Les solutions offertes par les techniques chirurgicales de neuromodulation

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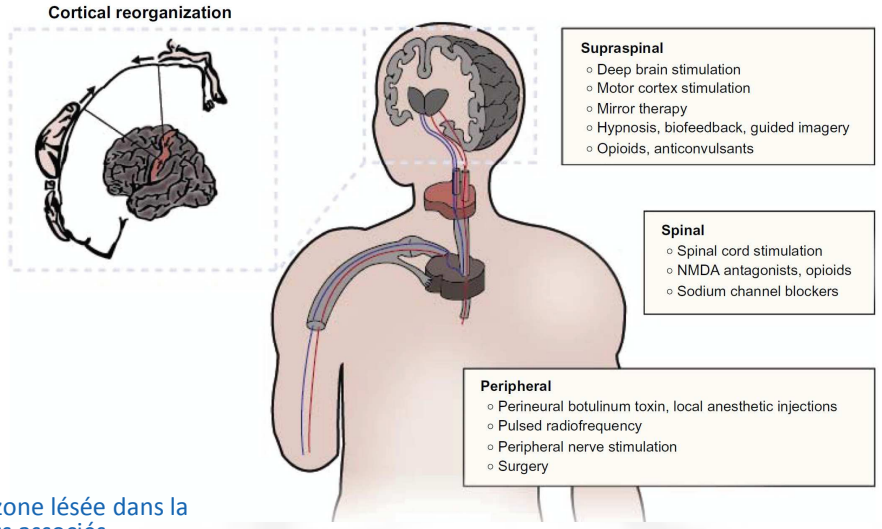
Douleur de membre fantôme

- 1552- Ambroise Paré
- Initialement classé dans les « désordres psychiatriques »
- 3 types de sensation
  - douleur du moignon
  - sensation du membre fantôme
  - douleur du membre fantôme
    - incidence 1-2/100 000
    - 55-85% des patients amputés
- Physiopathologie
  - périphérique
    - inflammation et sprouting nerveux au niveau de la zone amputée
      - décharges ectopique au niveau du névrome
    - activité spontannée –décharges éctopiques au niveau du DRG
  - spinal
    - desafferantation par diminution de la représentation de la zone lésée dans la corne dorsale et perte des contrôles inhibiteurs descendants associés
  - supraspinal
    - réorganisation thalamique et du cortex somésthésique dans les zones adjacentes au territoire amputé

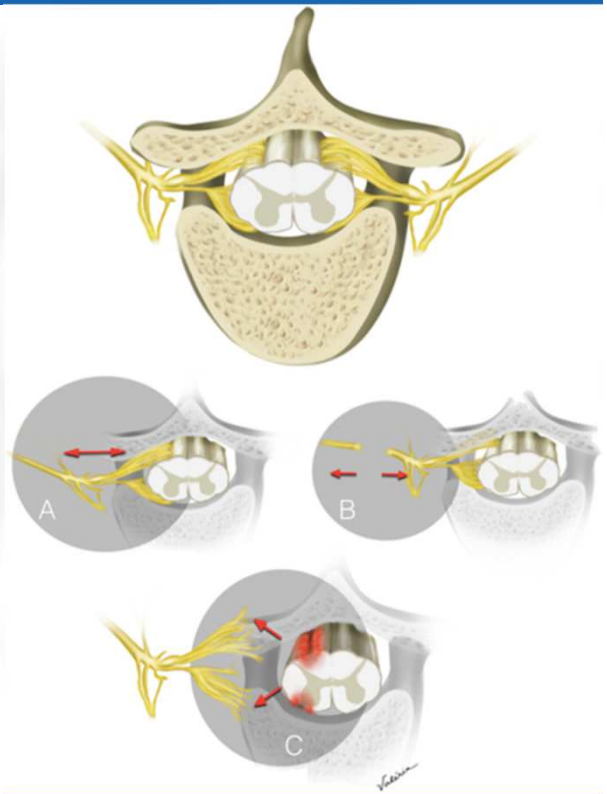
→ Combinaison de mécanismes périphériques et centraux

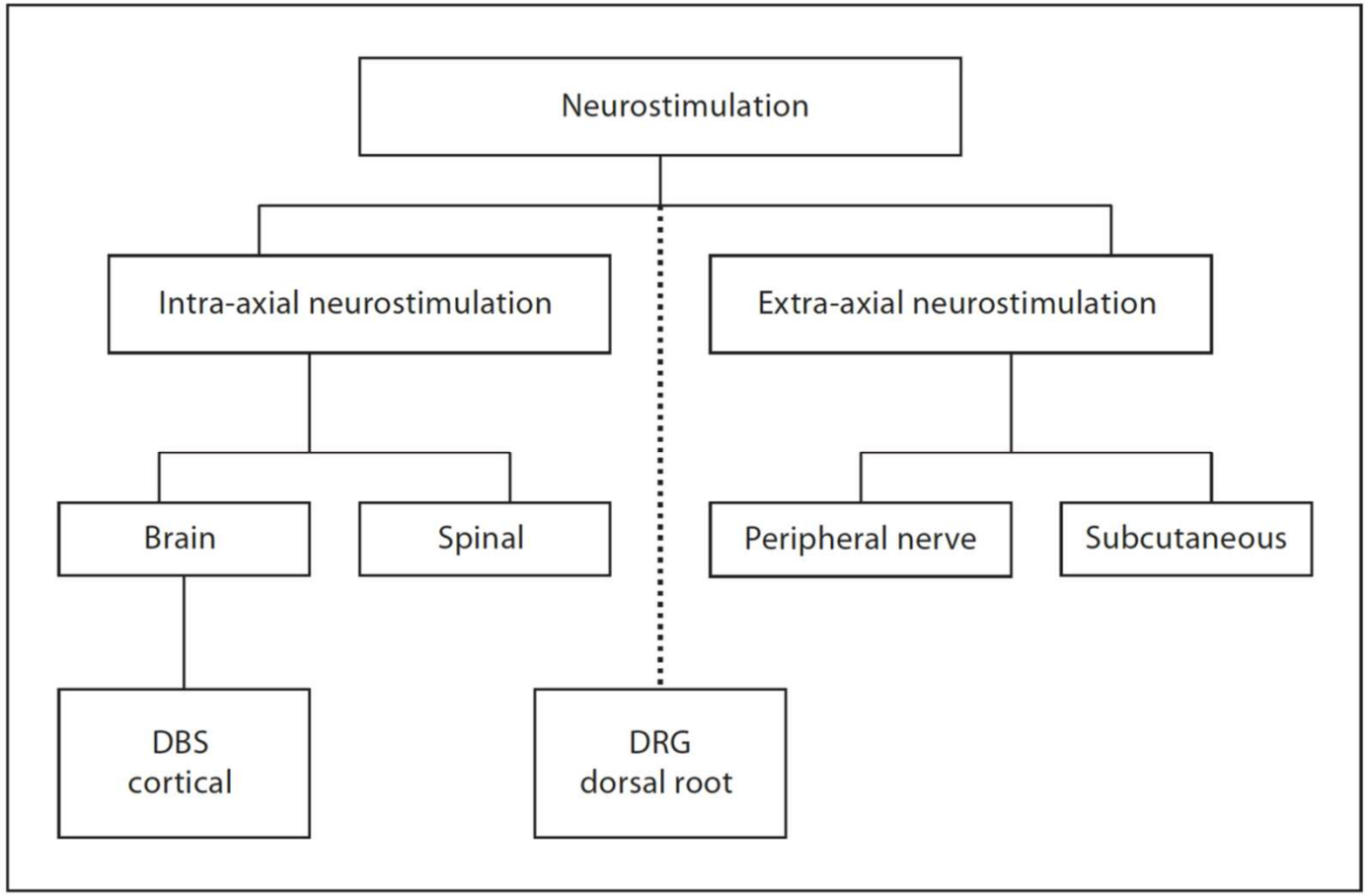


Douleur d'avulsion du plexus brachial

- 1872 – Duchenne de Boulogne
- 70% avulsion post-traumatique (AVP moto)
- Douleur dans 25-90% des cas
- Tableau clinique
  - douleur
    - continue
      - brulure, battement → neuroplasticité thalamique
    - paroxystiques
      - décharges → hyperactivité corne dorsale
  - atrophie musculaire
  - troubles vasomoteurs
- Physiopathologie
  - atteinte pré-ganglionnaire
    - deconnection des fibres nerveuses sensitives et motrices
  - modifications au niveau du tractus de Lissauer et substance gélatineuse liées à la déconnection des fibres dorsales

  → perte du contrôle inhibiteur
- Distinguer avulsion complète / partielle



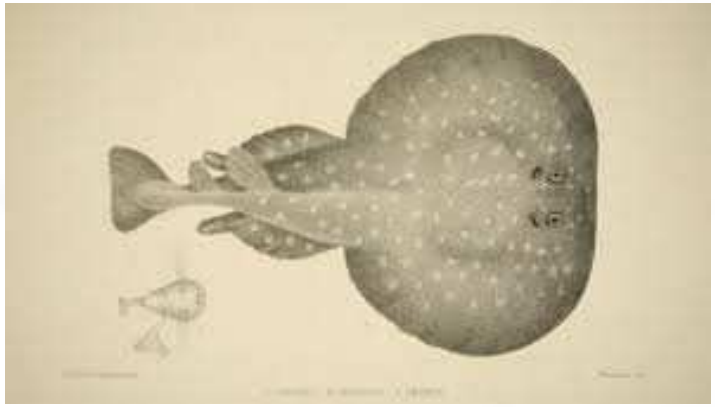


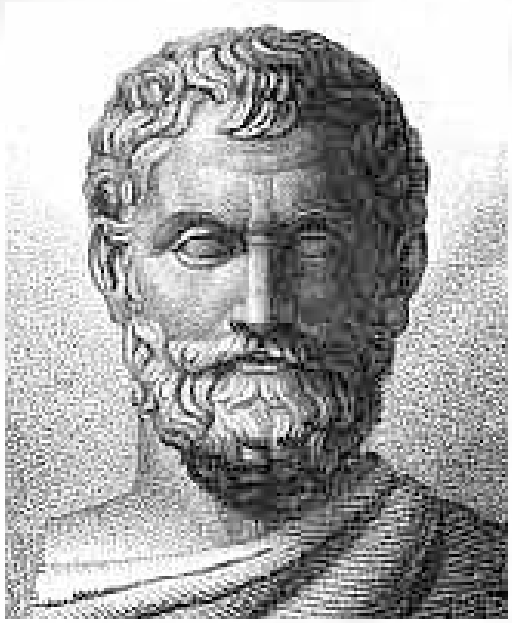
Abejon et al., Prog Neurol Surg. 2011

STIMULATION NERVEUSE PERIPHERIQUE

Aspect historique

- *Scribonus Largus*
  - effet thérapeutique de la stimulation éléctrique





Aspect historique

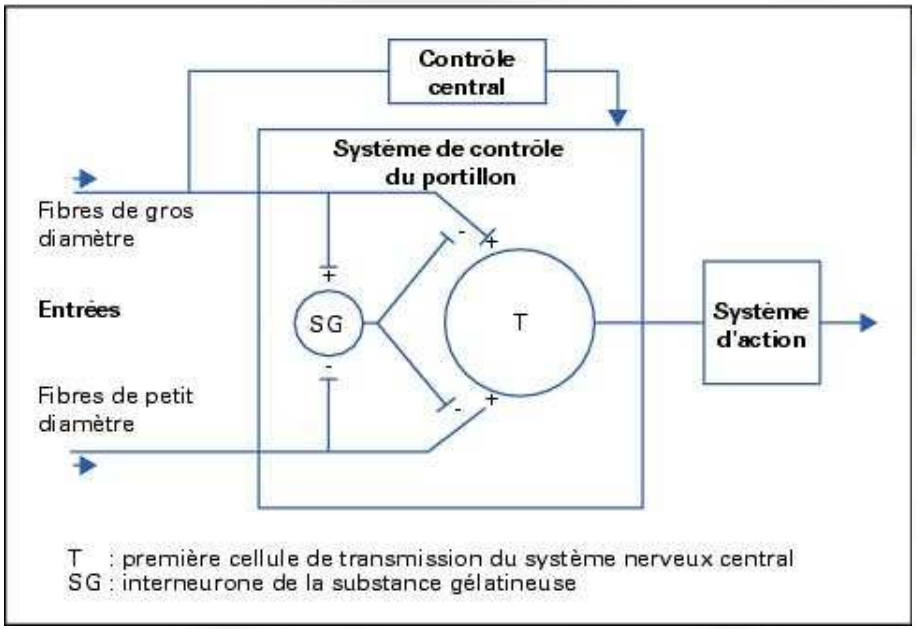
- *1859: Julius Althaus*

. . .'a direct reduction of sensibility in a nerve can be accomplished in the following way: if a continuous, or a rapidly interrupted induced current of medium intensity is sent through the trunk of a nerve – say the ulnar, or the sciatic. . . and the action of the current be kept up for a quarter of an hour or more, the pain which is excited by this proceeding becomes much less, after a certain time, than it was at the beginning of the operation, and a feeling of numbness is produced in the limb. I do not mean to say that sensibility can be entirely destroyed by this local application of electricity, but I am quite satisfied that it is notably diminished by it. The result is much more striking if there is a morbid increase in sensibility in a nerve, as in the case in neuralgia, than if a nerve in its normal state is acted upon.'

Slavin, Prog Neurol Surg. 2011

Historique des techniques

- 1965: Melzach & Wall
  - Gate control
- 1967:Wall & Sweet

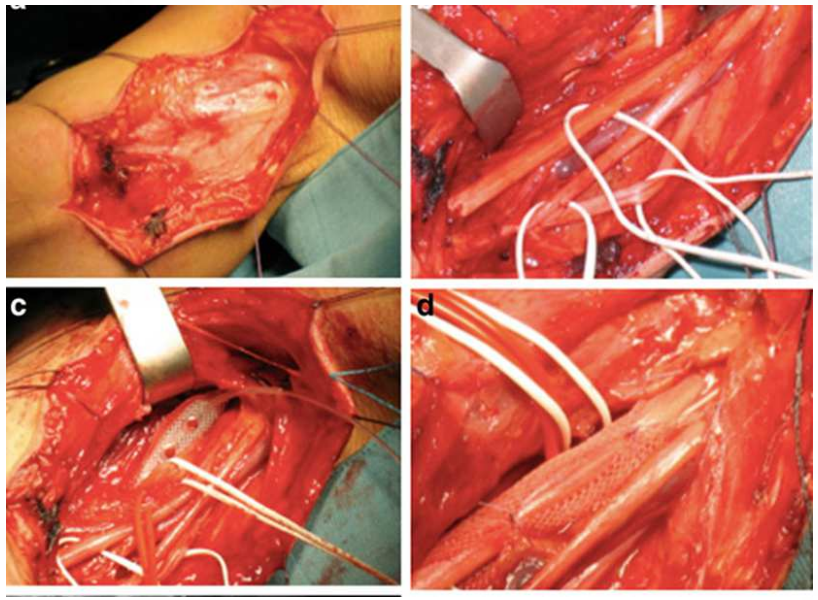


Sweet & Wepsic , Trans Am Neurol Assoc 1968

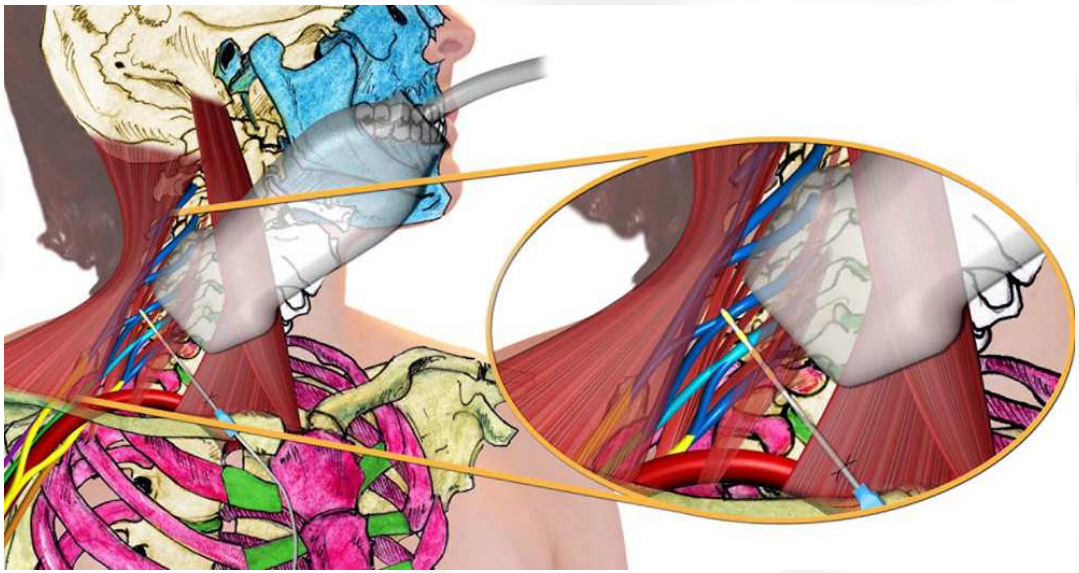
Indications

- Douleurs neuropathiques chroniques réfractaires
  - prise en charge multidisciplinaire
  - focales
    - territoire limité 1 ou 2 dermatomes
      - CRPS I & II
      - lésion nerveuse périphérique
      - post- amputation
- Positionnement de l'électrode proximal par rapport à la lésion
- Efficacité
  - du TENS
  - des blocs nerveux périphériques ou KT périnerveux
- CI
  - Nécessité d'un suivi IRM régulier

Technique chirurgicale vs percutanée



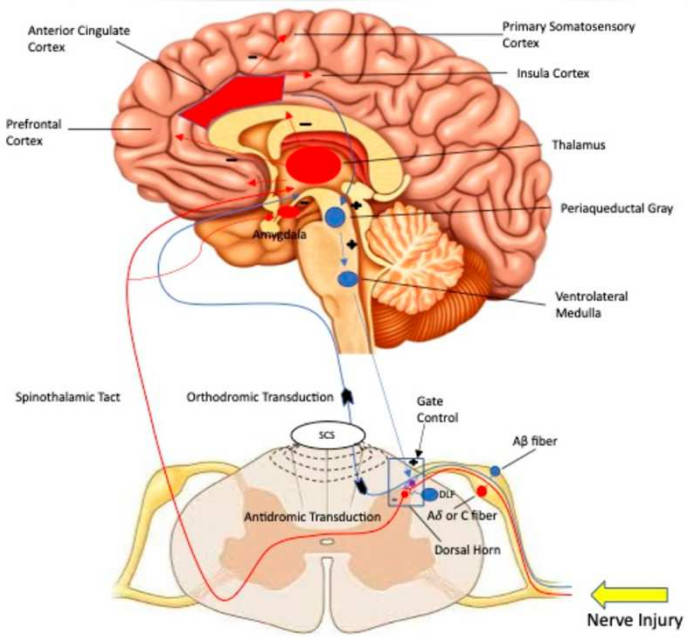
Stevanato et al. 2014



Bouche et al. 2017

Mécanismes d'action

- Réduction du tonus sympathique
  - *Sokal et al., J. Pain Research 2017*
- Réduction de l'information nociceptive à S1
  - *Ellrich & Lamp, Neuromodulation 2005*
- Inhibition périphérique
  - *Wall & Gutnik, Nature 1974*
- Mécanisme de Gate control
  - *Wall & Sweet 1967*
- Activation du système opioide endogéne
  - *Nam et al., Yonsei Medical Journal 1992*
- Régulation centrale
  - *Kupers et al., European Journal of Pain 2012*



Ong Sio et al. 2023

Complications

- Geste chirurgical
  - lésion nerveuse
  - plaie vasculaire
- Suivi
  - migration électrode 2-30%
  - infection 4-10%
  - fracture électrode 2-5%
  - érosion cutanée 0-4%

Résultats sur les douleurs d'amputation

Certainty Assessment							Impact	Certainty
№ of Studies	Study Design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Considerations		
CRPS Pain								
3	observational studies	serious [a]	not serious	not serious	not serious	strong association	All 3 studies reported improvements in pain caused by CRPS with avergage reductions in pain scores ranging from 56% to 83%	⊕⊕◯◯ Low
Shoulder Pain								
2	observational studies	not serious	not serious	not serious	serious [b]	strong association	Both studies reported improvements in pain, ranging from 48.8% to 80% reductions.	⊕⊕◯◯ Low
Phantom Limb Pain								
3	observational studies (2 RCTs)	not serious	not serious	not serious	not serious	strong association	All three studies reported reductions in pain. Average reductions were greater than 50%. In the RCT and its follow up, more patients in the PNS group experienced significant long term pain relief.	⊕⊕⊕◯ Moderate

Char et al.; Biomedecine 2022

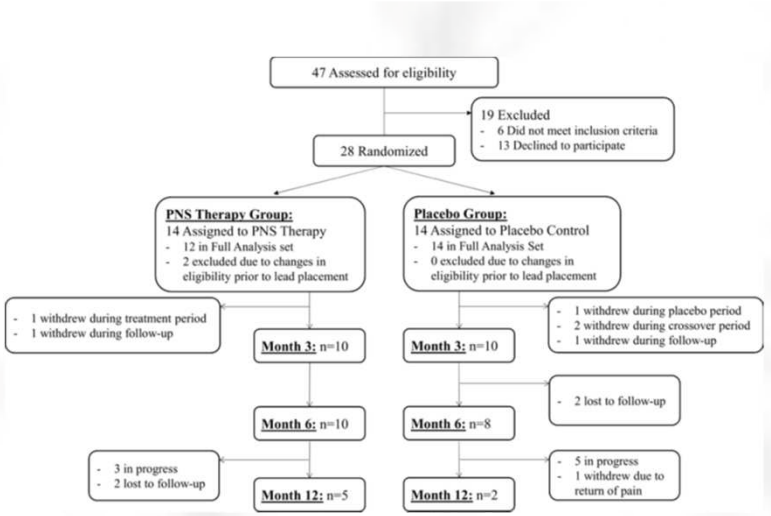
Original article

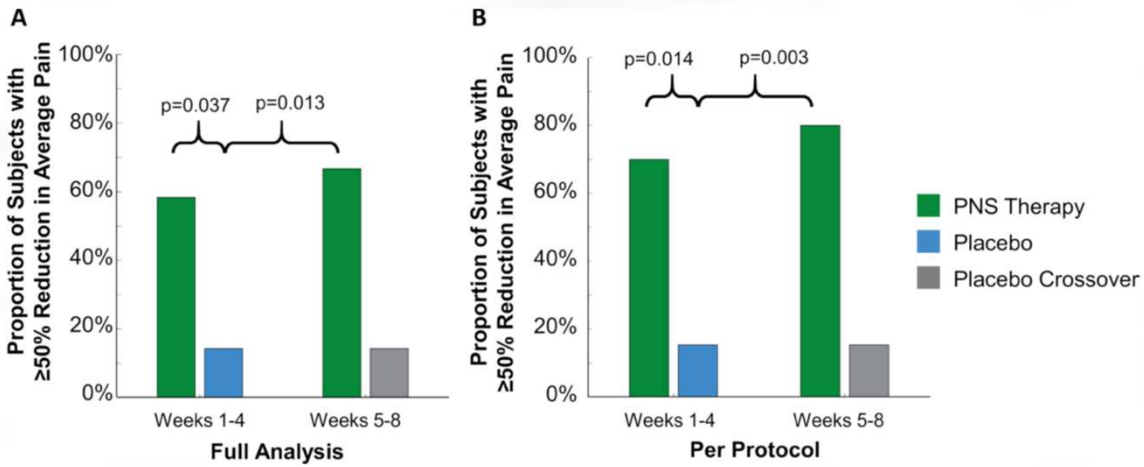
OPEN ACCESS

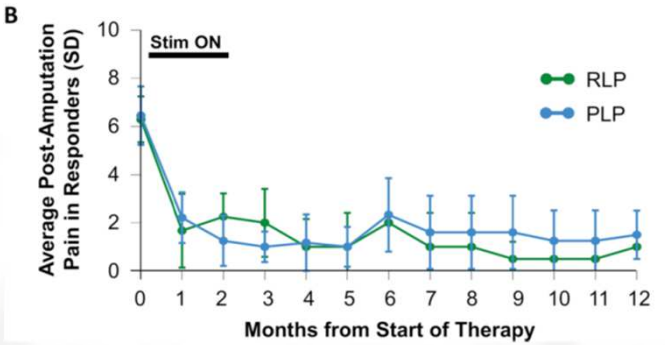
Percutaneous peripheral nerve stimulation for the treatment of chronic neuropathic postamputation pain: a multicenter, randomized, placebo-controlled trial

Christopher Gilmore,[1] Brian Ilfeld,[2] Joshua Rosenow,[3] Sean Li,[4] Mehul Desai,[5] Corey Hunter,[6] Richard Rauck,[1] Leonardo Kapural,[1] Antoun Nader,[7] John Mak,[4] Steven Cohen,[8] Nathan Crosby,[9] Joseph Boggs[9]

Reg Anesth Pain Med: first published as 1





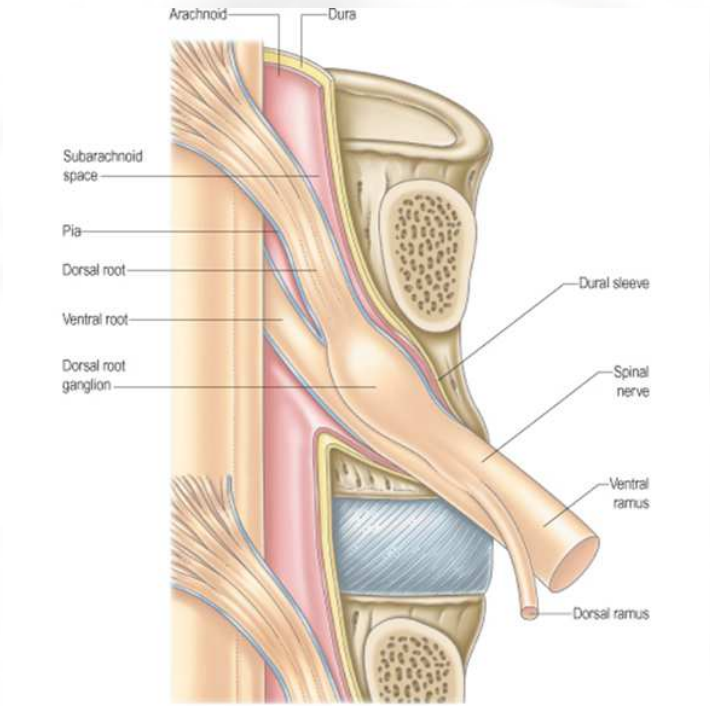


58% d'amélioration

DRG

DRG

- Contient
  - les corps cellulaires en T des neurones périphériques
    - voie spinothalamique
    - voie lemniscale
  - des cellules gliales
- Douleurs neuropathiques
  - décharges ectopiques des neurones périphériques naissent corps cellulaires en T
  - perte du rôle de régulation du message nocicepteur au niveau du corps cellulaire
  - animal
    - modification de la polarité membranaire du corps cellulaire
    - modification de l'expression génomique → augmentation des canaux membranaires



Avantages théoriques

- Stimulation directe des corps cellulaires en T
  - limiter les décharges ectopiques
  - renforcer le rôle de filtre du message nocicepteur
- Pas de fibres motrices
  - pas de recrutement
- Moins de variations de stimulation en fonction de la position
- Réduction de la consommation
  - traitement focal
  - faible couche de LCR

Indications

- Douleurs neuropathiques focales
  - post-herpétique
  - SDRC
  - douleur radiculaires
    - post-amputation
    - FBSS
  - douleurs post-chirurgicales
    - hernies inguinales
    - prise de greffe iliaque

Patient no.	Sex/ age, y	Amputation, cause, interval since amputation	Baseline phantom, effect of percussion over stump neuromas (Tinel →), notes	Level	Effect of foraminal block on…			Notes
					PLP	npPLS	Tinel →	
1	M/61	R AKA, diabetes, 30 y	PLP lateral foot (severe), npPLS leg below knee, Tinel → PLP	L3	Lost	Lost	Lost	↑ PLP provoked during insertion; result maintained during 5 d infusion
4	M/52	L AKA, trauma, 3 y, R AKA, vascular, 1 y	L PLP (modest "shooting"), R PLP (severe, "pulsing"), npPLS bilaterally, Tinel → stump pain	R–L5	Lost	Lost	Lost	↑ PLP and npPLS provoked during insertion
			7 days later	L–L5	Lost	Lost	Not certain	
5	F/24	R hip disarticulation, trauma, 2 y	PLP, npPLS knee to foot, Tinel → PLP	L4	↓90%	↓90%	Lost	"Shadow" of phantom remains
7	M/48	R AKA, trauma,10 y	PLP, npPLS, stump (itch + burning), Tinel → PLP (lateral toes)	L4	Lost	No change	Lost	
8	M/22	R lateral foot (toes 2–5), trauma, 9 y	PLP (severe in toe 5), npPLS, Tinel → stump pain, scar "cold"	L5	Lost	Lost	Lost	
9	M/24	R BKA, trauma, 10 y	PLP (toes 4, 5), npPLS, ongoing stump pain	L4	Lost	Lost	Lost	
10	M/39	R BKA, trauma, 10 y	PLP ("pinching, like a very tight sock"), npPLS, Tinel → PLP + stump pain, ongoing stump pain (cold)	L5	Lost	Quality changed	Lost	PLP replaced with "pleasant" npPLS
11	M/51	L foot, trauma, 10	PLP (sole), npPLS (foot), Tinel → stump pain	L5	Lost	No change	Not certain	
12	F/55	R BKA, trauma, 17 y	PLP (foot only), npPLS (foot only), Tinel → stump pain	L4	Lost (→ "numb")	↓60%	No change	Foot telescoped to stump, can be moved
			Next day	L5	Not certain	↓, not certain	Lost	
13	M/55	L BKA, trauma, 11 y	PLP, npPLS ("tingling"), Tinel → PLP (in toe 1)	L5	↓60%	Lost	↓50%	Foot telescoped to stump, toes can be moved.
14	M/57	R foot, trauma, 11 y	PLP (toe 1 "bound"), npPLS (toes 2–5), Tinel → PLP (all toes, "electric")	L5	Lost	Only movement lost	To medial toes lost	Foot telescoped to stump, can be moved
			Soon after L5	L4	Still absent	Lost	To lateral toes ↓ 80%	
15	M/52	L at knee, diabetes, 45 d	PLP (toe 1 and ankle), npPLS (whole leg), Tinel → stump pain	L4	Lost	Lost	Lost	Result maintained during 12 d infusion
16	F/77	L medial toe (toe 1), diabetes, 17 d	PLP ("sharp"), npPLS, Tinel → stump pain	L5	Lost	Not certain	Lost	Result maintained during 10 d infusion

Vaso et al.; Pain 2014

Study	Intervention parameters	Results
Eldabe *et al.* 2015[64,79]	Narrow quadripolar neurostimulation leads using an epidural approach and curved stylets. Stimulating contacts placed near relevant DRGs based on individual pain distributions. All patients underwent a multiple-day period of trial stimulation: ≥ 50% pain relief was considered successful. Frequency: 20–40 Hz	Mean follow-up duration: 14.4 months. Mean VAS score at last follow-up was 38.9 (SD 27.1). Mean of 52.0% (SD 31.9%) pain reduction (stump and/or PLP) Eight out of eight patients received a permanent implant (100% trial success rate) % pain relief for the four patients who had only PLP: 0% (at 24 months), < 20% (at 24 months), 29% (at 13 months), 100% (at 5 months) Five patients had good pain relief outcomes. Three patients experienced poor outcomes, despite good initial results EQ-5D assessed in two patients: 'significant improvement' reported but numbers not presented. No complications were reported for any of the patients
Love-Jones *et al.* 2015[63] (conference abstract)	Specifically designed quadripolar leads placed in the epidural space near the relevant DRG following standard procedures Patients underwent trial period	Results not reported separately for PLP and stump pain 16 of 22 patients received a permanent implant (73% trial success rate) At 6 months, VAS score was reduced to 37.8 (SD 35.4) ($n = 10$) Six of 16 permanently implanted patients reported ≥ 50% pain relief EQ-5D index score improved from 0.27 (SD 0.29) ($n = 14$) to 0.60 (SD 0.28) ($n = 10$); $p < 0.05$ Total weighted rank and number of words chosen in MPQ improved from 44.9 (SD 13.4) to 19.0 (SD 17.3) and 14.9 (SD 4.61) to 7.3 (SD 5.7), respectively; $p < 0.05$ One patient was explanted for inadequate pain relief after 6 months
Wahlstedt and Leljevahl 2013[65] (conference abstract)	Patients underwent a trial in which specifically designed leads were implanted at the target DRGs. Following successful trial, patients received a fully implantable neuromodulation device	After 1 week, PLP improved in one patient by 100%; results not reported for 1-month time point Results not reported for the second PLP patient

Corbet et al.; 2018

Résultats sur les douleurs d'amputation

Patient	Age/sex	Reason for amputation	Location of amputation	Major area of pain	Years postamputation	Lead location	Amplitude (μA), PW (μs), *f* (Hz)	Pain relief at last follow-up (%)	Follow-up duration (months)
1	38/F	CRPS	Left foot	Left foot*	1	L L5; R L5	500/400/20; 750/420/20	28.6	13
2		—	Left leg	—	—	L L4; L L5	725/270/20; Not used	50.0	20
3	28/F	Rocket attack	Above knee	Feet and ankles*	11	L L4; L L5	600/200/20; 250/280/20	—	24
4	-/M	Motor cycle accident	Left foot	Entire left foot*	6	L L5; LS1	850/200/40; 1800/250/20	<20	24
5	76/M	Accident	Above knee	Leg and foot*	18	R L3; R L4	150/200/20; 350/200/20	100.0	5
6	60/F	Arterial embolism	Right arm	Hand†	1.5	—	—	0.0	12
7	62/F	Traumatic injury of aorta	Right leg	Foot†	3	—	—	33.3	12
8	35/F	Genocide	Left arm	Entire upper arm‡	15	L C7	—	67.8	5

*PLP.
†PLP (worst) and stump pain.
‡Stump pain (worst) and PLP.

Soulagement moyen 52%

3 patients DRG non efficace
→ Mauvais positionnement

Eldabe et al.; Neuromodulation 2015

Résultats sur les douleurs d'amputation

Table 3. Phantom Limb Paresthesia Generated with DRG Neuromodulation.

Case	Paresthesia description	Location of the phantom
1	The patient complained of electric sensations intermittently in her phantom limb; the stimulator was therefore used at subthreshold amplitudes.	Left foot
3	The patient felt the stimulation in the most painful area of her phantom foot, and reported motor contraction when stimulation was turned too high.	Left foot
4	Stimulation-induced paresthesia from the L5 lead was felt at the bottom of the phantom foot. The S1 lead elicited painful muscle tics at high stimulation amplitudes.	Left foot
5	The L3 lead elicited paresthesia just at the top of his foot, while the L4 lead covered his pain in the stump. Final programming left the patient reporting pain relief at subthreshold amplitudes.	Right foot
8	When stimulation was turned on, the patient described disappearance of the phantom limb and the pain associated with the stump. She does not feel her phantom limb anymore while the paresthesia covers her painful stump.	Left arm

Eldabe et al.; Neuromodulation 2015

Résultats sur les douleurs d'amputation

Selective Radiofrequency Stimulation of the Dorsal Root Ganglion (DRG) as a Method for Predicting Targets for Neuromodulation in Patients With Post Amputation Pain: A Case Series

Corey W. Hunter, MD*; Ajax Yang, MD†; Tim Davis, MD‡

Objective: While spinal cord stimulation (SCS) has established itself as an accepted and validated treatment for neuropathic pain, there are a number of conditions where it has experienced less, long-term success: post amputee pain (PAP) being one of them. Dorsal root ganglion (DRG) stimulation has shown great promise, particularly in conditions where traditional SCS has fallen short. One major difference between DRG stimulation and traditional SCS is the ability to provide focal stimulation over targeted areas. While this may be a contributing factor to its superiority, it can also be a limitation insofar stimulating the wrong DRG(s) can lead to failure. This is particularly relevant in conditions like PAP where neuroplastic maladaptation occurs causing the pain to deviate from expected patterns, thus creating uncertainty and variability in predicting targets for stimulation. We propose selective radio-frequency (RF) stimulation of the DRG as a method for preoperatively predicting targets for neuromodulation in patients with PAP.

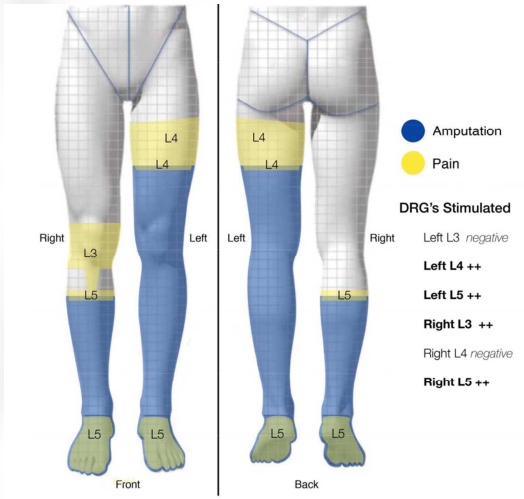
Methods: We present four patients with PAP of the lower extremities. RF stimulation was used to selectively stimulate individual DRG's, creating areas of paresthesias to see which most closely correlated/overlapped with the painful area(s). RF stimulation to the DRG's that resulted in the desirable paresthesia coverage in the residual or the missing limb(s) was recorded as "positive." Trial DRG leads were placed based on the positive RF stimulation findings.

Results: In each patient, stimulating one or more DRG(s) produced paresthesias patterns that were contradictory to know dermatomal patterns. Upon completion of a one-week trial all four patients reported 60–90% pain relief, with coverage over the painful areas, and opted for permanent implant.

Conclusions: Mapping the DRG via RF stimulation appears to provide improved accuracy for determining lead placement in the setting of PAP where pain patterns are known to deviate from conventional dermatomal mapping.

Patient	Age/Gender	Amputation	Anatomic location of pain	Corresponding DRG
1	59/M	L BKA	L residual limb, thigh, and the groin	Left L4, L5
2	32/F	R BKA	R phantom foot, residual limb pain in thigh, and stump pain	Right L3, L5
		L AKA	Left phantom foot, residual limb pain in knee, and stump pain	Left L4, L5
3	67/M	L Syme	Left phantom foot	Left L3, L4 L5 (minimally)
4	30/M	L AKA	Left phantom ankle/foot, stump pain, residual limb throughout entire leg	Left L4, L5

M, male; F, female; BKA, below knee amputation; AKA, above knee amputation.



Author & year	Type of study & journal	# of cases	Lead location	Pain intensity pre-DRG stimulation	Pain intensity post-DRG stimulation	Quality of life improvement	Follow-up (mos)
Goebel et al. 2018 (45)	Case Study Pain Practice	1	L4	BPI: 9	BPI: 5.9	-Sleep duration increased by 3 hours -Stopped use of crutches -Mood Stabilization	17
Eldabe et al. 2015 (46)	Retrospective Case Series Neuromodulation	8	C6-C7 L3-S1	VAS: 83.5 ± 10.5 mm	VAS: 38.9 ± 27.1 mm	EQ-5D index score: score not reported Significant improvement in quality of life (n = 2)	Post-implant: 9.0 ± 6.3
Hunter et al. 2017 (43)	Case Series Neuromodulation	4 (trialed)	L3-L5	NRS-11: #1: 7-8 #2: 6-7 #3: 7-9 #4: 7-8	% decrease #1: 85% #2: 60% #3: 90% #4: 90%	N/A	Until end of trial period (5 to 7 days)
Love-Jones et al. 2015 (47)	Prospective Case Series (conference abstract in Neuromodulation)	16 (implanted), 22 (total trialed)	N/A	VAS: 86.1 ± 10.5 mm (n = 14)	VAS: 37.8 ± 35.4 mm (n = 10)	EQ-5D index score: 0.271 ± 0.288	6
Wahlstedt A & Leljevahl E. 2013 (48)	Retrospective Case Series (conference abstract in Neuromodulation)	2 PLP	N/A	VAS*: 60.9% ± 13.1% (n = 4) *Also includes 1 CRPS & 2 groin pain	VAS*: 64.6% ± 17.7% (n = 3) After one week, phantom hand pain had improved by 100% in the postamputation pain patient.	N/A	1

- 5 études
- 37 cas
  - 31 implantés
- 31.5 % - 59.3% soulagement rapporté

Srinivasan et al.; Pain Physician 2022

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REVIEW

Best Practices for Dorsal Root Ganglion Stimulation for Chronic Pain: Guidelines from the American Society of Pain and Neuroscience

Kenneth B Chapman[1–3], Dawood Sayed[4], Tim Lamer[5], Corey Hunter[6], Jacqueline Weisbein[7], Kiran V Patel[1–3], David Dickerson[8,9], Jonathan M Hagedorn[10], David W Lee[11], Kasra Amirdelfan[12], Timothy Deer[13], Krishnan Chakravarthy[14,15]

Table 3 ASPN Best Practices Guidelines for DRG Stimulation Evidence Ranking

Indication	Grade	Level of Certainty	Evidence	Studies
CRPS I and II	A	High	I	[1,10,14,72,88–106]
Post-Hernia Repair	B	Moderate	II-2	[101,105,114–117]
Post-Joint Surgery	C	Low	III	[99,102,104,121–124]
FBSS	C	Low	III	[2,8,77,82,106,125,126]
Post-Amputation	I	Low	III	[103,135]
Nonsurgical Low Back Pain	C	Low	III	[9]
Peripheral Neuropathy	C	Low	III	[58,127–134]
Pelvic Pain	C	Low	III	[97,98,143–147]
Post-Herpetic Neuralgia	I	Low	III	[71,121,136–141]

STIMULATION MEDULLAIRE

Résultats sur les douleurs d'amputation

SCS	Subdural	Nielson et al[98]	6	Subjective pain relief	7–25 months	4 excellent, 1 good
SCS	Subdural, endodural	Hunt et al[100]	5	Excellent: complete pain relief Partial: incomplete pain relief	Not noted	1 excellent, 1 partial, 3 no benefit
SCS	Epidural	Miles and Lipton[101]	9	Excellent: no narcotics Some: need for occasional narcotics	1 year	6 excellent, 1 some, 2 none
SCS	Subdural, endodural	Krainick et al[99]	61	% subjective pain relief	Not noted	0% – 28 1%–25% – 7 26%–50% – 12 51%–75% – 13 >75% – 1
SCS	Epidural	Sanchez-Ledesma et al[102]	3 trials 6 implants	>75% subjective pain relief	5.5 years	57% met success criteria
SCS	Epidural	Broggi et al[104]	23 trials 26 implants	Verbally classified pain intensity > 50%, life standard	2 years	58% met success criteria
SCS	Epidural	Kumar et al[103]	3	>50% improvement subjective pain relief	6 months to 15 years	0
SCS	Epidural	McAuley et al[111]	12	>50% improvement VAS	5–20 years	5/12

Hsu & Cohen , J Pain Research 2013

Résultats sur les douleurs d'amputation

Patient	Subjective Pain Relief	Would Choose to Have Stimulator Implanted Again	Change in Usual Amount of Pain*	Change in Total Symptom Score
1	>80%	Equivocal	Decreased by 2	Decreased by 13 (42%)
2	>80%	Yes	Decreased by 2	Decreased by 14 (70%)
3	>80%	Yes	Decreased by 2	Decreased by 4 (25%)
4	>80%	Yes	No change	Increased by 5 (45%)†

* Determined by numerical pain scale.
† Attributable to recurrent cancer and treatment.

Table 4. Patient Subscores along Brief Pain Inventory

	Patient 1		Patient 2		Patient 3		Patient 4	
Symptoms	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop
Fatigue	4	2	2	2	6	1	3	3
Nausea	0	0	0	0	0	0	3	0
Depression	0	2	4	2	3	1	1	0
Anxiety	0	0	0	0	3	2	0	0
Drowsiness	4.5	2	3	0	2	2	3	4
Difficulty thinking clearly	3	2	4	0	1	1	1	2
Shortness of breath	4	0	0	0	0	0	0	0
Poor appetite	5	4	0	0	0	1	0	2
Insomnia	6.5	6	5	2	1	3	0	0
Feeling of well-being	4	0	2	0	0	1	0	5
Total	31	18	20	6	16	12	11	16

Viswanathan et al.; Pain practice 2010

Case	Duration of stimulation (years)	Mean battery life (years)	Initial pain relief (%)	Final pain relief (%)	% used	Complications	Stimulation ongoing
1	11	5	80	80	100	Battery site stimulated stoma, settled when replaced.	Yes. Worthwhile benefit
2	14	8	50	60	100	No	Yes. Worthwhile benefit
3	19	10	75	0–25	At night	Positional dependence, frequent electrode setting changes, connector breakage, eventual loss of benefit as stimulation sometimes painful	No. Long-lasting worthwhile benefit but waned after 19 years.
4	1	–	50	–	100	Repositioned electrodes but stimulation only on right not left.	Lost to follow-up, initially worthwhile benefit.
5	1	–	80	–	100	Electrode contact changes required, relieved pain when sitting but not when standing on left leg	Lost to follow-up, initially worthwhile benefit
6	5	–	50	50	100	Electrode revision after a fall. Control box failure after two years. Causalgia pain at battery site.	Yes. Worthwhile benefit
7	2	–	60	60	100	Revision of electrodes after one year due to shift in electrode position	No. Worthwhile benefit but lead fracture after 2 years and not replaced.
8	3	–	50	0	100	As phantom limb and anterior stump pain subsided, electrode revisions for posterior L5 pain	No. Lack of benefit for the new radicular pain.
9	3	–	75	0	100	Revision of electrodes after one year and four years as stimulation in left leg only	No. Temporary benefit only. Below knee amputation when stimulation failed.
10	–	–	0	–	–	Stimulation could only be achieved into the right buttock and left foot.	No. Revisions not attempted
11	20	8	90	90	Little	Cyst at electrode site; unit failure from airport security devices; frequent reprogramming for position; now uses intermittently as pain infrequent and relieves after half an hour of use. Stimulation also affects right leg and function thereof so only uses when required.	Yes. Worthwhile benefit
12	8	–	60	50	10	New electrodes after three years due to positional effect with original electrodes	Yes. Worthwhile benefit

McAuley et al. Neuromodulation 2012

Areas of caution	USPSTF evidence strength (9)	USPSTF recommendation strength (9)
When considering SCS for the patient with multiple or poorly defined pain generators or diagnoses	II-3	C
In patients who have areas of spinal stenosis or cord compression from disk disease, bony overgrowth, or other structural abnormalities in areas where lead placement is required for therapeutic stimulation	III	I
For those undergoing SCS with an indwelling pacemaker or automatic implanted cardiac defibrillator, proper evaluation and monitoring should be available, and the patient should be cleared by cardiology prior to permanent implant; many patients have been implanted successfully with both systems, and this may become more common with work being done on congestive heart failure	III	C
When using SCS or PNS for patients with active malignancies who may require MRI scanning to monitor disease progress. The use of neurostimulation is warranted for patients with moderate to severe neuropathic or mixed pain who are in remission or have tumors expected to grow at a slow and often painful rate	III	C, consensus panel moderate
When considering SCS or PNS for nonradicular focal bone pain; this therapy should only be considered in extreme cases	III	C
The use of SCS for the treatment of axial back pain after identifying a specific pain generator(s)—for PnfS, both alone or in combination to treat axial back pain, should be performed with use of strict protocols; the use of combined SCS and PNfS should be considered when pain is equal or slightly greater in the axial back or neck; in dominant axial back pain, complex paddle leads or complex percutaneous leads should be considered; kilohertz-frequency SCS and burst SCS may change this recommendation in future	III	I, consensus panel strong
When using conventional SCS as a treatment for chest wall pain, PNS, PNfS, and DRG stimulation offer potential options in areas difficult to capture with dorsal column targeting	III	I, consensus panel strong
When using SCS to treat HIV neuropathy, decision-making should be performed on an individual basis, based on comorbidities and medications	III	I, consensus panel strong
Use of SCS to treat painful diabetic peripheral neuropathy is often helpful but should be approached with caution considering the increased risk of infection; SCS might improve blood flow in this group, which may promote wound healing and limb salvage	III	I, consensus panel strong
Use of SCS to treat postamputation pain, realizing that the pain may vary and results may be unpredictable	II-3	C
Spinal cord injury should be approached on a case-by-case basis and neuromodulation therapies used judiciously if the pain extends beyond a well-circumscribed, segmental distribution	III	I, consensus panel moderate
The use of PNS should be reserved for patients in whom the pain distribution is primarily in and in close proximity to a named nerve known to innervate the area of pain	II-2	B
With PNS or PNfS, the temporary relief of the patient's pain by an injection of local anesthetic in the nerve distribution should be seen as an encouraging sign, but not mandatory, as prognostic value is not established	III	I, consensus panel moderate

DRG, dorsal root ganglion; PNfS, peripheral nerve field stimulation; PNS, peripheral nerve stimulation; SCS, spinal cord stimulation.

Deer et al.; Neuromodulation 2014

Protocoles en cours

ClinicalTrials.gov identifier and title	Intervention	Study design	Participants	Location	Status (November 2017)
NCT02684201; *Epidural Spinal Cord Stimulation for Sensory Restoration and Phantom Limb Pain in Upper-Limb Amputees*[37]	SCS	Single-group study	PLP	USA	Recruiting participants
NCT03027947; *Spinal Root and Spinal Cord Stimulation for Restoration of Function in Lower-Limb Amputees*[38]	SCS	Single-group study	PLP	USA	Recruiting participants

Résultats sur les douleurs d'avulsion

Author	Year	# BPA patients /total	Age, sex	Injury pattern mentioned in article	Duration of pain	Previous treatments (not including medications)	Type of stimulation	Lead type; lead level	Pain outcome measure	Pre-SCS	Post-SCS	Follow-up duration
			29, F		5 y			feedback to area of stimulation				
			42, M		4 y							
Piva et al. (17)	2003	4 / 4	45, M	C6 - C8 avulsions	2 y	Stellgate ganglion blocks (1 underwent amputation of hand)	Conventional 50–100 Hz	Percutaneous; 7 contacts - top at C2; lowest over T1-T2	VAS	8	6	9 mo
			36, M	C5 - T1 avulsions	16 y					9	5.5	
			43, M	C5 - T1 avulsions	13 y					9	5	
			34, M	C6 - C8 avulsions	4 y					10	7	
Lai et al. (19)	2009	1 / 1	70, M	C4 - C7 avulsions	15 y	DREZ x 2–14 years (pain reoccurred 6 mo later) and 3 mo ago	NR	Paddle; over C3-C5	NR	NR	"Sleep well…and did not use any analgesics"	12 mo
Wolter and Kieselbach (18)	2012	3 / 23	65, M	Nerve root avulsion	NR	NR	NR	Percutaneous; tip at C3	NR	NR	Unpleasant stimulation	8-day trial
			58, M					Percutaneous; tip at C5			Insufficient pain reduction despite optimal paraesthesia	23-day trial
			40, M					Percutaneous; could not be advanced past C6 due to intradural scarring			Insufficient paraethesia coverage with inability to advance lead past C6	Trial procedure aborted
Abdel-Aziz and Ghaleb (20)	2014	1 / 1	25, M	Complete C6 - T1 avulsion	5 y	NR	NR	Paddle; C3-C5	NRS	7/10	"Good coverage of pain"	1 mo
Chang-Chien et al. (10)	2014	1 / 1	42, F	L C5 - C7 BPA	~ 14 mo	13 stellate ganglion blocks	Conventional 60 Hz	Percutaneous; C2 - C5 (L), C4 - C7 (R)	NRS	9/10	2/10	10 mo
Floridia et al. (21)	2018	1 / 1	32, F	C5 - C6 avulsions	13 mo	Tonic SCS w/ leads at C4 - C5	High-frequency	Percutaneous; tip at C2	NRS	8/10	80% pain improvement, improved QoL, pain medication stopped	6 mo
Watanabe et al. (22)	2018	1 / 1	36, M	R BPA	20 y	NR	25 Hz	Percutaneous; dorsal lead tip at C5 (cathode), ventral lead over C5 - C6 (anode)	VAS	8.9	5.5	5 mo

Dombovy-Johnson et al. 2019

Journal of Pain Research

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CASE REPORT

Treatment of pain post-brachial plexus injury using high-frequency spinal cord stimulation

This article was published in the following Dove Press journal:
Journal of Pain Research

Daniela Floridia
Francesco Cerra
Giuseppe Guzzo
Silvia Marino
Nunzio Muscarà
Francesco Corallo
Alessia Bramanti
Antonino Chillura
Antonino Naro

IRCCS Centro Neurolesi Messina, Messina, Italy

Purpose: Brachial plexopathy can sometimes cause severe chronic pain. There are many possible treatments for such neuropathic pain, including neuromodulation. However, rigorous scientific evidence on the usefulness of spinal cord stimulation (SCS) is still scarce. Here, we report the use of high-frequency (10 kHz) SCS (HFSCS) in a patient with brachial plexus injury (root avulsion).

Objective: To assess the efficacy of HFSCS in root avulsion and to investigate the putative neurophysiological mechanisms of HFSCS.

Methods: A 32-year-old woman visited our center following an iatrogenic brachial plexus injury. She underwent traditional, paresthesia-inducing, tonic SCS with cervical lead placement. She reported that stimulation-induced paresthesia was uncomfortable, without any pain reduction. After the successful trial of HFSCS, the patient was assessed at 1 month (T1) and 6 months (T6) after HFSCS implantation with pain and quality of life (QoL) scales. Moreover, she underwent a neurophysiological assessment (somatosensory evoked potentials [SEPs], reciprocal inhibition [RI], pain-motor integration [PMI], and the habituation of intraepidermal electrical stimulation-induced evoked potentials [IEPs]) with the stimulator switched on and switched off at T6.

Results: The patient reported 100% paresthesia-free pain relief, a consistent improvement of QoL, and a complete discontinuation of her previous pain treatment at T1 and T6. Moreover, we found suppression of SEPs, restored habituation of IEPs, and strengthening of RI and PMI.

Conclusion: This is the first report to illustrate the usefulness and safety of HFSCS for treating root avulsion in a patient with failed tonic SCS. Our data indicate that HFSCS may either block large-diameter fibers or stimulate medium-/small-diameter fibers, thus inducing analgesia without paresthesia, probably by reducing the activation of the wide-dynamic-range neurons. Moreover, HFSCS seems to modulate spinal inhibitory mechanisms and the descending corticospinal inhibitory output. Thus, HFSCS can be an effective option for treating refractory pain following root avulsion.

Table 1 Indications for SCS (also see Appendix 2)	
Good indications for SCS (likely to respond)	Neuropathic pain in leg or arm following lumbar or cervical spine surgery (FBSS/FNSS)
	Complex regional pain syndrome (CRPS)
	Neuropathic pain secondary to peripheral nerve damage
	Pain associated with peripheral vascular disease
	Refractory angina pectoris (RAP)
	Brachial plexopathy: traumatic (partial, not avulsion), post-irradiation
Intermediate indications for SCS (may respond)	Amputation pain (stump pain responds better than phantom pain)
	Axial pain following spinal surgery
	Intercostal neuralgia, such as post-thoracotomy or post-herpetic neuralgia
	Pain associated with spinal cord damage
	(other peripheral neuropathic pain syndromes, such as those following trauma may respond)
Poor indications for SCS (rarely respond)	Central pain of non-spinal cord origin
	Spinal cord injury with clinically complete loss of posterior column function
	Perineal or anorectal pain
Unresponsive to SCS	Complete spinal cord transection
	Non-ischaemic nociceptive pain
	Nerve root avulsion

Recommandations société britannique de prise en charge de la douleur

RECRUITING

NCT04733599

Neurostimulation for Treatment of Chronic Upper Limb Pain After **Brachial Plexus** Injury

Conditions

Brachial Plexus Injury

Locations

Rochester, Minnesota, United States

Study Overview

Brief Summary

The purpose of this study is to see how much pain intensity is affected by high frequency **spinal cord stimulation** therapy in individuals with serious brachial plexus injury.

Detailed Description

This single-site prospective observational cohort study will include all adults (> 18 years old) with brachial plexus avulsion injury who are candidates for high frequency (HF10) spinal cord stimulation (SCS). We plan to prospectively observe patients who undergo implantation of HF10 SCS for the indication of chronic neuropathic pain of the upper limb following brachial plexus avulsion injury.

Official Title

High Frequency **Spinal Cord Stimulation** for Neuropathic Pain Following **Brachial Plexus Avulsion Injury**: a Prospective Observational Cohort Study

Study Start (Actual)

2021-02-01

Primary Completion (Estimated)

2025-12

Study Completion (Estimated)

2025-12

Enrollment (Estimated)

20

Study Type

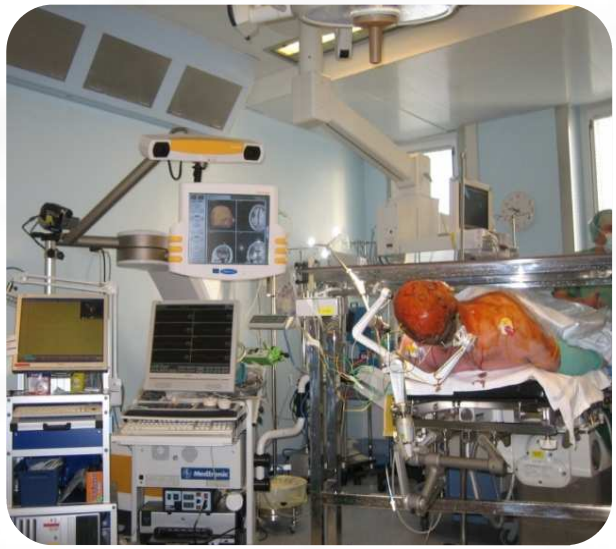
Observational

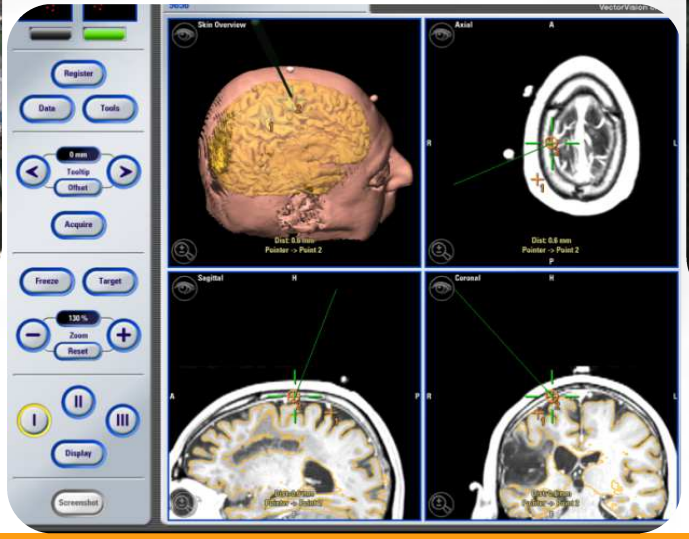
STIMULATION CORTICALE

Stimulation du cortex moteur

- Historique
  - résection de M1 (*White & Sweet 1955, Lende et al*. 1971)
  - stimulation du cortex préfrontal (*Tsubokawa et al. 1985*)
  - stimulation de M1 *(Hirayama et al. 1990, Tsubokawa et al. 1991)*
- Indications
  - douleurs post-AVC (*Lefaucheur et al. 2001*)
  - douleurs neuropathiques par atteinte du V (*Lazorthes et al. 2007*)
  - douleurs post-avulsion du plexus bracial & post-amputation
- Mécanismes
  - composante sensori-discriminative (*Masri et al. 2009, Drouot et al. 2002*)
    - contrôle thalamique anti-dromique
    - activation du système opioïde inhibiteur descendant
  - composante émotionnelle (*Garcia-Larréa et al. 1999, Manola et al. 2007)*
- Facteur prédictif
  - réponse à la rTMS
- En 2018- 700 patients implantés (*Henssen et al. 2019*)

Technique chirurgicale





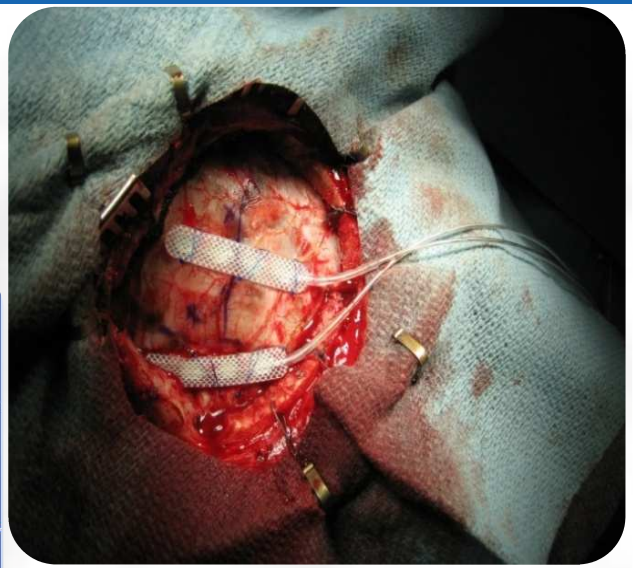


TABLE 1: Summary of literature results of MCS for chronic neuropathic pain*

Series	Corresponding Redundant Series†	No. of Patients	FU (mos)	No. of Patients (%) Pain Relief >70%	Pain Relief >50%	Pain Relief >40%	Pain Relief >30%
Tsubokawa et al., 1993	Tsubokawa et al., 1991	11	>24	—	—	6 (54.5)	—
Meyerson et al., 1993	none	10	12.7	2 (20)	5 (50)	—	—
Hosobuchi, 1993	none	6	9–30	—	3 (50)	—	—
Herregodts et al., 1995	none	7	12.7	2 (28.6)	5 (71)	5 (71)	5 (71)
Katayama et al., 1998	Katayama et al., 1994, & Yamamoto et al., 1997	31	>24	—	15 (48.3)	—	—
Nguyen et al., 1999	Nguyen et al., 1997 & 2000, & Drouot et al., 2002	32	27.3	15 (46.9)	—	23 (71.9)	—
Caroll et al., 2000	Smith et al., 2001, & Nandi et al., 2002	10	21–31	3 (30)	4 (40)	—	—
Saitoh et al., 2001	Saitoh et al., 1999 & 2000	15	24.1	—	—	7 (46.7)	—
Sol et al., 2001	Roux et al., 2001	3	27.3	2 (66.7)	2 (66.7)	2 (66.7)	2 (66.7)
Velasco et al., 2002	none	9	12	4 (44.5)	—	6 (66.7)	6 (66.7)
Brown & Pilitsis, 2005	none	10	10	4 (40)	6 (60)	—	—
Nuti et al., 2005	Mertens et al., 1999	31	49	3 (9.7)	7 (22.6)	16 (51.6)	21 (67.7)
Pirotte et al., 2005	none	18	29.7	10 (55.6)	11 (61.6)	11 (61.1)	11 (61.8)
Rasche et al., 2006	Ebel et al., 1996	17	49.7	1 (5.9)	4 (47)	5 (29.4)	8 (47.1)
total‡	—	210	—	44/147 (29.9)	62/143 (43.4)	81/143 (56.6)	53/85 (62.4)

Fontaine et al.; J Neurosurg 110:251–256, 2009

Résultats dans les membres fantômes

Auteurs	Patients	Soulagement
Caroll et al. 2000	3	2/3 patients soulagement > 75%
Saitoh et al. 2000	2	1/2 soulagement > 75%
Sol et al. 2001	3	3/3 soulagement > 70%
Hosomi et al 2008	3	1/3 soulagement 90%

Motor Cortex Stimulation for Neuropathic Pain: A Randomized Cross-over Trial

Julia A.E. Radic, Ian Beauprie, Paula Chiasson, Zelma H.T. Kiss, Robert M. Brownstone

ABSTRACT: ***Background:*** Chronic motor cortex stimulation (MCS) has been used to treat medically refractory neuropathic pain over the past 20 years. We investigated this procedure using a prospective multicentre randomized blinded crossover trial. ***Methods:*** Twelve subjects with three different neuropathic pain syndromes had placement of MCS systems after which they were randomized to receive low ("subtherapeutic") or high ("therapeutic") stimulation for 12 weeks, followed by a crossover to the other treatment group for 12 weeks. The primary outcome measure was the pain visual analogue scale (VAS). Secondary outcome measures included McGill Pain Questionnaire (MPQ), Beck Depression Inventory-II, medication log, work status, global impression of change, and SF-36 quality of life scale. ***Results:*** The trial was halted early due to lack of efficacy. One subject withdrew early due to protocol violation and five subjects withdrew early due to transient adverse events. Six subjects with upper extremity pain completed the study. There was no significant change in VAS with low or high stimulation and no significant improvement in any of the outcome measures from low to high stimulation. SF-36 role physical and mental health scores were worse with high compared to low stimulation ($p = 0.024$, $p = 0.005$). ***Conclusions:*** We failed to show that MCS is an effective treatment for refractory upper extremity neuropathic pain and suggest that previous studies may have been skewed by placebo effects, or ours by nocebo. We suggest that a healthy degree of skepticism is warranted when considering this invasive therapy for upper extremity pain syndromes.

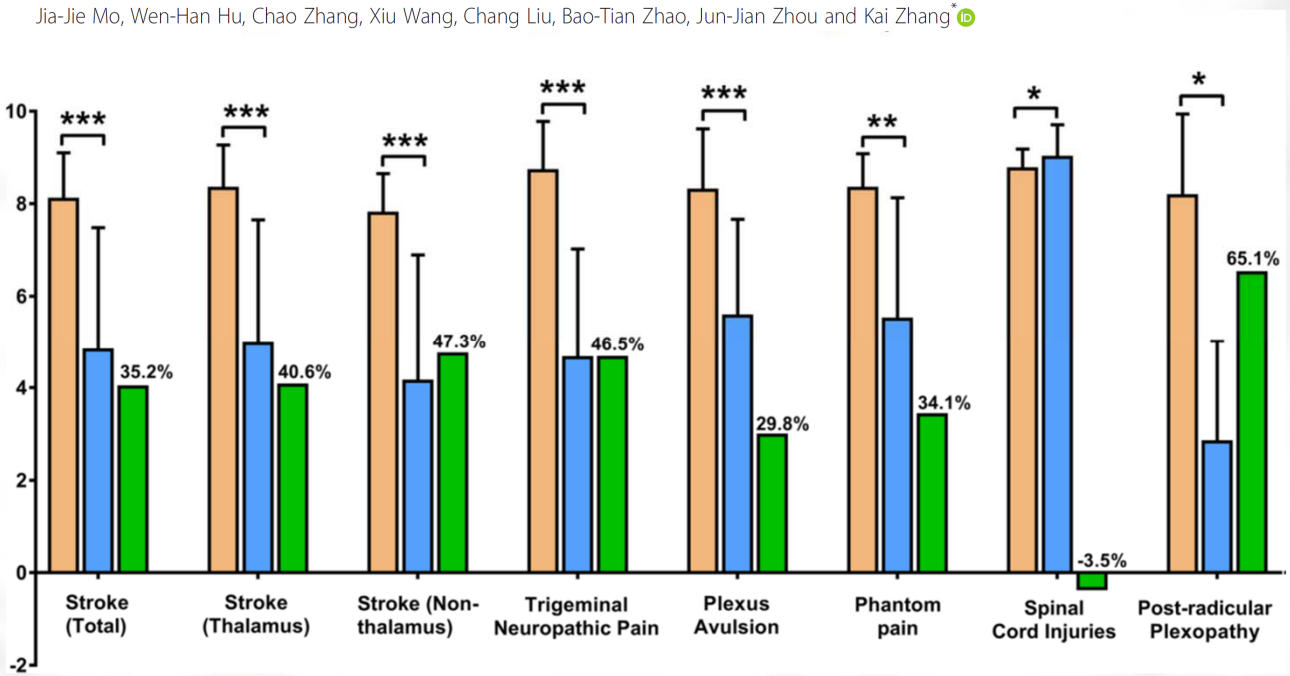
Mo *et al. BMC Neurology* (2019) 19:48
https://doi.org/10.1186/s12883-019-1273-y

BMC Neurology

RESEARCH ARTICLE Open Access

Motor cortex stimulation: a systematic literature-based analysis of effectiveness and case series experience

Jia-Jie Mo, Wen-Han Hu, Chao Zhang, Xiu Wang, Chang Liu, Bao-Tian Zhao, Jun-Jian Zhou and Kai Zhang*



- 12 études
- 198 patients
- Douleurs post-avulsion ou de membre fantôme
  - 30%

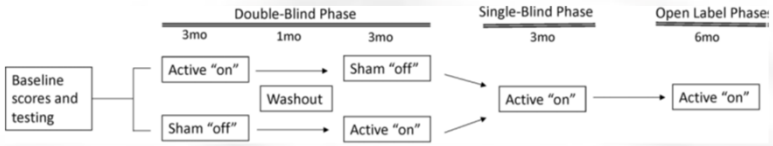
doi:10.1093/brain/awab189 BRAIN 2021: Page 2994 of 3004 | 2994

BRAIN
CLINICAL TRIAL

Motor cortex stimulation for chronic neuropathic pain: results of a double-blind randomized study

Clement Hamani,[1,2,†] Erich T. Fonoff,[1,†] Daniella C. Parravano,[1] Valquiria A. Silva,[3] Ricardo Galhardoni,[3] Bernardo A. Monaco,[1] Jessie Navarro,[1] Lin T. Yeng,[3] Manoel J. Teixeira[1,3] and Daniel Ciampi de Andrade[1,3]

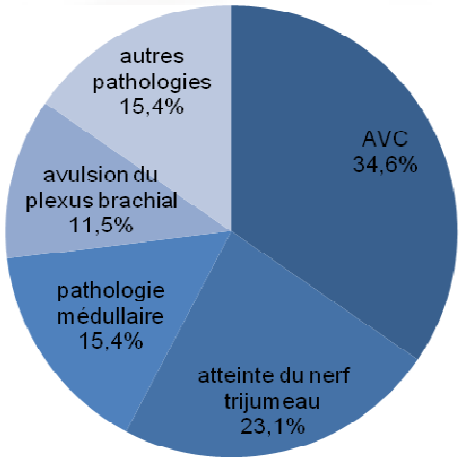
Patient	Sex	Diagnosis	Age (years)	Pain duration (months)	Pain intensity (NRS)	Pain location	Medications	Additional treatments
1	Male	Post-stroke	61	118	7	UE/Face	AD, AC, GP	Phys, ACP
2	Male	Post-stroke	61	71	7	UE/Face	AD, AC, GP	ACP
3	Male	Post-stroke	71	215	6	UE	AD, AC, GP	ACP
4	Female	Post-stroke	49	71	8	UE	AD, AC, GP	Phys, ACP
5	Male	Facial pain	55	31	10	Face	AD, AC, GP	–
6	Male	Facial pain	37	22	9	Face	AD, AC, GP	Phys
7	Male	Br plexus	33	27	9	Hand	AD, AC, GP	ACP, Surg
8	Male	Br plexus	25	21	8	Hand	AD, AC, GP	Phys, Surg
9	Male	Pht limb	57	109	9	Hand	AD, AC, GP	ACP
10	Female	Pht limb	40	52	8	Hand	AD, AC, GP	Phys, ACP
11	Male	Br plexus	51	17	9	Hand	AD, AC, GP	Phys
12	Male	Br plexus	47	161	7	UE	AD, AC, GP	Phys, Surg
13	Male	Br plexus	60	200	10	Hand	AD, AC, GP	Phys
14	Male	Br plexus	37	36	10	UE	AD, AC, GP	Phys, ACP
15	Male	CRPS	47	41	8	UE	AD, AC, GP	Phys, ACP
16	Female	CRPS	38	42	10	UE	AD, AC, GP	Phys, ACP
17	Female	Facial pain	65	128	9	Face	AD, AC, GP	Phys, ACP
18	Male	Pht limb	58	72	7	UE	AD, AC	Phys

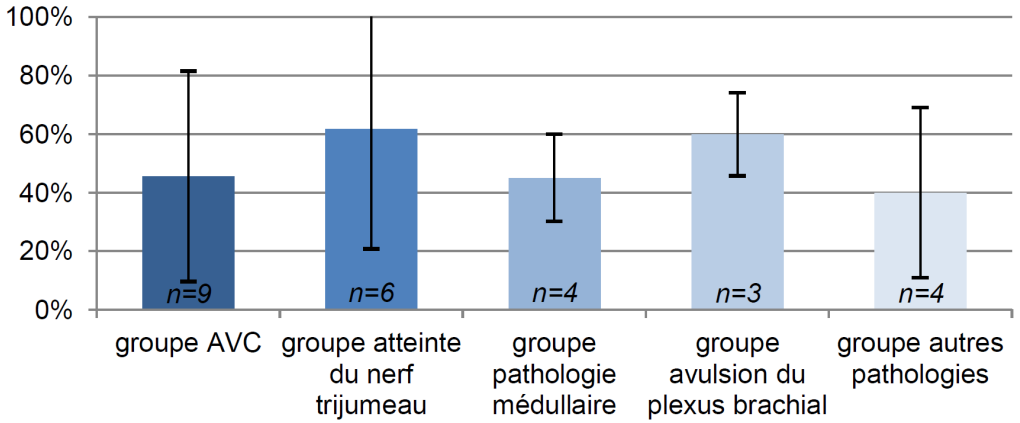


- 6/18 avulsion plexus
- 3/18 post-amputation
- Bonne réponse clinique
  - douleur mb fantôme
  - douleur faciale
- Mauvaise réponse
  - douleur post-avulsion
  - douleur post-AVC

Résultats sur les avulsions du plexus

- 26 patients
- Age moyen : 56 ans
- Evolution : 86 mois





Soulagement: 60%

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RESEARCH-HUMAN-CLINICAL STUDIES

Differential Efficacy of Electric Motor Cortex Stimulation and Lesioning of the Dorsal Root Entry Zone for Continuous vs Paroxysmal Pain After Brachial Plexus Avulsion

Ali, Mohamed MD; Saitoh, Youichi MD, PhD; Oshino, Satoru MD, PhD; Hosomi, Koichi MD, PhD; Kishima, Haruhiko MD, PhD; Morris, Shayne MD; Shibata, Masahiko MD, PhD; Yoshimine, Toshiki MD, PhD

Author Information

Neurosurgery 68(5):p 1252-1258, May 2011. | ***DOI:*** 10.1227/NEU.0b013e31820c04a9

BUY

Metrics

OBJECTIVE:

To analyze the differential effect of EMCS and DREZotomy on continuous vs paroxysmal BPA pain in a series of 15 patients.

METHODS:

Fifteen patients with intractable BPA pain underwent DREZotomy alone (n = 7), EMCS alone (n = 4), or both procedures (n = 4). Pain intensity was evaluated with the Visual Analog Scale, and separate ratings were recorded for paroxysmal and continuous pain. Pain relief was categorized as excellent (> 75% pain relief), good (50%-75%), or poor (< 50%). Favorable outcome was defined as good or better pain relief.

RESULTS:

Eight patients had EMCS; 7 were followed up for an average of 47 months. Of those 7 patients, 3 (42%) with continuous pain had favorable outcomes compared with no patients with paroxysmal pain. Eleven patients had DREZotomy; 10 were followed up for an average of 31 months. Of those 10 patients, 7 (70%) with paroxysmal pain had favorable outcomes compared with 2 (20%) with continuous pain.

CONCLUSION:

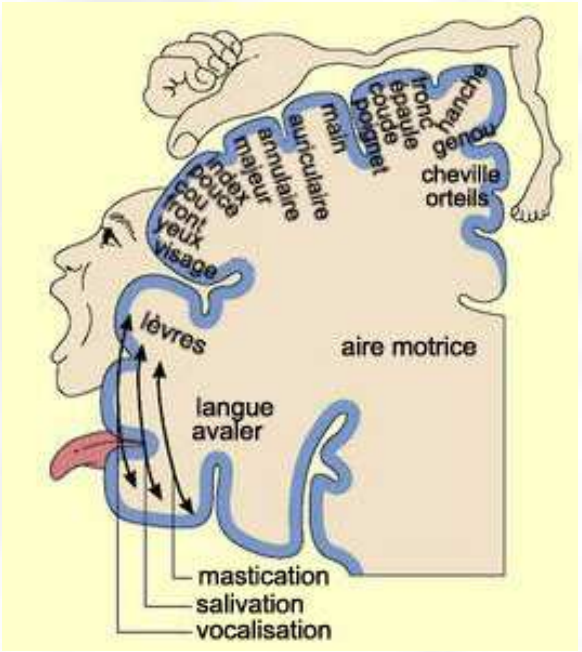
EMCS was ineffective for paroxysmal pain but moderately effective for continuous pain. DREZotomy was highly effective for paroxysmal pain but moderately effective for continuous pain. It may be prudent to use EMCS for residual continuous pain after DREZotomy.

Complications

- Infection 5%
- Hématome extradural 1%
- Epilepsie induite 10%
  - peropératoire
  - réglage stimulateur

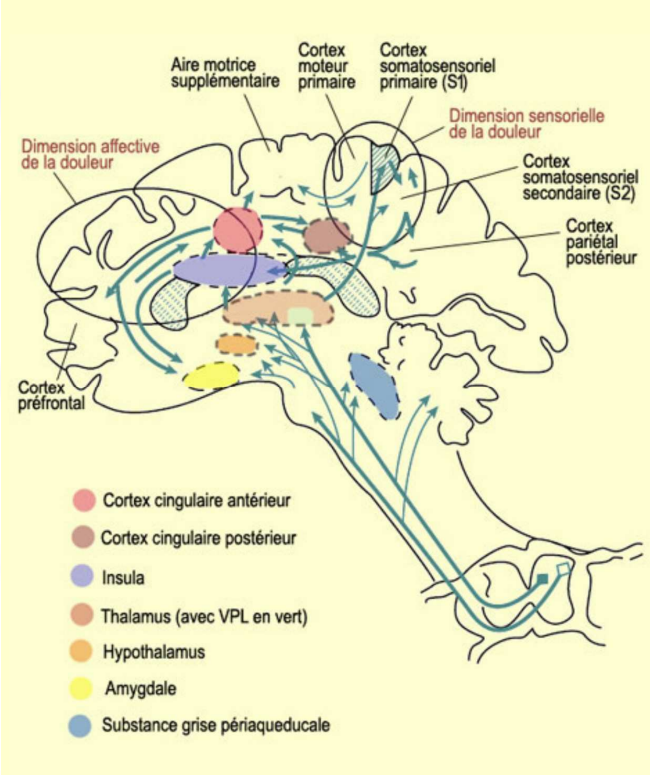
Facteurs pronostiques

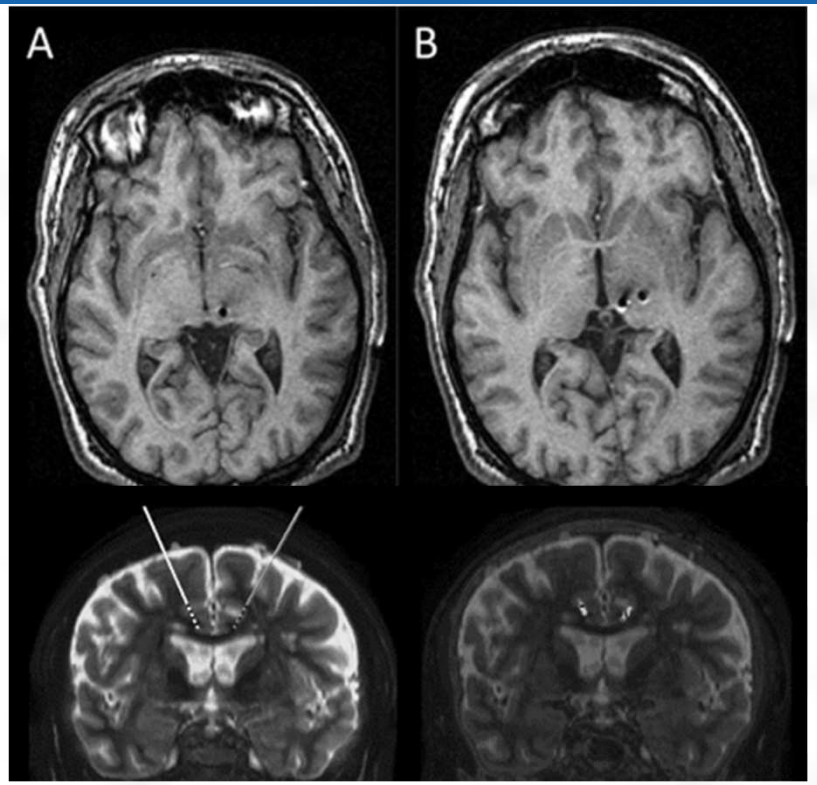
- Douleur membre inférieur
- Pathologie
- rTMS
- Positionnement éléctodres
  - volet crânien > burr hole
  - neuronavigation + electrophy
- Paramètres
  - pas de guidelines



STIMULATION CEREBRALE PROFONDE

Cibles





Boccard et al.
J Clin Neuroscience 2015

		VAS			UWNPS			BPI			SF-36		
		Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall
Pre - Operative													
Outcome score	Min	4	8	4	47	46	46	9	8	8	187	364	187
	Max	10	10	10	99	87	99	19	19	19	606	676	676
	Median	6	9	9	63	60	61.5	11.5	13.4	13.1	462	454	458
	Interquartile range	4	2	4	35	12	16	7	4	4	248	161	163
One year follow-up													
Outcome score	Min	0	0	0	6	0	0	1	0	0	519	289	289
	Max	3	7	7	51	73	73	4	15	15	659	625	659
	Median	1	6	3.5	9	54	39.5	2	11	6.6	618	547	616.5
	Interquartile range	3	4	6	27	33	53	3	7	11	83	230	136
% Improvement	Median	80	33.3	57.8	83.0	19.2	28.7	89.5	26.7	49.6	33.8	1.4	10.5
	Interquartile range	35	41.4	55	56.3	49.3	93.0	27	57.2	68.5	132.7	49.7	52.3
p value *		0.0169	0.0345	0.000098	0.0379	0.79299	0.0577	0.0180	0.633	0.0075	0.4043	0.9998	0.666
2 years follow-up													
Outcome score	Min	0	0	0	2	0	0	0	0	0	563	254	254
	Max	1	8	8	32	80	80	3	16	16	666	680	680
	Median	0.3	2	1	9	49	34.5	1	7	5	576	585	580.5
	Interquartile range	1	7	5	25	31	48	3	7	7	97	294	216
% Improvement	Median	83.3	75	78.9	83	26.7	33.2	90.8	54.7	65.2	22.7	−0.2	15.8
	Interquartile range	22.5	67.8	54.2	46	43.7	64.3	25.6	67.6	43	148.4	36.5	39.4
p value *		0.0031	0.0013	7.083 E-07	0.0305	0.4086	0.01579	0.0028	0.073	0.0004	0.2912	0.9999	0.7799
3 years follow-up													
Outcome score	Min	0	0	0	2	0	0	0	0	0	539	311	311
	Max	4	7	7	46	66	66	5	15	15	659	707	707
	Median	2	5	4	31	51	41	4	7	6.5	655	494	552.5
	Interquartile range	3	3	4	28	27	29	2	5	6	106	136	169
% Improvement	Median	66.7	40	52.8	50.8	22.7	30.7	65.2	47.8	55.0	16.7	16	16.3
	Interquartile range	51.7	31.9	45.4	62.9	37.1	49.2	31.6	62.8	32	140.2	42.7	30.3
p value *		0.0494	0.01298	0.00021	0.3225	0.4632	0.0590	0.1623	0.189	0.00737	0.2406	0.9953	0.4754

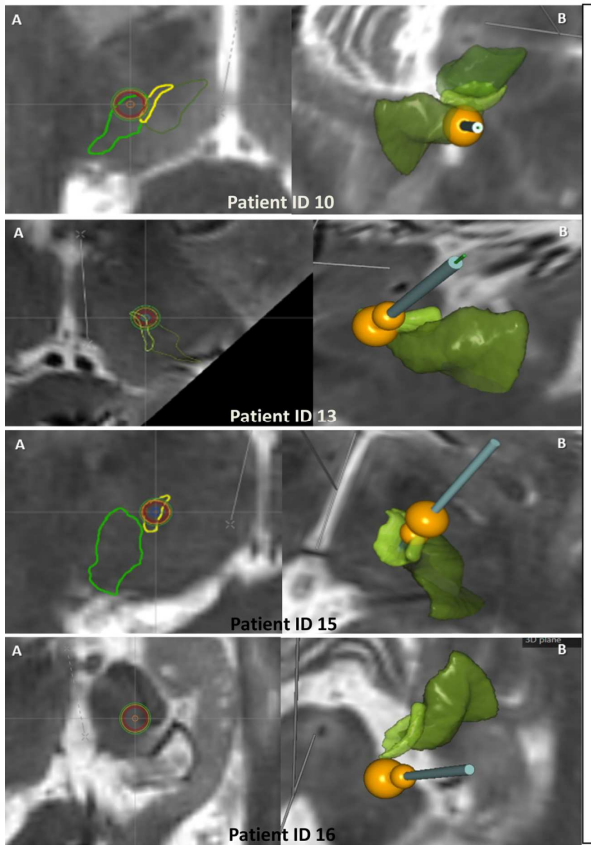
* *p* value calculated on the difference between postsurgical and baseline scores. Statistically significant improvements ($p < 0.05$) in bold.
Min = minimum patient outcome score within subgroup and overall population; Max = maximum patient outcome score within subgroup and overall population.

- Stim VPL
- 16 patients
  - 6 A
  - 10 PB
- Suivi 36 mois

Abreu et al.; Neuromodulation 2017

	VAS			UWNPS			BPI			SF-36		
	Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall	Amputation	Brachial plexus injury	Overall
Pre-Operative												
Outcome Score												
Min	4	8	4	47	46	46	9	8	8	187	364	187
Max	10	10	10	99	87	99	19	19	19	606	676	676
Median	6	9	9	63	60	61.5	11.5	13.4	13.1	462	454	458
Interquartile Range	4	2	4	35	12	16	7	4	4	248	161	163
3 year follow-Up												
Outcome Score												
Min	0	0	0	2	0	0	0	0	0	539	311	311
Max	4	7	7	46	66	66	5	15	15	659	707	707
Median	2	5	4	31	51	41	4	7	6.5	655	494	552.5
Interquartile Range	3	3	4	28	27	29	2	5	6	106	136	169
% Improvement												
Median	66.7	40	52.8	50.8	22.7	30.7	65.2	47.8	55.0	16.7	16	16.3
Interquartile Range	51.7	31.9	45.4	62.9	37.1	49.2	31.6	62.8	32	140.2	42.7	30.3
P Value †	**0.0494**	**0.01298**	**0.00021**	0.3225	0.4632	0.0590	0.1623	0.189	**0.00737**	0.2406	0.9953	0.4754
5 years follow-Up												
Outcome Score												
Min	0	0	0	2	0	0	0	0	0	416	279	279
Max	4	10	10	56	67	67	6	13.7	13.7	657	672	672
Median	1	2	2	30	44	39	3.75	7	4	539	499	519
Interquartile Range	3	5	4	36	33	29	3.5	8.3	7	206	264	215
% Improvement												
Median	90	75	76.4	55.5	26.7	35.2	65.2	50	65.1	16.6	- 6.62	5
Interquartile Range	56.6	55.9	62.5	79.3	57.5	58.3	42	66.2	48.2	167.8	54.1	58.4
P Value †	**0.0442**	**0.0015**	**0.0001**	0.0923	0.2705	0.3582	0.0654	0.2523	0.0505	0.7966	0.9159	0.7406

Abreu et al.; Neurochirurgie 2021

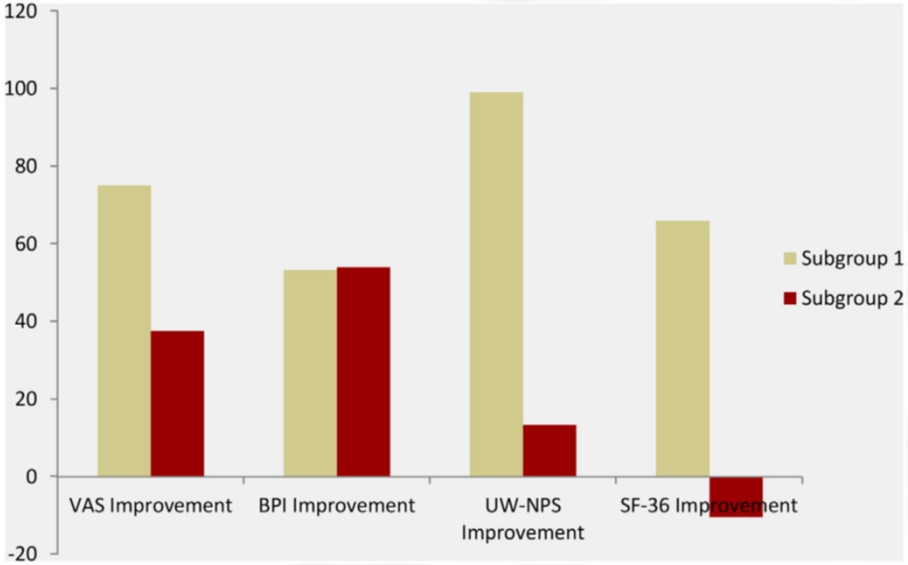


Good clinical outcomes (**100% and 80%** improvement in VAS and BPI, respectively) with associated eVAT o **51.3%**

Poor clinical outcomes (**0% and 26%** improvement in VAS and BPI, respectively) with associated eVAT of **0.9%**

Good clinical outcomes (**80% and 77%** improvement in VAS and BPI, respectively) with associated eVAT of **58.5%**

Relatively good clinical outcomes (**67% and 65%** improvement in VAS and BPI, respectively) with associated eVAT of **0%**



Abreu et al.; Neurochirurgie 2021

Auteurs	Cohorte	Cible	Soulagement
Bittar et al. 2005	3 patients	PAG +VPL	57%
Yamamoto et al. 2006	11 patients	VPL	> 60% dans 8/11
Owen et al.	7 patients	PAG	> 50% dans 6/7
Boccard et al. 2013	1 patient	VPL/PAG	39%
Perreira et al. 2013	5 patients	VPL	90%
Abreu et al. 2017	6 patients	VPL	67% à 3 ans