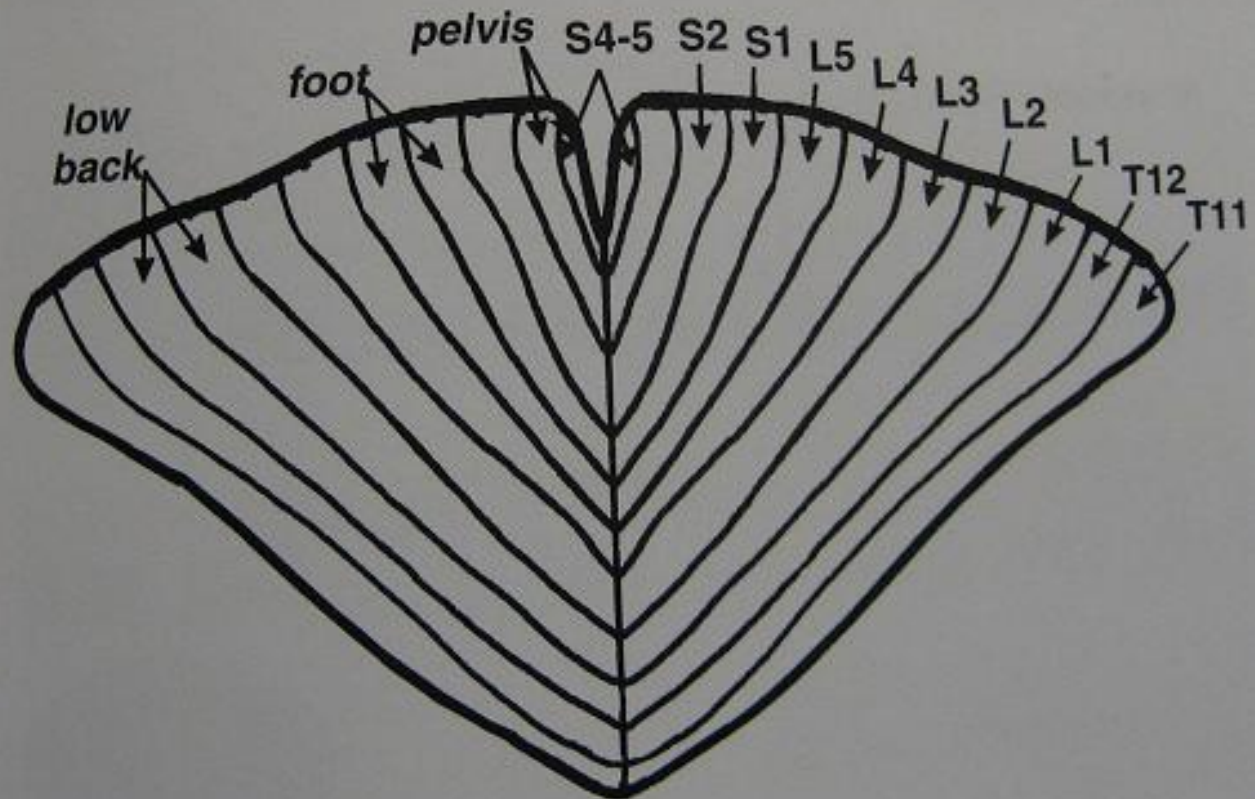
- Dermatomes are innervated by nerve roots
- Dorsal – sensory
- Ventral - Motor
- Dorsal and ventral fibers combine to form mixed nerves as they exit the spine
- Idea behind SCS is to stimulate sensory and avoid motor effects
- DC is organized somatotopically
- Lateral fibers represent more cranial dermatomes, medial structures represent more caudal structure

Cont.....

- At any point on the DC there are fibers representing everything below that level
- Therefore lower extremity stimulation can be achieved with cervical leads
- Nerve root fibers connect to the DC several segments above their entry vertebrae- e.g.- L3 dermatome stimulation requires lead placement at T9.

Somatotropic representation at T11

Figure 5.4 Somatotopic representation of the dermatomes in the dorsal columns of the T11 spinal segment. Reprinted from Feirabend HK, Choufoer H, Ploeger S, et al. Morphometry of human superficial dorsal and dorsolateral column fibres: significance to spinal cord stimulation. *Brain* 2002 May;125(Pt 5):1137–49, with permission from Oxford University Press.



Voltage = Current x Resistance

- Ohms law $V=IR$
- The higher the resistance the more voltage is required to maintain constant current
- This increases power consumption and reduces battery life
- Increased resistance due to increased distance from required area of stimulation
- Increased CSF, Epidural scarring, thick Dura, fibrosis around leads

Perception Threshold

- ⦿ This is the minimum stimulation amplitude required to generate perceived stimulation
- ⦿ In a constant voltage setup voltage is fixed. Increased resistance will cause reduced current flow and degrading stimulation over time
- ⦿ In a constant current setup increased resistance automatically causes voltage to go up to maintain constant current and overall stimulation perception
- ⦿ Third system can adjust current independently to each individual electrode contact as required to maintain stimulation perception

Programming

- ⦿ 3 variables that can be controlled on an electrode
- ⦿ FREQUENCY
- ⦿ AMPLITUDE
- ⦿ PULSE WIDTH
- ⦿ To obtain paresthesia the electrode has to be first denoted as an anode, cathode or off. Once paresthesia has been obtained in the desired area then the amplitude, pulse width and frequency can be fine tuned

Amplitude

- ⦿ This is governed by voltage and current
- ⦿ Akin to a volume knob
- ⦿ Once it is turned up and paresthesia felt –this denotes the minimum sensory threshold
- ⦿ Turning up the amplitude eventually leads to an uncomfortable sensation- this is the upper limit of stimulation threshold
- ⦿ The difference between these 2 extremes is the COMFORT ZONE
- ⦿ The ratio between the minimum and maximum threshold should be no less than 1.5

Pulse Width

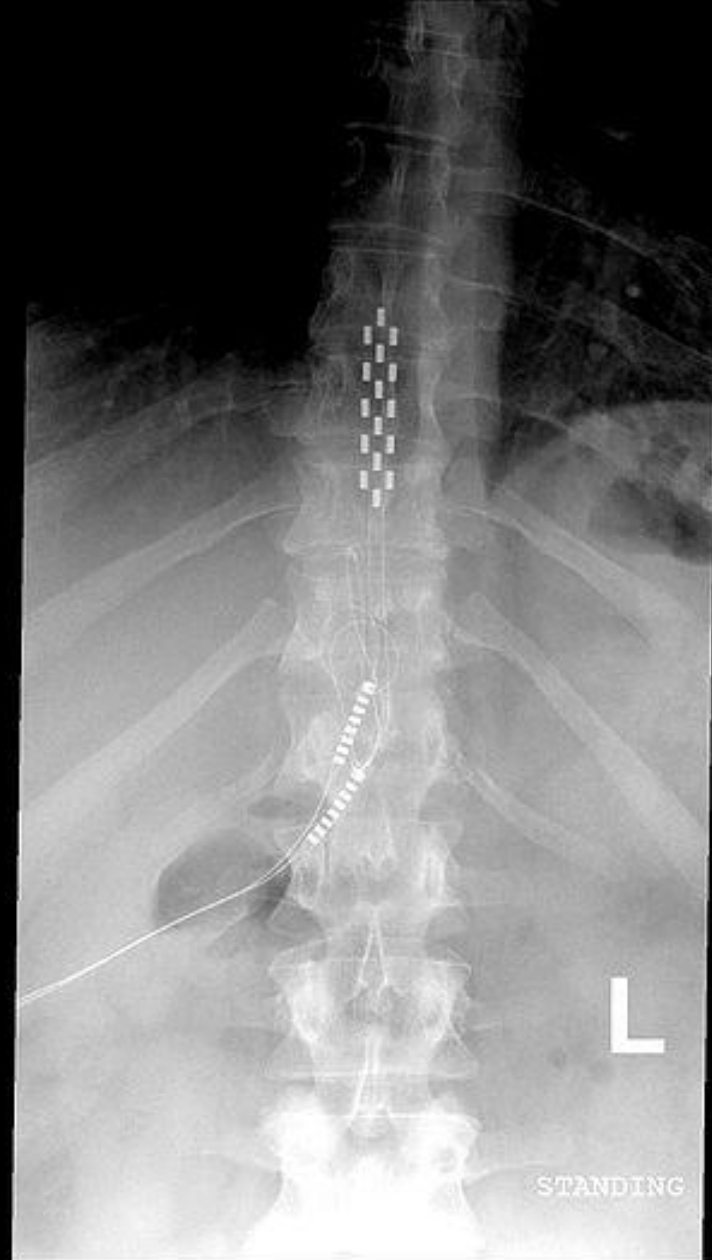
- Defined as the duration of a single pulse
- Typically lasts 150-600 milliseconds
- Stimulus intensity and duration must be enough to provoke action potential
- Lower intensity means longer stimulus
- Packet of energy required for depolarization is dependant on current and PW
- Narrow PW activates large fibers
- Wider PW will recruit smaller fibers
- Patients tolerate wider/longer PW better- often 1000 microseconds

Frequency

- ⦿ This is the number of pulses per second
- ⦿ Can be adjusted so stimulation is comfortable
- ⦿ Frequency affects QUALITY of paresthesia not LOCATION
- ⦿ Usual range for LBP is 40-70Hz
- ⦿ CRPS patients use 80-250Hz

Single Vs Dual Leads

- ⦿ Governed by location of the pain- unilateral vs. bilateral.
- ⦿ Many implanters now implant dual leads even for unilateral pain
- ⦿ This is to compensate for lead migration.
- ⦿ If there are 2 leads stimulation can be electronically transferred vertically or horizontally to recapture sweet spot
- ⦿ Leads can cross talk and achieve ample penetration into the midline of the DC
- ⦿ Sloppy lead placement cannot be condoned



Efficacy

- Well documented last 40yrs
- Reduction in VAS typically 50%
- Decreased pain meds
- Improved functional scores
- Improved ADL score
- Improved quality of life score
- Return to work
- Confirmation patients would again choose SCS

SCS vs. Reoperation

- 50 patients with FBSS-
 - All reoperative candidates
 - Randomized to reop or SCS
 - Voluntary crossover to other groups at 6 months
 - Reop – 67% crossover to SCS
 - SCS- 17% crossover to reop
 - Statistically significant
- North RB. SCS Vs Reop for FBSS. Acta neuro 1995

Cost

- Meta analysis of 14 studies showed implant cost were offset by reduction in post implant cost
 - Reduction is from no further surgeries, reduced ER visits, hospitalization, medication use, office visits , imaging studies and further nerve blocks
 - Average cost is 25,000 USD for trial and implant of SCS
 - Mean saving of 30,000USD per patient/per year
 - 90,000 USD saving over 3yrs
-
- Mekhail. Cleveland clinic study
 - Taylor RS. Cost effectiveness of SCS in pain treatment

Patient Selection

- ⦿ This is **Critical** to have good outcomes
- ⦿ **BEST CANDIDATES**
- ⦿ Neuropathic, radicular, ischemic pain
- ⦿ Unilateral, anatomically defined
- ⦿ Poor response to conservative rx/6 mnth
- ⦿ Not a surgical candidate
- ⦿ No psychiatric Dz
- ⦿ No substance abuse
- ⦿ No secondary gain
- ⦿ Successful trial

Patient selection Cont...

- ⦿ **POOR CANDIDATES**
- ⦿ Nociceptive pain
- ⦿ Diffuse, CENTRAL pain
- ⦿ Malignant pain
- ⦿ h/o of psychiatric DZ
- ⦿ Substance abuse
- ⦿ Secondary gain
- ⦿ Poor trial

FDA approved indications

- FBSS
- Radiculopathy
- Plexopathy
- Arachnoiditis
- Epidural fibrosis
- Peripheral neuropathy
- CRPS

OFF label

- SCS has profound effect on inhibiting sympathetic mediated vascular tone resulting in vasodilation in extremities
- Ischemic pain in PVD
- Ischemic ulcer healing
- Angina pectoris
- **PERIPHERAL NERVE STIMULATION**
- Migraines, cervicogenic and occipitogenic headaches.
- Post op ilioinguinal neuralgia, ankle pain

SCS for Vascular Disease

- First reported in 1976 (cook, Oxygar NY state J Med)
- Patient had diabetic neuritis/ulcers
- Cervical intradural electrodes
- 11 month follow up
- Stimulation reduced pain and promoted ulcer healing
- Leads broke- ulcers/pain came back
- Repaired- re healed

Field Stimulation

- Regional stimulation vs. nerve stimulation
- Easy to do, subcutaneous lead placement
- Popularized for occipital neuralgia
- Now being used for headache and face pain syndromes, ilioinguinal, axial LBP
- Electro trickery







Unsuccessful applications

- ⦿ Spinal cord injury with complete cord transection
- ⦿ Paraplegia, quadriplegia
- ⦿ Partial cord transection with loss of posterior column function
- ⦿ Brachial plexus avulsion
- ⦿ Non ischemic non neuropathic Nociceptive pain
- ⦿ Central pain non spinal in origin

Contraindications

- **ABSOLUTE**
- Pregnancy
- DREZ
- Critical spinal stenosis
- Neurologic deficit that is amenable to surgery
- Spine instability
- Psychiatric DZ, cognitive issues, substance abuse

Contraindications cont.....

- **RELATIVE**
- Prior surgery causing epidural scarring and difficult lead placement
- Untreated infection
- Existence of another chronic pain condition
- Secondary gain, pending litigation
- Untreated psychiatric Dz
- Inconsistency on history and physical exam
- Occupational requirement

Psychological Evaluation

- **Necessary**
- Pain causes mood disturbances that amplify the pain response and experience
- Constant pain changes the hardwiring of the nervous system causing neuroplastic changes and changes of neurotransmitter levels
- Pain patients have coexisting depression, anxiety, cognitive errors of perception, catastrophising, hopelessness, poor coping mechanisms
- Some insurance carriers make this mandatory

Psychological Contraindications

- ◎ **Some people will not implant on the following**
- ◎ Personality disorder
- ◎ Unstable/ unsupported family/relations
- ◎ Suicidal tendency
- ◎ Severe depression/ mood disorder
- ◎ Somatoform disorder
- ◎ Alcohol/drug abuse
- ◎ Marked cognitive impairment

Characteristics Assoc with good outcomes

- Psychological stability
- Self confidence, self reliance
- Realistic goal
- Optimistic of outcome
- Ability to cope with side effects without catastrophising
- Cognitive ability to control remote
- Supporting family
- Willingness to undergo comprehensive medical evaluations and lifestyle modifications

PROCEDURE-

Trial

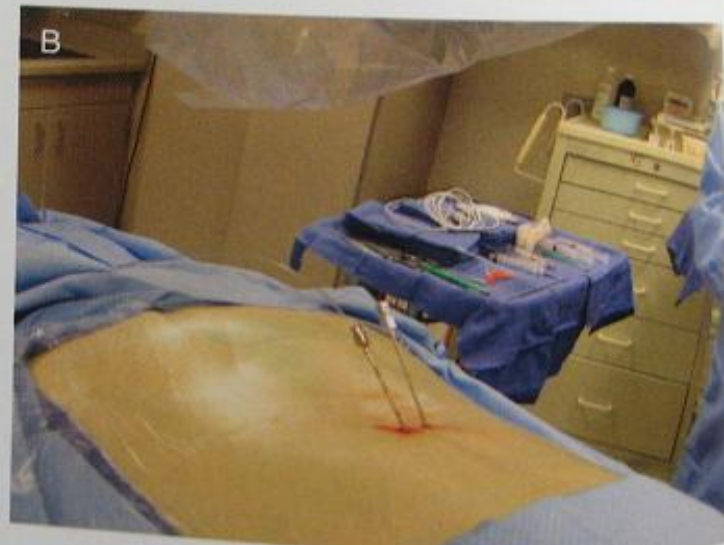
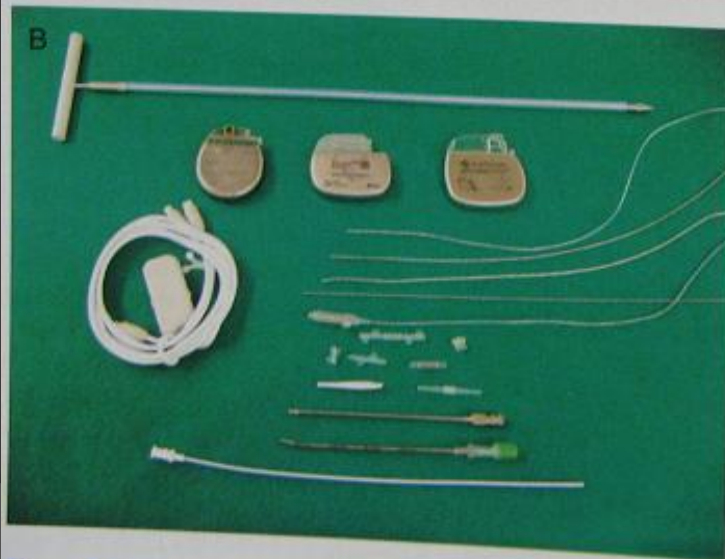
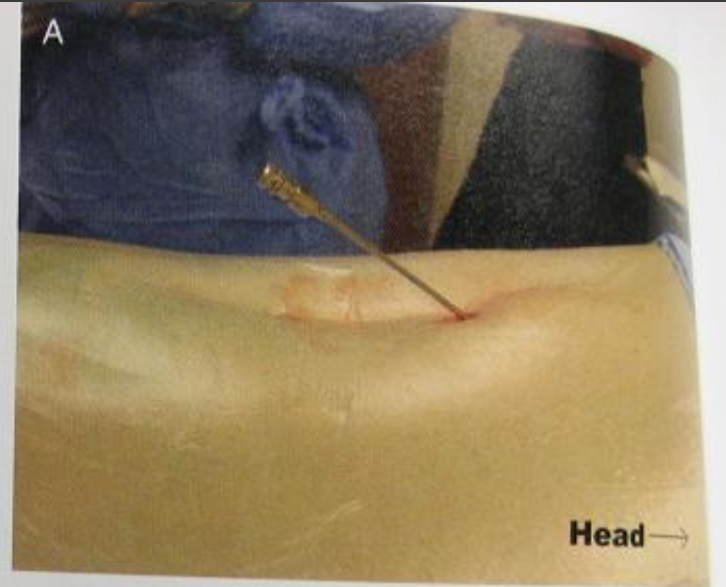
Screening trial usually 5-8 days

Critically informative about lead placement, setting and amount of pain relief

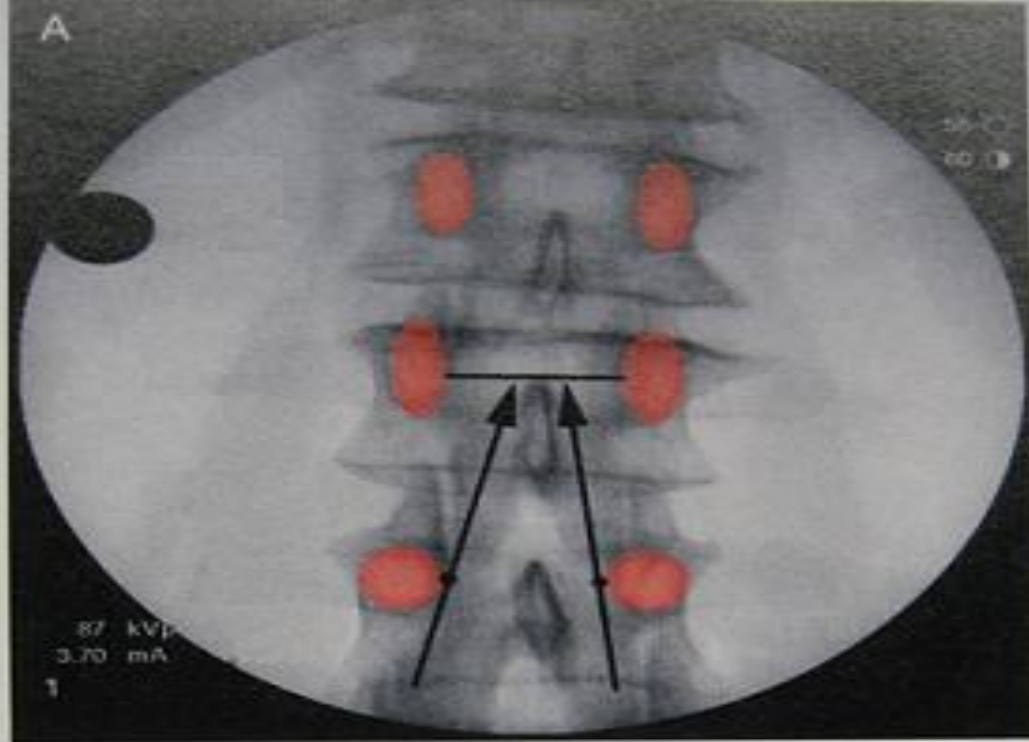
At least 50% reduction in pain and patient able to tolerate, function the system

Trials can be Percutaneous or tunneled

Equipment, Skin needle entry.



ENTRY into Epidural Space



Steering the lead

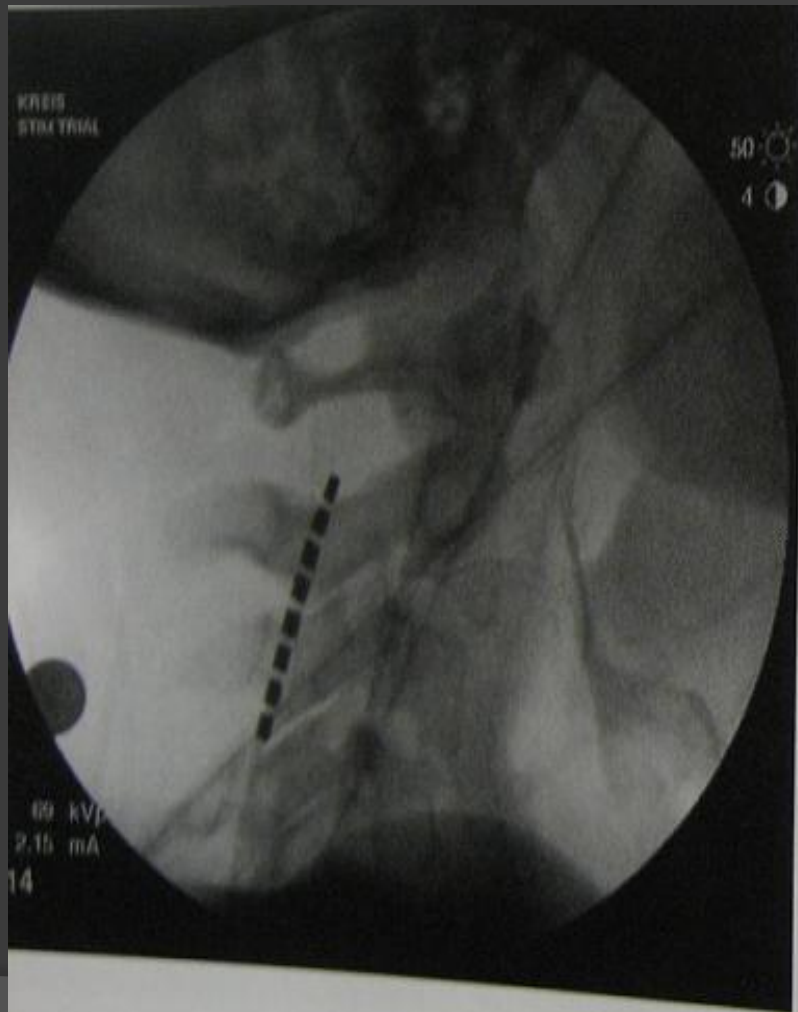


Figure 7.16 Grasping the lead.



Percutaneous Trial- USA

- ⦿ Can be done in office setting, no OR pre booking
- ⦿ Fast
- ⦿ No post trial scar
- ⦿ No patient feeling of obligation
- ⦿ Final lead placement in permanent can be adjusted depending on feedback from trial period
- ⦿ Disadvantage- if difficult lead placement during trial it can be difficult to recapture the same stimulation on the permanent placement. Cost of disposing of trial leads.

Tunneled Trial- Europe, AUS

- ⦿ Needs to be done in OR +/- sedation
- ⦿ More pain during procedure, can interfere with post procedure eval, scar pain vs. LBP.
- ⦿ More chance of infection
- ⦿ More patient obligation to go on to permanent placement
- ⦿ Reposition is difficult and time consuming after tunneled trial
- ⦿ Advantages- Time between trial and permanent placement is shorter
- ⦿ No disposal of trial leads
- ⦿ Faster permanent implant time

Complications

“In surgery, a surgeons experience can be measured by his complications, but his wisdom is measured by how he deals with it” William S Hatelstad

- ◎ Lead migration- 13% ... Anchor lead properly, strain relief
- ◎ Lead Breakage- 6-9%.. insert anchor through fascia
- ◎ Infection 3%.. follow sterile procedure
- ◎ Poor coverage 12% ... Reprogram unit

Hematoma

- ⦿ Hematoma in pocket-
- ⦿ Watch for expansion
- ⦿ Watch for drainage
- ⦿ Long standing hematoma can become infected cause wound dehiscence
- ⦿ Painful hematoma- sterile, surgical evacuation
- ⦿ Infection- remove hardware put on IV Abs Rx
- ⦿ Baseline CBC, ESR, CRP drawn

Wet Tap

- ⦿ Inadvertent Dural puncture
- ⦿ Make sure tuohy needle is not blocked with bone or clot
- ⦿ Proceed or not?
- ⦿ Some people will go at a different level.
- ⦿ Tear with a 14G needle leads to persistent CSF leak, changing the impedance in the epidural space.
- ⦿ Persistent headache will interfere with the evaluation of the trial.
- ⦿ CSF leak during perm implant can cause back tracking of the CSF into the pocket and cause hygroma
- ⦿ High chance of infection, meningitis if this occurs.
- ⦿ Explantation needs to be done if sterile aspiration of CSF Hygroma gives positive cultures.

Rx of Wet Tap

- ⦿ Cancel procedure, treat headache
- ⦿ Blood patches have been successful in permanent implant patients who have post op PDPH
- ⦿ After 3 blood patches the efficacy is very low and alternatives to blood patch have to be considered- e.g.-
- ⦿ open patching of Dural tear under direct visualization- neurosurgery
- ⦿ Percutaneous epidural injection of Fibrin glue . 4cc in epidural space. Shown to be effective

Post OP/ Follow up

- Wound healing, fibrosis, remodeling of tissues occurs for up to 2 yrs post op
- Watch out and closely monitor high risk patients for post op wound complication
- Patients are discharged same day as surgery
- Post op check day 3-5 and 7-10. Remove staples/sutures on day 7.
- 3 week post op check to see wound, check coverage and patients use/benefits from device.

FUTURE DEVELOPMENTS

- ① Positional feedback- modulates stimulation depending on body position standing vs. supine
- ① Activity related feedback- adjusts for activity- pacemakers can do this
- ① Electrical Feedback- to increased stimulation when painful nerve impulse discharge increases