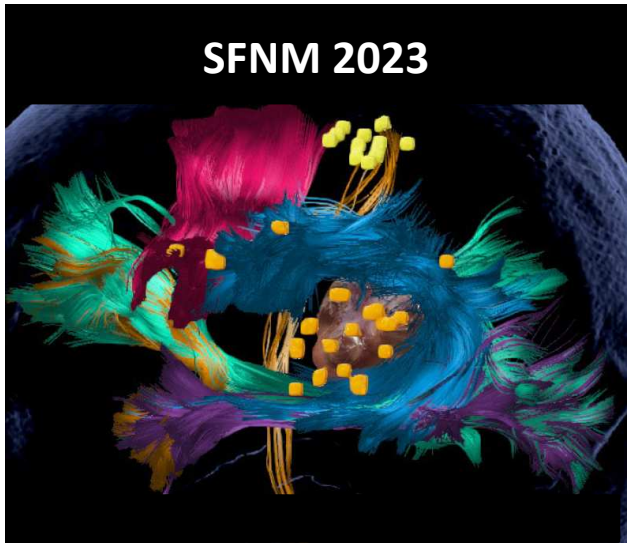
UPEC
Connaissance - Action
UNIVERSITÉ PARIS-EST CRÉTEIL VAL DE MARNE

MONDOR



La TMS pour le traitement des douleurs neuropathiques - quid des cas d'arrachement du plexus brachial ?

Dr Yann Sühan SENOVA

Neurochirurgien, Praticien Hospitalo-Universitaire
Responsable de Structure Douleur Chronique ARS-APHP
Responsable Pédagogique DU Neuromodulation UPEC

Université Paris Est Créteil
Service de Neurochirurgie CHU Henri Mondor- APHP
Laboratoire INSERM U955 « Neuropsychiatrie Translationnelle »

HÔPITAUX UNIVERSITAIRES HENRI MONDOR
ALBERT CHENEVIER · JOFFRE-DUPUYTREN · EMILE ROUX · GEORGES CLEMENCEAU

Y a-t-il une place pour la rTMS dans le traitement de la douleur neuropathique?

- Pas d'AMM pour la rTMS dans le traitement de la douleur neuropathique
- La réponse de la SFETD (2020):

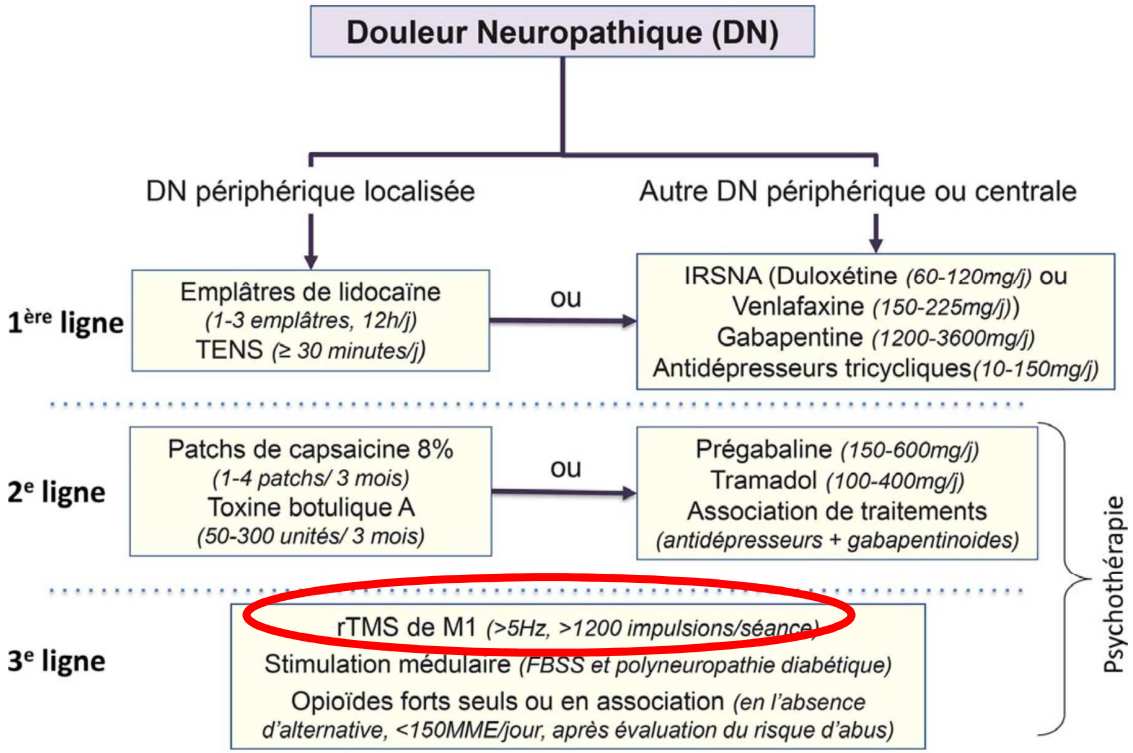


Fig. 1 Algorithme thérapeutique proposé pour la prise en charge de la douleur neuropathique de l'adulte. TENS : *transcutaneous electrical nerve stimulation* ; IRSNA : antidépresseur inhibiteur de recapture de la sérotonine et de la noradrénaline ; rTMS : *repetitive transcranial magnetic stimulation*

Neuromodulation: quelles questions?

➢ Qui?

- Quel(le)s patients/ pathologies/ symptômes?
- Quels critères d'inclusion/exclusion?
- Quels biomarqueurs pour déterminer meilleurs répondeurs?

➢ Où?

- Quels circuits neuronaux?
- Quel(s) nœud(s) au sein de ces circuits?
- Noyau ou matière blanche? corticale ou profondeur?

➢ Pourquoi?

- Annihiler une activité pathologique
- Renforcer une activité neuronale saine/ circuit?
- Moduler les oscillations cérébrales? Le taux de décharge? plasticité synaptique? neurogénèse? Facteurs neurotrophiques?...

➢ Comment?

- en boucle-ouverte ou boucle-fermée?
- A quelle(s) fréquence(s)?...

Effets antalgiques de la stimulation du cortex moteur

Stimulation Epidurale (1991)

Treatment of Thalamic Pain by Chronic Motor Cortex Stimulation

TAKASHI TSUBOKAWA, YOICHI KATAYAMA, TAKAMITSU YAMAMOTO, TERUYASU HIRAYAMA, and SEIGOU KOYAMA

From the Department of Neuorological Surgery, Nihon University School of Medicine, Tokyo, Japan

precentral gyrus (M1)

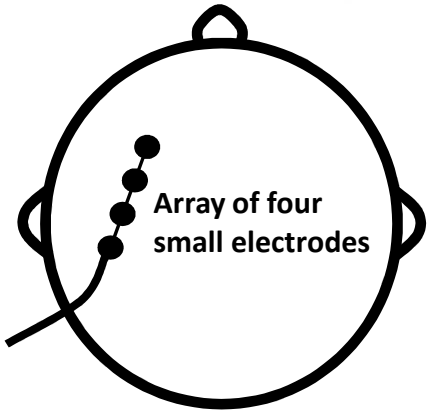
rTMS (1998)

18-03

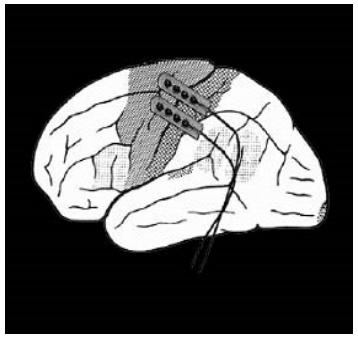
CHRONIC PAIN TREATED BY rTMS OF MOTOR CORTEX

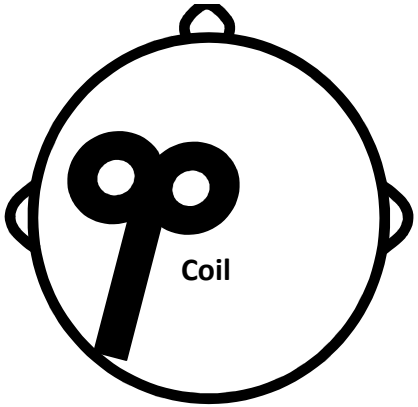
Lefaucheur-JP[1], Nguyen-JP[2], Drouot-X[1], Pollin-B[2], Keravel-Y[2], Harf-A[1]
[1]Dept. of Clinical Neurophysiology, [2]Dept. of Neurosurgery, Henri Mondor Hospital, Creteil, France

International Symposium on Transcranial Magnetic Stimulation
September 30 - October 4, 1998
Göttingen, Germany

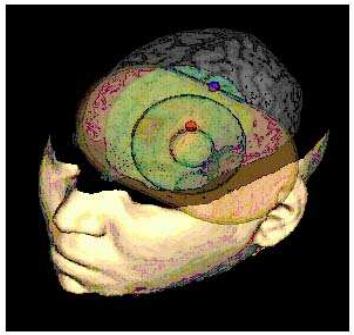


ECS





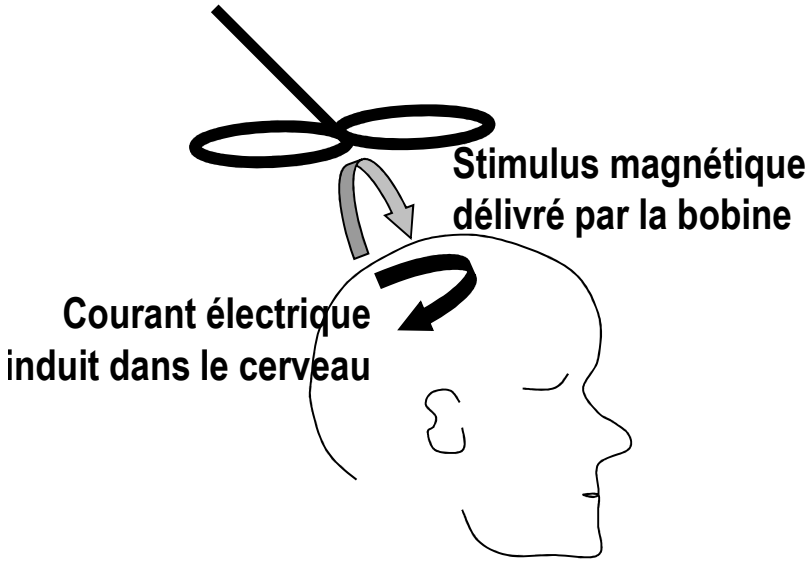
rTMS



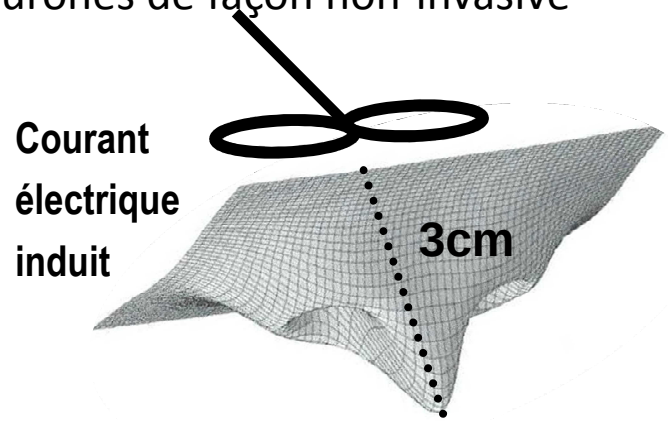
Stimulation magnétique transcrânienne (TMS)

- **Résulte en une stimulation électrique du cortex**

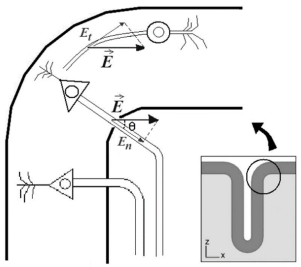
Principe de l'induction électromagnétique (Faraday, 1831)

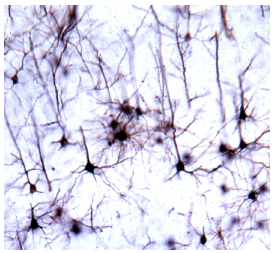


Le champ magnétique (2T) délivré rapidement (<1ms) sur le scalp traverse la boîte crânienne et induit un courant électrique (E/m²) dans le cortex cérébral, activant les neurones de façon non-invasive



- **Mécanisme d'action de la neuromodulation**





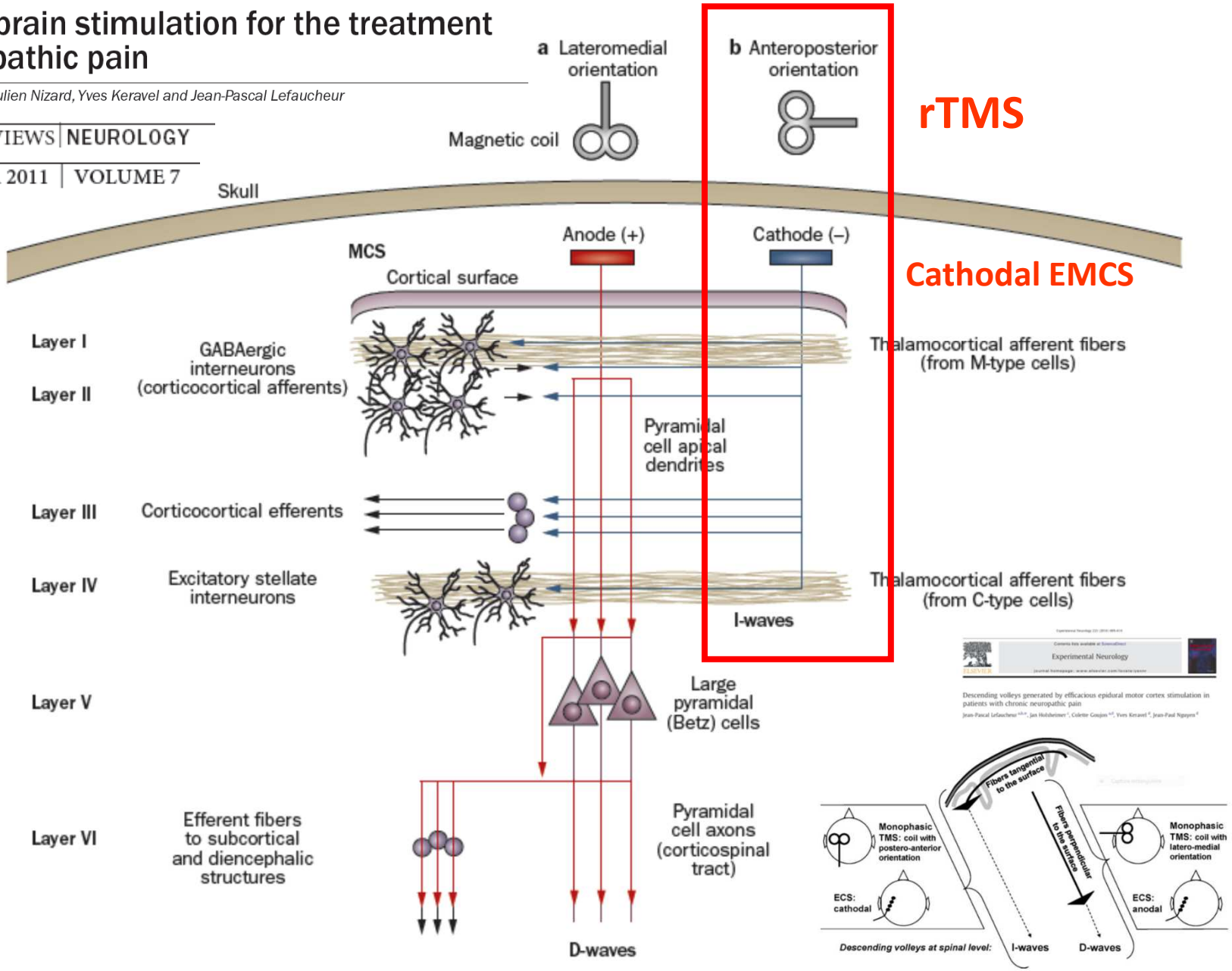
- Action sur des fibres et non sur les corps cellulaires
- Différentes populations neuronales peuvent être concernées: axones de circuits excitateurs ou inhibiteurs
- Augmenter ou diminuer l'excitabilité de circuits excitateurs ou inhibiteurs

« DIRTY STIMULATION »

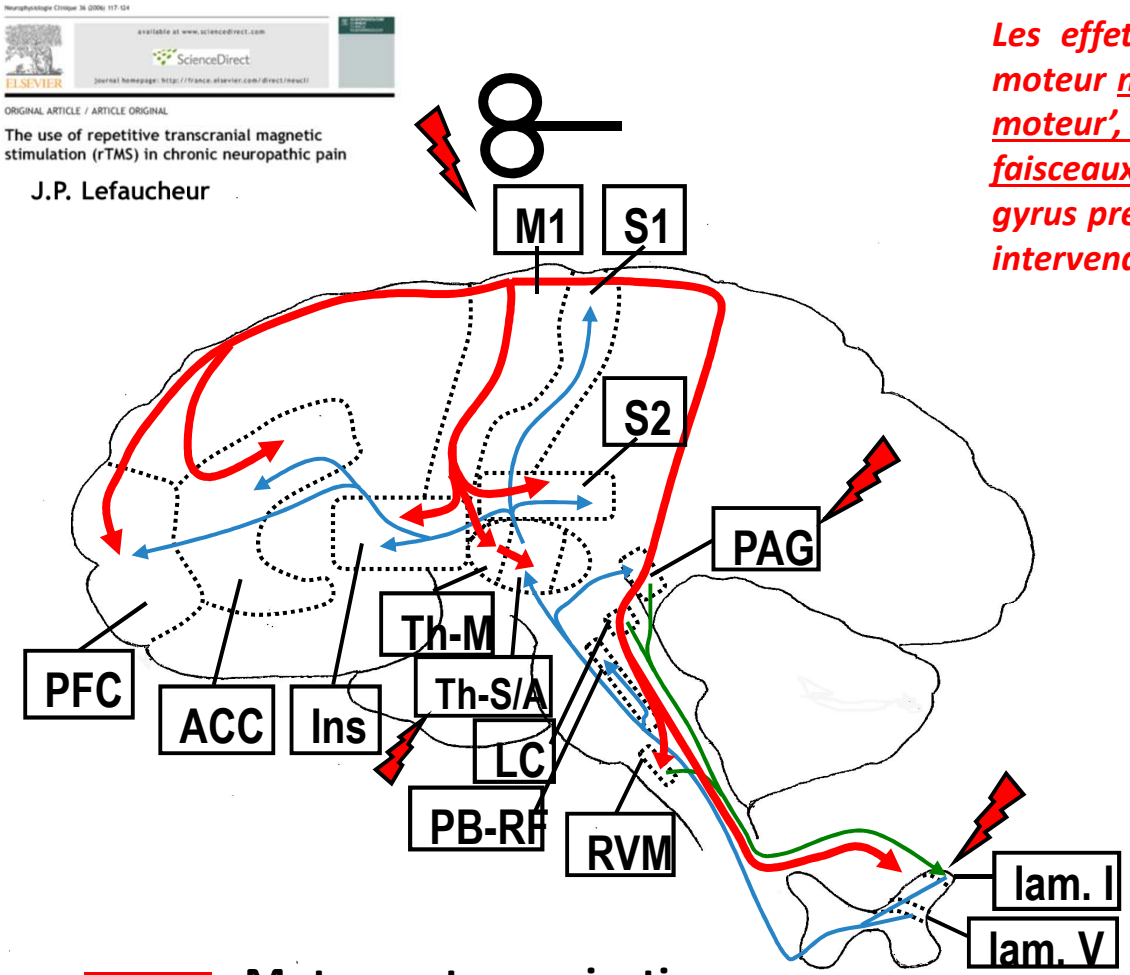
Invasive brain stimulation for the treatment of neuropathic pain

Jean-Paul Nguyen, Julien Nizard, Yves Keravel and Jean-Pascal Lefaucheur

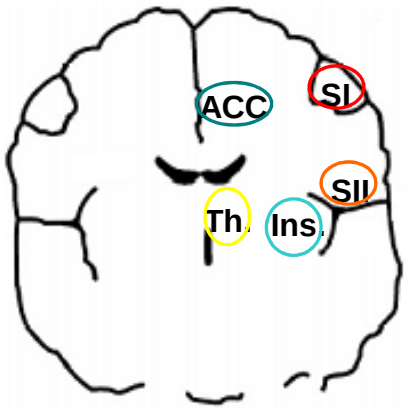
NATURE REVIEWS | NEUROLOGY
DECEMBER 2011 | VOLUME 7

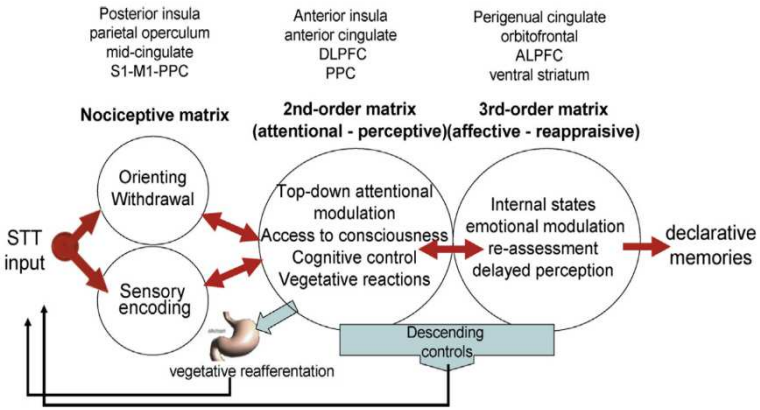


Mécanismes d'action rTMS (1) – Modulation de réseaux



Les effets antalgiques de la stimulation du cortex moteur <u>ne sont pas dus</u> à une <u>activation du 'système moteur',</u> mais ils <u>sont liés à</u> une activation de divers <u>faisceaux et circuits non-moteurs</u> passant dans le gyrus précentral (projections efférentes ou afférentes intervenant dans le contrôle moteur)





Motor cortex projections

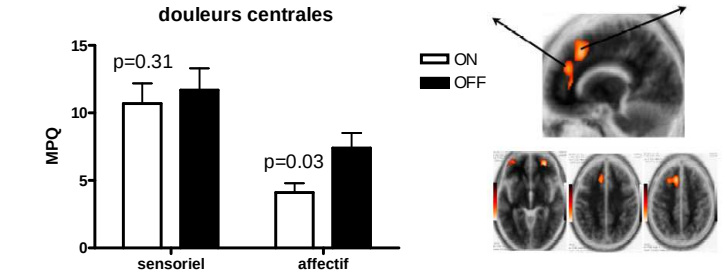
Nociceptive ascending pathways

Descending inhibitory controls

Mécanismes d'action rTMS (2)

Anatomie

Action sur les circuits et aspect émotionnel de la douleur



ORIGINAL RESEARCH

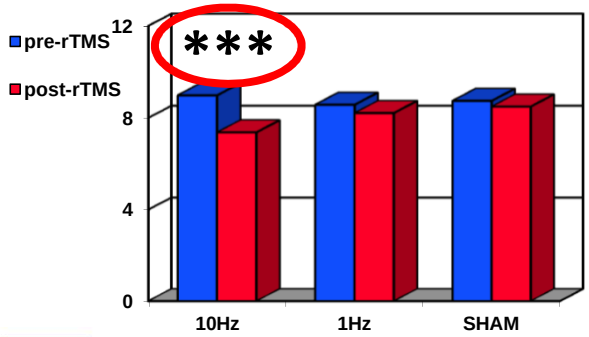
Treatment of chronic neuropathic pain by motor cortex stimulation: Results of a bicentric controlled crossover trial

Jean-Paul Nguyen, MD[a], Francisco Velasco, MD[b], Pierre Brugières, MD[c], Marcos Velasco, MD, PhD[b], Yves Keravel, MD[a], Bernardo Boleaga, MD[d], Francisco Brito, MD[b], Jean-Pascal Lefaucheur, MD, PhD[e]

Motor cortex stimulation in neuropathic pain. Correlations between analgesic effect and hemodynamic changes in the brain. A PET study☆

Roland Peyron,[a,b,d,e,*] Isabelle Faillenot,[b,d] Patrick Mertens,[c,d] Bernard Laurent,[a,b,d] and Luis Garcia-Larrea[d,e]

Action sur les circuits et aspect sensoriel de la douleur



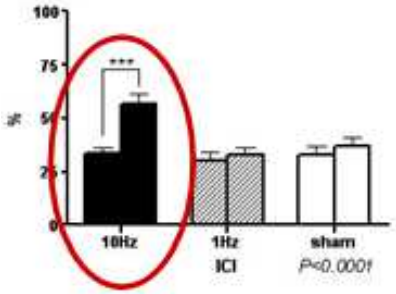
Motor cortex rTMS in chronic neuropathic pain: pain relief is associated with thermal sensory perception improvement

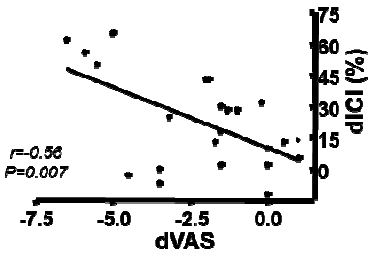
J-P Lefaucheur, X Drouot, I Ménard-Lefaucheur, Y Keravel and J-P Nguyen

J. Neurol. Neurosurg. Psychiatry 2008;79;1044-1049; originally published online 25 Jan 2008;

Pharmacologie

Effets sur la secrétion intracorticale GABAergique





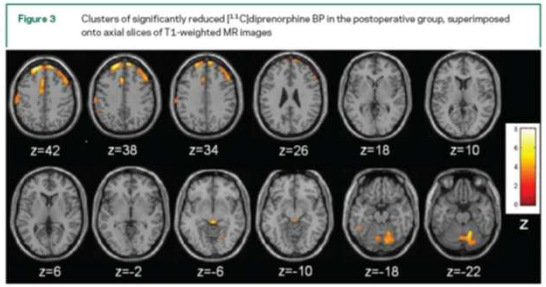
Motor cortex rTMS restores defective intracortical inhibition in chronic neuropathic pain

J.P. Lefaucheur, MD, PhD; X. Drouot, MD, PhD; I. Ménard-Lefaucheur, MSc; Y. Keravel, MD; and J.P. Nguyen, MD

Effets opioidergiques

Motor cortex stimulation for pain control induces changes in the endogenous opioid system

J. Maarrawi, MD, PhD
R. Peyron, MD, PhD
P. Mertens, MD, PhD
N. Costes, PhD
M. Magnin, PhD
M. Sindou, MD, DSc
B. Laurent, MD, PhD
L. Garcia-Larrea, MD, PhD



Recommandations

« Qui? »

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): An update (2014–2018)

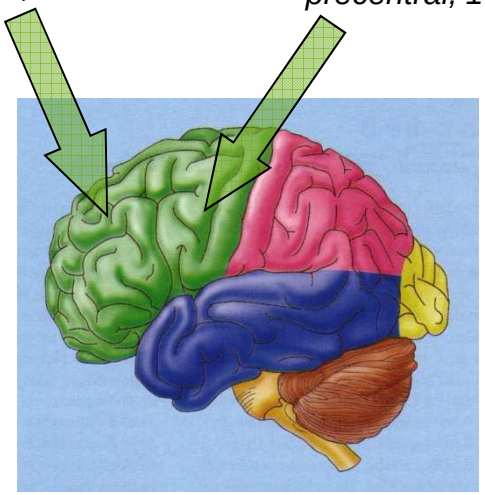
Jean-Pascal Lefaucheur[a,b,*], André Aleman[c], Chris Baeken[d,e,f], David H. Benninger[g], Hélène Bruneau[h], Vincenzo Di Lazzaro[i], Saša R. Filipović[j], Christian Grefkes[l], Satu K. Jääskeläinen[q], Berthold Langguth[r], Letizia Leocani, Jean-Paul Nguyen[x,y], Thomas Nyffeler[z,aa,ab], Albino J. Oliv, Frank Padberg[m], Ulrich Palm[m,ag], Walter Paulus[ah], Emma, Fady Rachid[ak], Irena Rektorová[al,am], Simone Rossi[an], Hann, David Szekely[ap], Ulf Ziemann[aq]

Neurogenic pain relief by repetitive transcranial magnetic cortical stimulation depends on the origin and the site of pain

J-P Lefaucheur, X Drouot, I Menard-Lefaucheur, F Zerah, B Bendib, P Cesaro, Y Keravel, J-P Nguyen

J Neurol Neurosurg Psychiatry 2004;75:612–616. doi: 10.1136/jnnp.2003.022236

- ***dépression*** — *préfrontal gauche, 10Hz*
- ***Douleur*** — *précentral, 10Hz*

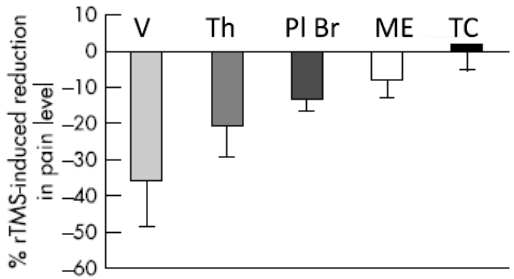


Pathologie	Protocoles	Grade
Douleur neuropathique	**HF-rTMS M1 controlatéral douleur**	**A**
Fibromyalgie	HF-rTMS M1 gauche (qualité de vie) HF-rTMS DLPFC gauche (antalgique)	B B
Parkinson	HF-rTMS M1 bilatéral (signes moteurs)	B
AVC	**Post-aigu : LF-rTMS M1 controlatéral lésion** HF-rTMS ipsilatéral M1 Chronique : LF-rTMS IFG droit Aphasie non fluente LF-rTMS M1 controlatéral	**A** B B C
Dépression	**HF-rTMS DLPFC gauche** LF-rTMS DLPFC droit Bilatéral HF-rTMS DLPFC G + LF-rTMS DLPFC D **SAINT protocol (piTBS * 10 / j, 5j/7)**	**A** B B **FDA +**

*Le plus fort niveau de preuve, si **douleur neuropathique focale** en stimulant le cortex moteur controlatéral*

Neurogenic pain relief by repetitive transcranial magnetic cortical stimulation depends on the origin and the site of pain

J-P Lefaucheur, X Drouot, I Menard-Lefaucheur, F Zerah, B Bendib, P Cesaro, Y Keravel, J-P Nguyen

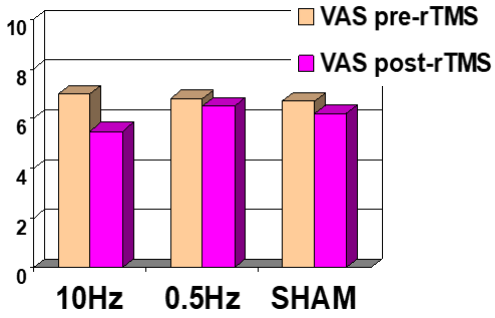


Douleur Neuropathique

« Comment? », Les paramètres importants & reconnus pour la rTMS :

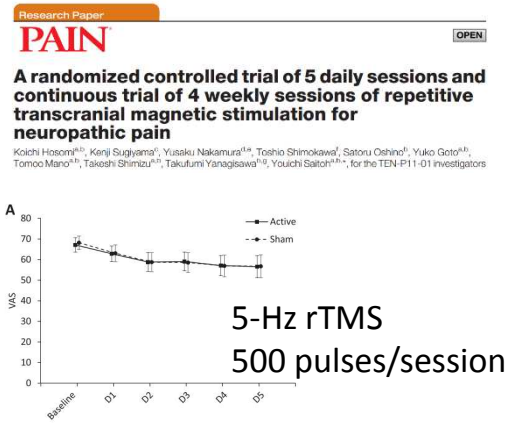
Fréquence de Stimulation

HF-rTMS ≥ 10 Hz



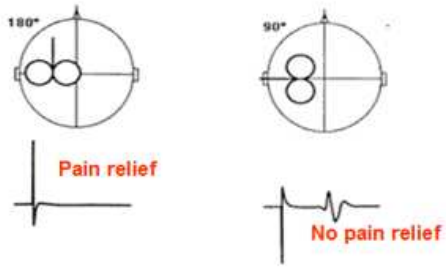
Nombre de pulses/session

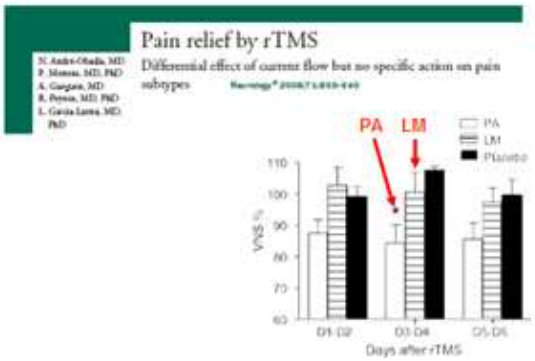
> 1000 pulses /session +++



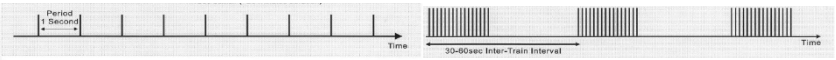
Orientation du Coil

Anterior -> Posterior current direction into the brain





Low-frequency (1Hz) *High-frequency (5-20Hz)*



Stimulation tonique à basse fréquence (1 Hz) ➔ dépression synaptique

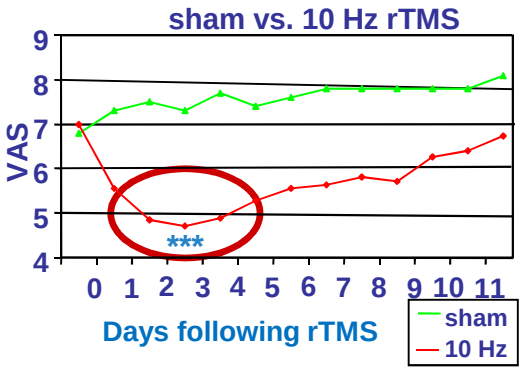
Stimulation trains à haute fréquence (5 à 20 Hz)➔ potentiation synaptique

Douleur Neuropathique

« Comment ?», Paramètres temporels en cours d'exploration

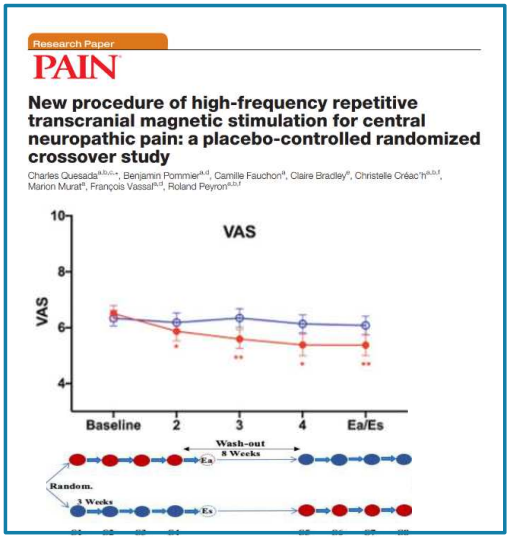
L'effet est retardé et de courte durée

Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex



Changes in VAS score following a single rTMS session

Rythme initial: valeur d'une phase d'induction?


Research Paper
PAIN

New procedure of high-frequency repetitive transcranial magnetic stimulation for central neuropathic pain: a placebo-controlled randomized crossover study

Charles Quesada[a,b,c,*], Benjamin Pommier[a,d], Camille Fauchon[a], Claire Bradley[e], Christelle Créac'h[a,b,f], Marion Murat[a], François Vassal[a,d], Roland Peyron[a,b,f]

Rythme

Pour la maintenance?

- hebdomadaires ?

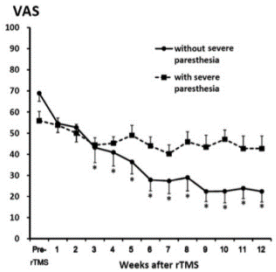
Repetitive Transcranial Magnetic Stimulation Once a Week Induces Sustainable Long-Term Relief of Central Poststroke Pain

Masahito Kobayashi, MD, PhD*†; Takamitsu Fujimaki, MD, PhD*; Ban Mihara, MD, PhD†; Takayuki Ohira, MD, PhD†

Neuromodulation 2015; 18: 249–254

18 Ma: AVC ischémiques ou hémorragiques

- rTMS 5 Hz, 500 stim une fois / sem, 12 sem
- 6 Ma: stim maintenue pendant 1 an: maintien de l'effet antalgique sans majoration par rapport à celui obtenu à S12



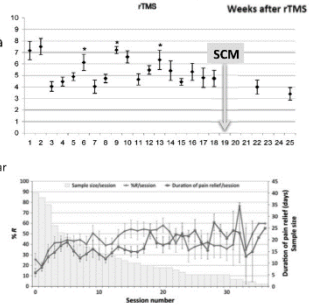
- mensuelles ?

- Un cas de maintien de l'effet antalgique pendant 16 mois grâce à des séances de stimulation mensuelles *(JP Lefaucheur, Clin Neurophysiol 04)*
- Etude prospective sur 40 patients stimulés toutes les 3 à 4 sem (440 sessions) *(Pommier, Eur J Pain 2016)*
  - 9 Ma: arrêt de rTMS après 4 sessions car inefficace
  - 31 patients: en moyenne, 41% réduction DI durant 15.6 j

Intensité et durée de l'effet antalgique corrélées à celles de la 1ère séance

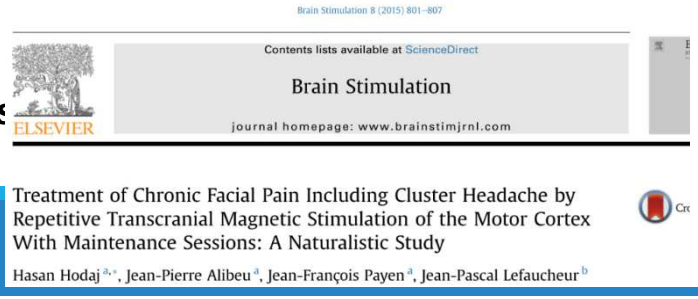
Pas de différence d'efficacité sur les différentes composantes de la douleur

Pas de différence d'efficacité selon l'ancienneté de la douleur



- 'dégressif' ? (consolidation expansée)

- ***5j/sem pdt 2 semaines***
- ***2j/sem pdt 1 semaine***
- ***1j/2 sem pdt 4 semaines***
- ***1j/ mois pdt 5 mois***


Brain Stimulation 8 (2015) 801–807

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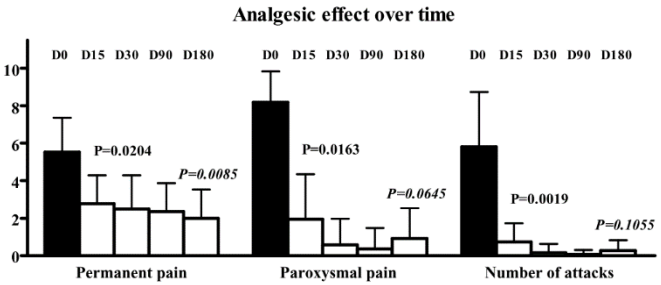
Brain Stimulation

journal homepage: www.brainstimjrnl.com

ELSEVIER

Treatment of Chronic Facial Pain Including Cluster Headache by Repetitive Transcranial Magnetic Stimulation of the Motor Cortex With Maintenance Sessions: A Naturalistic Study

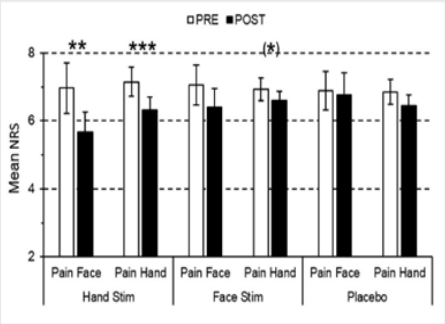
Hasan Hodaj[a,*], Jean-Pierre Alibeu[a], Jean-François Payen[a], Jean-Pascal Lefaucheur[b]



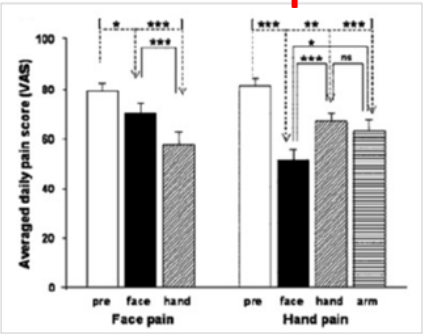
Douleur Neuropathique

« Où? », La cible M1:

Aire de la main? OU **Somatotopie?**



André-Obadia, EJP 2018



Lefaucheur, Neurology 2006

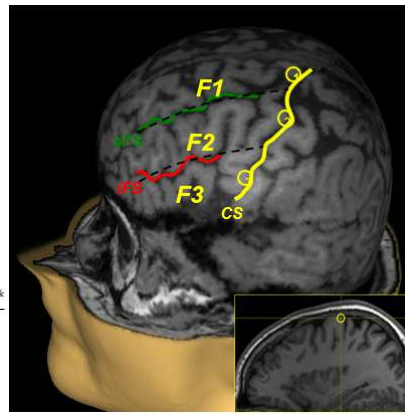
Hotspot? OU **Représentation anatomique ?**

Brain Topogr (2016) 29:590–597
DOI 10.1007/s10548-016-0486-2

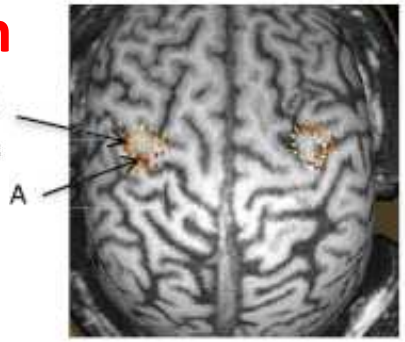
ORIGINAL PAPER

The Hand Motor Hotspot is not Always Located in the Hand Knob: A Neuronavigated Transcranial Magnetic Stimulation Study

[1] · Samar S. Ayache[1,2,3] · Pierre Brugières[4] · Wassim H. Farhat[1,2] · …cheur[1,2]



Neuronavigation



Neuromodulation: Technology at the Neural Interface

Received: February 14, 2016; Revised: March 16, 2016; Accepted: April 2, 2016

(onlinelibrary.wiley.com) DOI: 10.1111/ner.12444

Motor Cortex Reorganization and Repetitive Transcranial Magnetic Stimulation for Pain—A Methodological Study

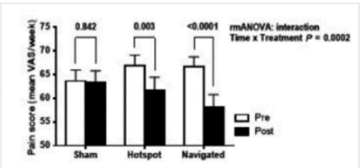
Turo Nurmikko, MD, PhD*†‡; Kathryn MacIver, PhD*‡; Rebecca Bresnahan, MRes†‡; Emily Hird, MSc†‡; Andrew Nelson‡§; Paul Sacco, PhD*‡

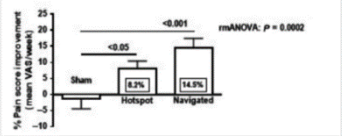
EJP European Journal of Pain

ORIGINAL ARTICLE

Analgesic effects of navigated motor cortex rTMS in patients with chronic neuropathic pain

S.S. Ayache[1,2,3], R. Ahdab[1,2,3], M.A. Chalah[1,2], W.H. Farhat[1,2], V. Mylius[1,2,4], C. Goujon[1,5], M. Sorel[1,6], J.-P. Lefaucheur[1,2]





Ayache Eur J Pain 2016
66 patients, douleur face, main, MI ou hémicorps

Douleur Neuropathique

« Où? », autres Cibles:

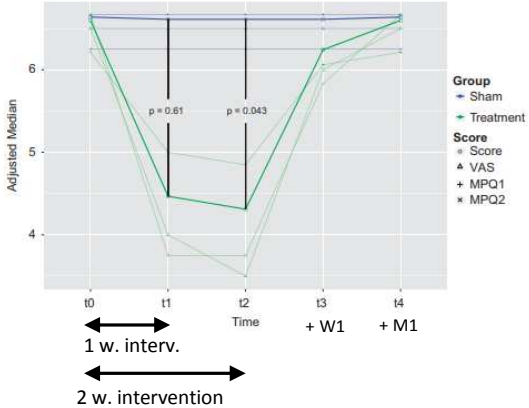
DLPFC?

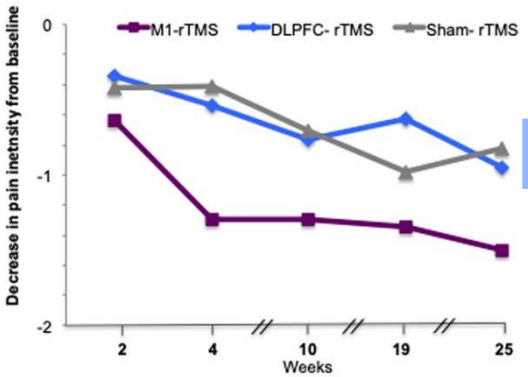
Spinal Cord (2017) 55, 20–25
© 2017 International Spinal Cord Society All rights reserved 1362-4393/17
www.nature.com/sc

ORIGINAL ARTICLE

rTMS of the prefrontal cortex has analgesic effects on neuropathic pain in subjects with spinal cord injury

R Nardone[1,2,3], Y Höller[1,3], PB Langthaler[1,3,4], P Lochner[2], S Golaszewski[1,3], K Schwenker[1,3], F Brigo[2,5]



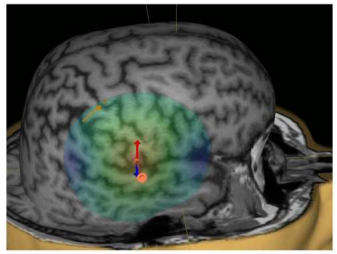


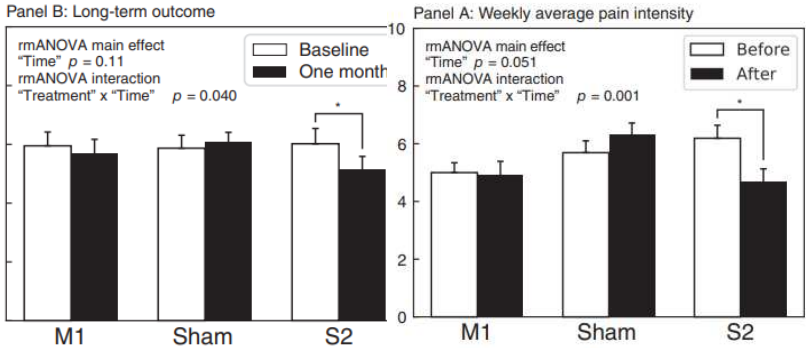
S2?

Neuromodulation: Technology at the N
Received: March 1, 2021 Revised: June 13, 2021 Accepted: June 21, 2021
(onlinelibrary.wiley.com) DOI: 10.1111/ner.13496

A Randomized, Sham-Controlled Trial of Repetitive Transcranial Magnetic Stimulatio Targeting M1 and S2 in Central Poststroke Pain: A Pilot Trial

Juhani Ojala, MD[1]; Jukka Vanhanen, MD[2,3]; Hanna Harno, MD, PhD[1]
Pantelis Lioumis, MS, PhD[3,5]; Selja Vaalto, MD, PhD[2]; Mari A. Kaunisto,
Jukka Putaala, MD, PhD[4]; Marko Kangasniemi, MD, PhD[7];
Erika Kirveskari, MD, PhD[2,3]; Jyrki P. Mäkelä, MD, PhD[3];
Eija Kalso, MD, PhD[1]





Repetitive transcranial magnetic stimulation for neuropathic pain: a randomized multicentre sham-controlled trial

Nadine Attal,[1,2] Frédérique Poindessous-Jazat,[1] Edwige De Chauvigny,[3]
Charles Quesada,[4] Alaa Mhalla,[5] Samar S. Ayache,[5,6] Christophe Fermanian,[7]
Julien Nizard,[3] Roland Peyron,[4] Jean-Pascal Lefaucheur[5,6] and Didier Bouhassira[1,2]

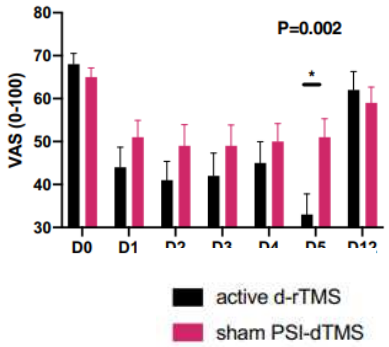
Insula postérieure?

Neurophysiologie Clinique/Clinical Neurophysiology 51 (2021) 291–302
ELSEVIER
Disponible en ligne sur ScienceDirect www.sciencedirect.com
Elsevier Masson France EM|consulte www.em-consulte.com/en

ORIGINAL ARTICLE

Posterior-superior insular deep transcranial magnetic stimulation alleviates peripheral neuropathic pain — A pilot double-blind, randomized cross-over study

Liu Dongyang[a], Ana Mércia Fernandes[a],
Pedro Henrique Martins da Cunha[a], Raissa Tibes[a], João Sato[a],
Clarice Listik[a], Camila Dale[a], Gabriel Taricani Kubota[a],
Ricardo Galhardoni[a], Manoel Jacobsen Teixeira[a],
Valquiria Aparecida da Silva[a], Jefferson Rosi[a],
Daniel Ciampi de Andrade[a,b,*]



Neurophysiologie Clinique/Clinical Neurophysiology (2019) 49, 301–307

ELSEVIER

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ScienceDirect
www.sciencedirect.com

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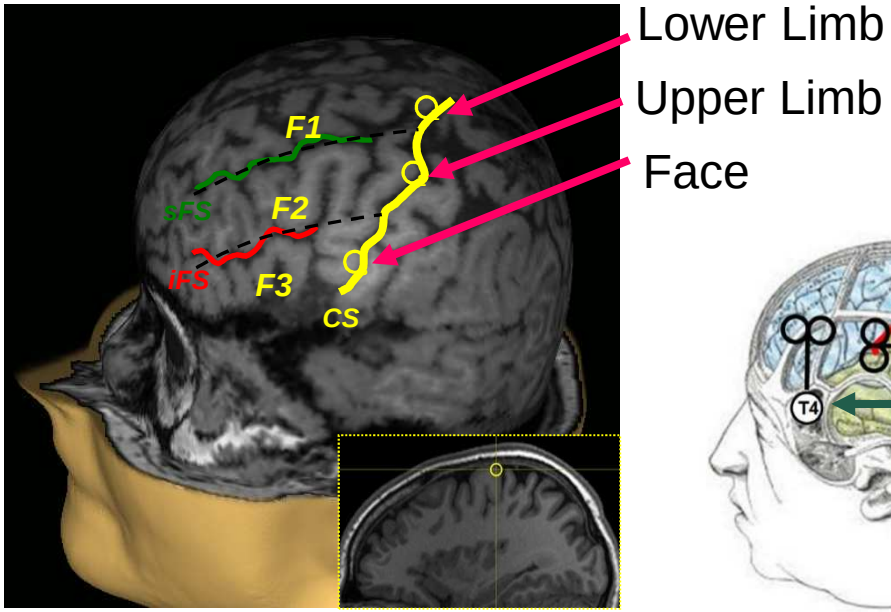
EM|consulte
www.em-consulte.com/en

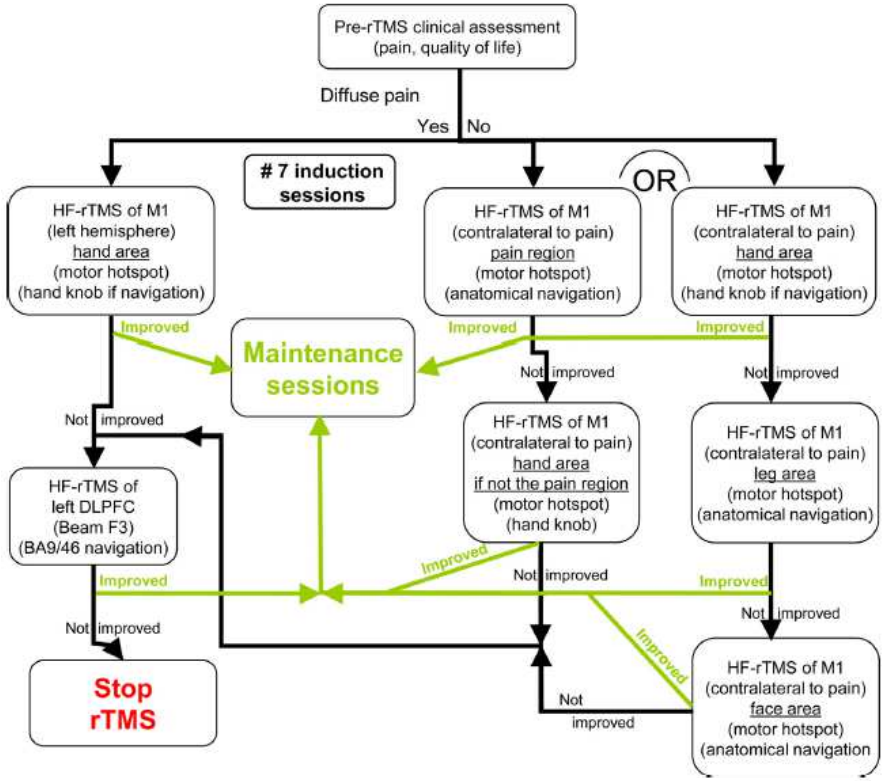
TECHNICAL NOTE

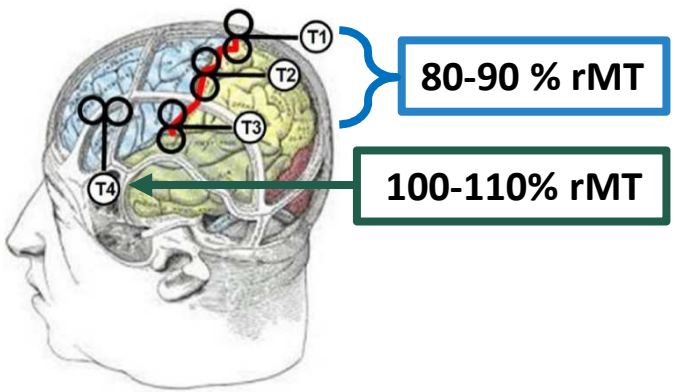
A practical algorithm for using rTMS to treat patients with chronic pain

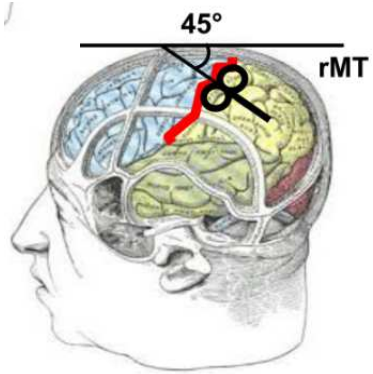
Jean-Pascal Lefaucheur[a,*], Jean-Paul Nguyen[b,c]

10 Hz, 15 minutes (30 trains de 10 s avec 20 s intertrain, soit 3000 pulses/séance)









Thérapie antalgique personnalisée?

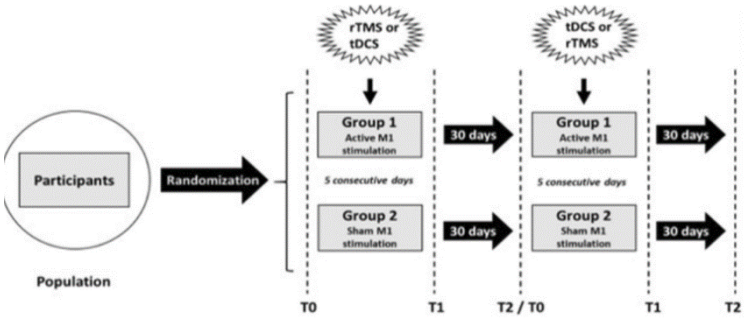
Peu d'études investiguant de manière spécifique la place de la rTMS pour le traitement des douleurs du Plexus Brachial

1 RCT

scientific reports (2022) 12:1440

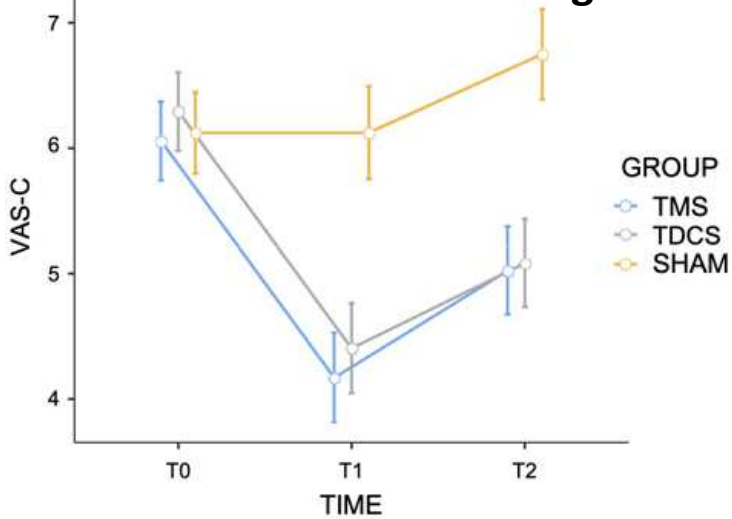
OPEN **Effects of rTMS and tDCS on neuropathic pain after brachial plexus injury: a randomized placebo-controlled pilot study**

Erickson Duarte Bonifício de Assis[1,2], Wanessa Kallyne Nascimento Martins[1],



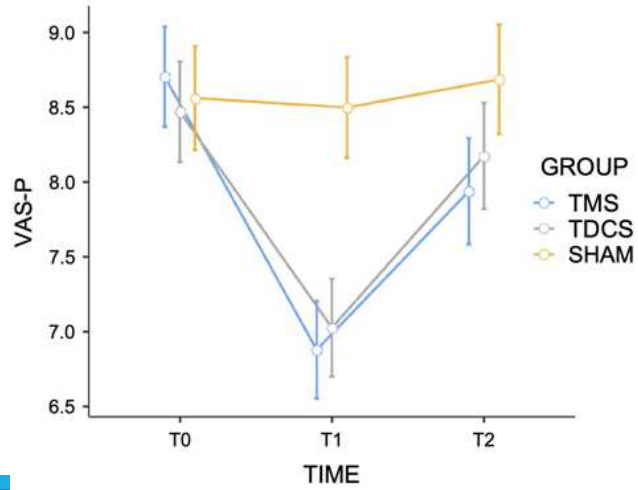
	Group 1 (n = 12) (active)	Group 2 (n = 8) (sham)	*p* value
Age (mean ± SD)	34 ± 10	31 ± 7	.466
Gender, % (n)			
Male	100 (12)	100 (8)	
Injury time in months (mean ± SD)	34.01 ± 31.04	44.44 ± 36.86	.468
Affected upper limb, % (n)			
Right	58.33 (7)	41.66 (5)	.319
Left	37.50 (3)	62.50 (5)	
Pain site, % (n)			
Hand	58.33 (7)	37.50 (3)	.750
Hand and forearm	16.67 (2)	37.50 (3)	
Arm	8.33 (1)	12.50 (1)	
Shoulder	8.33 (1)		
Whole upper limb	8.33 (1)	12.50 (1)	
Affected myotomes (C5-T1), % (n)			
C5	83.33 (10)	87.50 (7)	.993
C6	100 (12)	100 (8)	
C7	100 (12)	100 (8)	
C8	91.67 (11)	100 (8)	
T1	75.00 (9)	100 (8)	
Horner's syndrome, % (n)	75.00 (9)	75.00 (6)	.936
Presence of motor function, % (n)			
Useful (MRC grade 3–4)	41.66 (5)	37.50 (3)	.850
Residual (MRC grade 1–2)	50.00 (6)	50.00 (4)	
Absent (MRC grade 0)	8.33 (1)	12.50 (1)	
Location with motor function, % (n)			
Shoulder	50.00 (6)	50.00 (4)	.787
Elbow	8.33 (1)	25.00 (2)	
Wrist	16.67 (2)	25.00 (2)	
Hand	25.00 (3)	25.00 (2)	
Whole upper limb	8.33 (1)		

Continuous Pain: « burning »



- « In BPA, continuous pain is thought to originate from supraspinal structures, particularly the thalamus ».

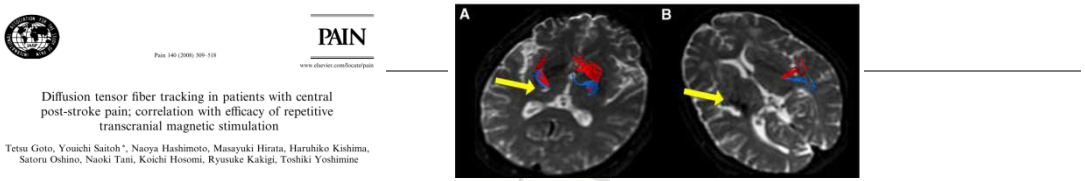
Paroxysmal Pain: « shooting »



- « In BPA, paroxysmal pain is thought to originate from hyperactive neurons in the dorsal horn ».
- « Neuronal hyperactivity has been also detected in thalamic nuclei »

Nouvelles approches en rTMS

- **QUI?- Facteurs pronostiques**


Pain 140 (2008) 509–518

PAIN

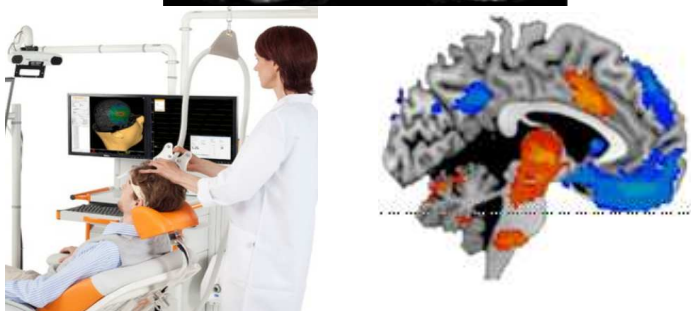
www.elsevier.com/locate/pain

Diffusion tensor fiber tracking in patients with central post-stroke pain; correlation with efficacy of repetitive transcranial magnetic stimulation

Tetsu Goto, Youichi Saitoh *, Naoya Hashimoto, Masayuki Hirata, Haruhiko Kishima, Satoru Oshino, Naoki Tani, Koichi Hosomi, Ryusuke Kakigi, Toshiki Yoshimine

- **OÙ- Optimisation du site de ciblage**

  ➔ Neuronavigation& Neuroimagerie de connectivité



- **POURQUOI?- Closed-loop**

Brain Stimulation xxx (xxxx) xxx

Contents lists available at ScienceDirect

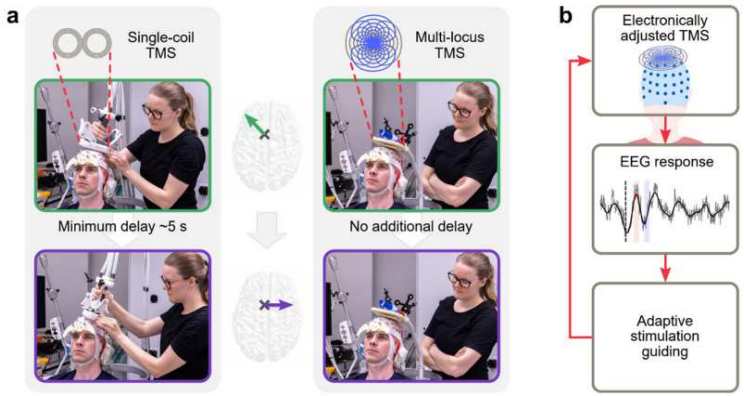
Brain Stimulation

journal homepage: http://www.journals.elsevier.com/brain-stimulation

ELSEVIER

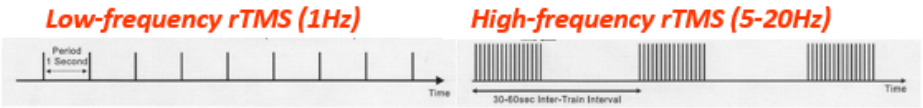
Closed-loop optimization of transcranial magnetic stimulation with electroencephalography feedback

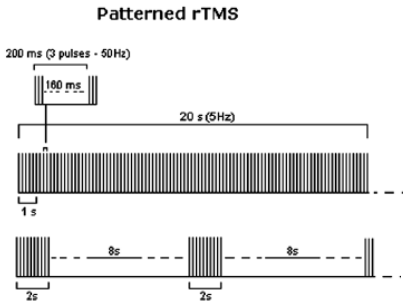
Aino E. Tervo [a, b, c, 1], Jaakko O. Nieminen [a, b, 1, *], Pantelis Lioumis [a, b, d], Johanna Metsomaa [a, e], Victor H. Souza [a, b], Heikki Sinisalo [a, b], Matti Stenroos [a], Jukka Sarvas [a, 2], Risto J. Ilmoniemi [a, b]



- **COMMENT? - Patrons** de stimulation

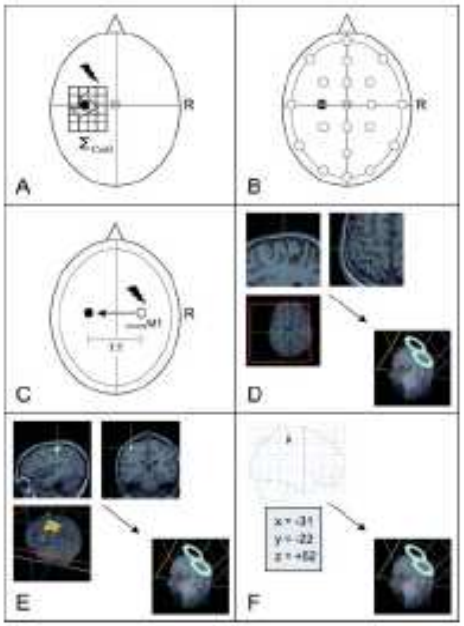
  Nombre de stimulation / session



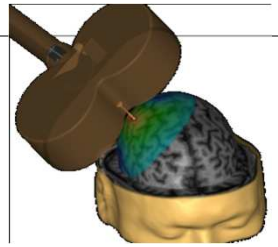


Optimisation du site de ciblage : Neuronavigation

Sparing et al.
HBM 2008

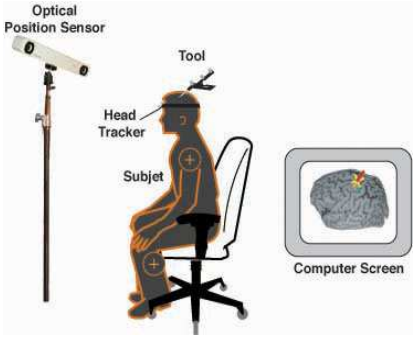


10-20 system



'function -guided'

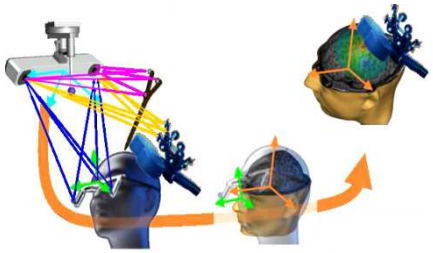
individual MRI



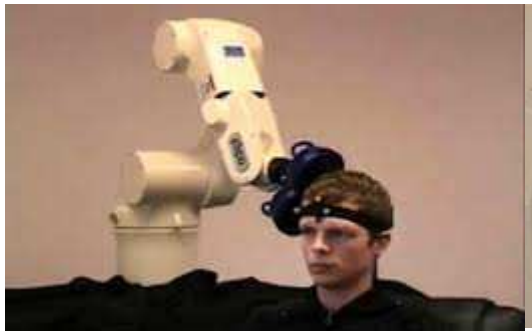
individual fMRI

'probabilistic' group approach

=> Système de neuronavigation



=> Robots



La TMS couplée à la neuronavigation de haute précision: Cartographie motrice

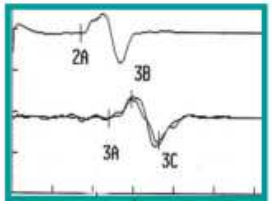
Utilisation en neurochirurgie en préopératoire

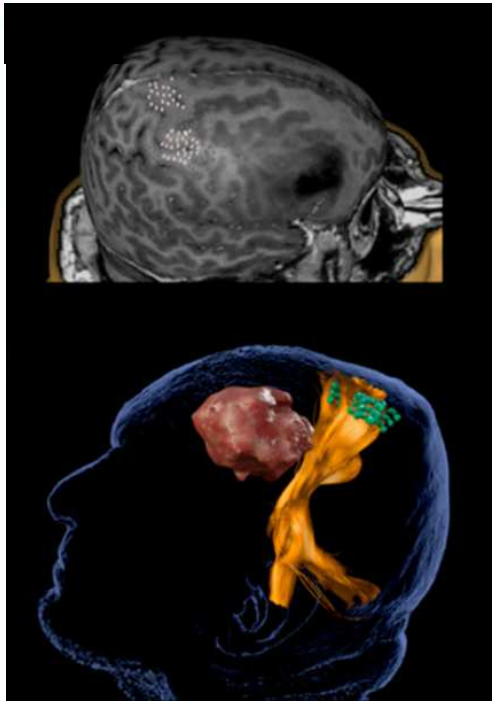
Stimulation magnétique transcrânienne (PEM)

- Associée à un **système de neuronavigation**
- Stimulation magnétique des régions corticales motrices avec une **précision millimétrique**[1,2]

➔ Permet d'établir des **cartes motrices fonctionnelles pour chaque muscle enregistré**

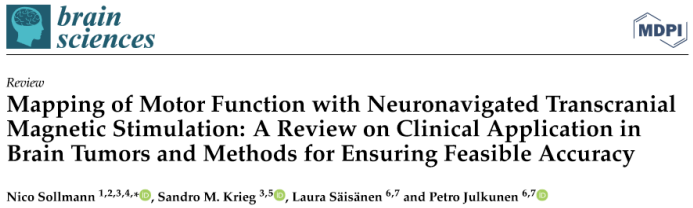
Potentiels Evoqués Moteurs





+ DTI : Permet une reconstruction fonctionnelle du faisceau corticospinal : tractographie nTMS-guidée[3]

- ➔ **Résolution nTMS supérieure à l'IRMf**
- ➔ **Reconstruction CST > tractographie** « classique »
- ➔ **Concordance avec DES per-opératoire**


brain sciences

MDPI

Review

Mapping of Motor Function with Neuronavigated Transcranial Magnetic Stimulation: A Review on Clinical Application in Brain Tumors and Methods for Ensuring Feasible Accuracy

Nico Sollmann [1,2,3,4,*], Sandro M. Krieg [3,5], Laura Säisänen [6,7] and Petro Julkunen [6,7]

1 Krieg SM, et al. Protocol for motor and language mapping by navigated TMS in patients and healthy volunteers; workshop report. Acta Neurochir. (Wien) (2017); 159: 1187–1195.
2 Krieg SM, et al. Utility of presurgical navigated transcranial magnetic brain stimulation for the resection of tumors in eloquent motor areas. J. Neurosurg. (2012); 116: 994–1001.
3 Weiss Lucas C, et al. Functional MRI vs. navigated TMS to optimize M1 seed volume delineation for DTI tractography. A prospective study in patients with brain tumours adjacent to the corticospinal tract. NeuroImage Clin. (2017); 13: 297–309.

Dépression : protocole SAINT

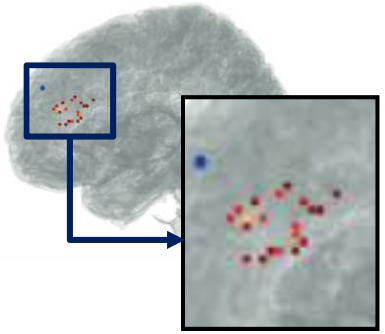
Stimulation du DLPFC par iTBS

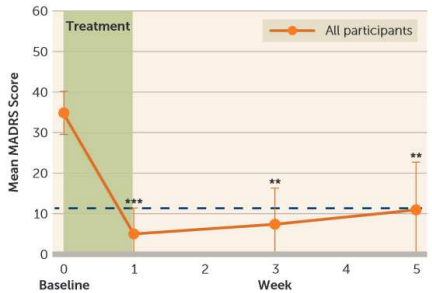
- Par **neuronavigation**
- **+ connectivité par IRMf**
- **Stimulation** de la **portion du DLPFC** la **plus décorrélée au subgénual du CCA**

The American Journal of Psychiatry

Stanford Accelerated Intelligent Neuromodulation Therapy for Treatment-Resistant Depression

Eleanor J. Cole, Ph.D., Katy H. Stimpson, B.S., Brandon S. Bentzley, M.D., Ph.D., Merve Gulser, B.S., Kirsten Cherian, Ph.D., Claudia Tischler, B.S., Romina Nejad, M.S., Heather Pankow, B.S., Elizabeth Choi, B.S., Haley Aaron, B.S., Flint M. Espil, Ph.D., Jaspreet Pannu, B.S., Xiaoqian Xiao, Ph.D., Dalton Duvio, B.S., Hugh B. Solvason, M.D., Jessica Hawkins, B.A., Austin Guerra, B.A., Booil Jo, Ph.D., Kristin S. Raj, M.D., Angela L. Phillips, Ph.D., Fahim Barmak, M.D., James H. Bishop, Ph.D., John P. Coetzee, Ph.D., Charles DeBattista, M.D., Jennifer Keller, Ph.D., Alan F. Schatzberg, M.D., Keith D. Sudheimer, Ph.D., Nolan R. Williams, M.D.



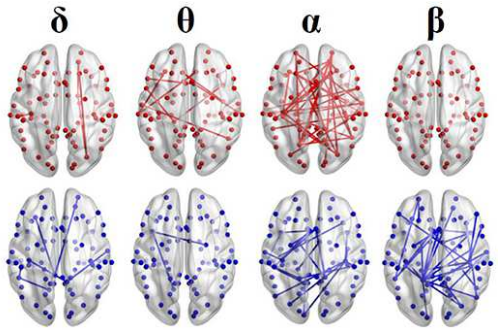


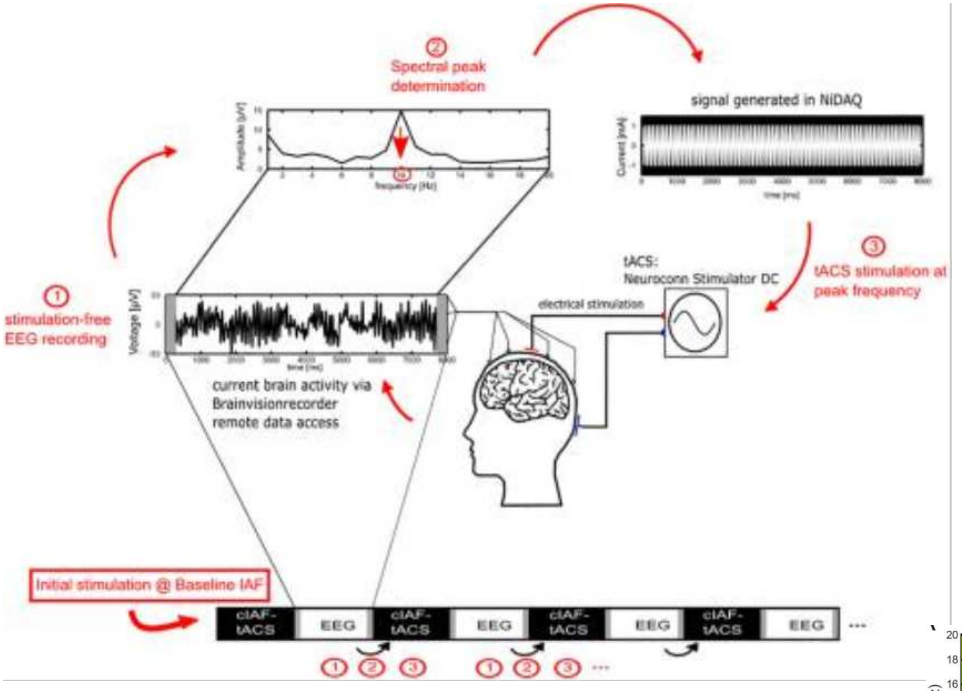
Avantages:

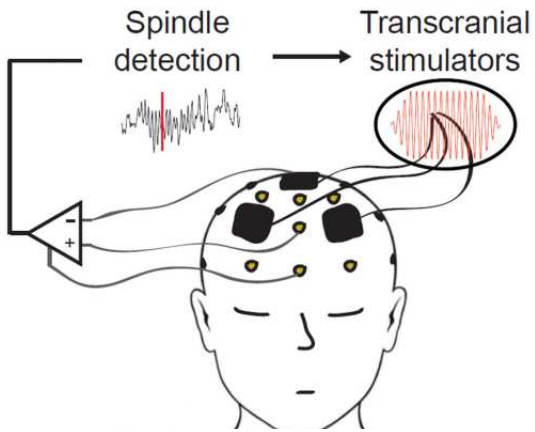
- **Localisation anatomique et fonctionnelle du DLFPC**
- **Résultats impressionnants** :
  90% de réponse à la fin du ttt (J6) → **70% à M1**
  FDA-Approved

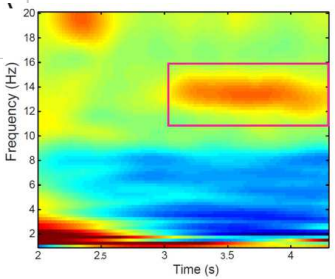
Stimulation couplée à l'EEG

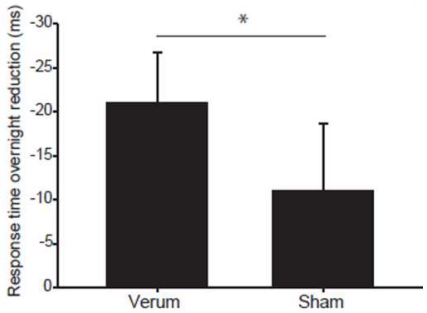
Développement de techniques de closed-loop couplées à l'EEG = spectre fréquentiel et/ou connectivité









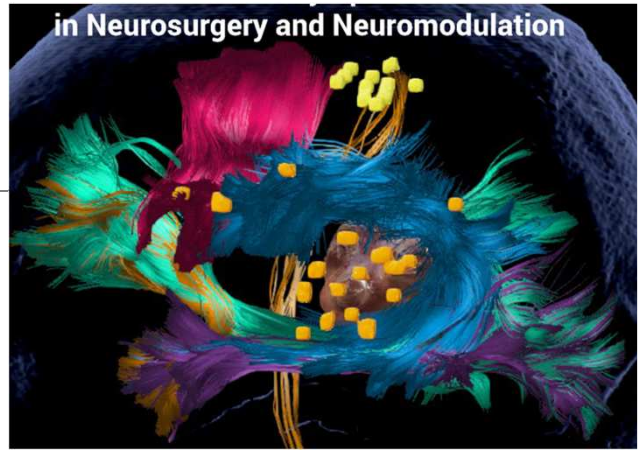


Curr Biol. 2016 August 22; 26(16): 2127–2136. doi:10.1016/j.cub.2016.06.044.

Feedback-controlled transcranial alternating current stimulation reveals functional role of sleep spindles in motor memory consolidation

Caroline Lustenberger[1], **Michael R. Boyle**[1,2], **Sankaraleengam Alagapan**[1], **Juliann M. Mellin**[1], **Bradley V. Vaughn**[3], and **Flavio Fröhlich**[1,2,3,4,5]

Conclusion



En pratique clinique:

- La rTMS a de très bons profils d'innocuité et de tolérabilité
  - (peu d'effets secondaires ou de contre-indications)
- Recommandation grade A pour douleur neuropathique (focale et périphérique +++) mais l'effet antalgique présente une grande variabilité interindividuelle
- La principale limitation est la nécessité de répéter les séances (thérapie de maintenance +++)

Dans le futur:

- Vers modes de stimulation plus rapide et nombre de stimulations plus élevé : pcTBS, piTBS
- Utilisation de la neuronavigation selon les cibles +/- couplée à l'IRM fonctionnelle
- Closed-Loop couplée à l'EEG
- Une thérapie antalgique individualisée par rTMS nécessitera une meilleure compréhension des mécanismes de la douleur chronique à l'echelle individuelle

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FORMATION CONTINUE

DU NEUROMODULATION THÉRAPEUTIQUE : DE LA THÉORIE À LA PRATIQUE

Sous réserve de la validation des instances de l'UPEC

LES OBJECTIFS :

- Connaître les indications en Neurochirurgie, Neurologie et en Psychiatrie des méthodes de neuromodulation cliniques invasives et non-invasives suivantes, lors de l'exercice en ville et en CHU : stimulation cérébrale profonde (SCP), stimulation médullaire, stimulation magnétique transcrânienne (TMS), stimulation transcrânienne à courant continu (tDCS), électroconvulsivothérapie
- Réaliser une séance de planification chirurgicale de SCP et d'insertion d'une électrode de SCP dans un fantôme de cerveau.
- Réaliser une séance de stimulation par TMS, tDCS et ECT.
- Maîtriser un outil de neuronavigation (localisation de la zone à stimuler grâce à un dispositif dédié) pour la SCP et la TMS.

LE PLUS DE LA FORMATION :

- Les techniques de neuromodulation représentent un formidable outil pour aider les personnes souffrant de pathologies neurologiques ou psychiatriques. Les médecins (neurochirurgiens

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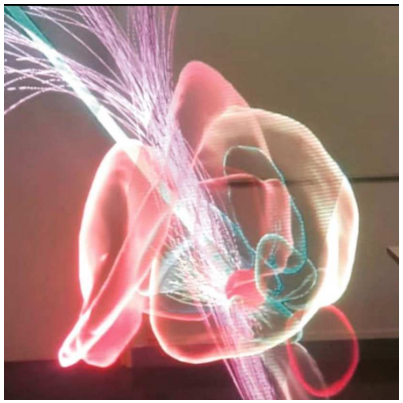
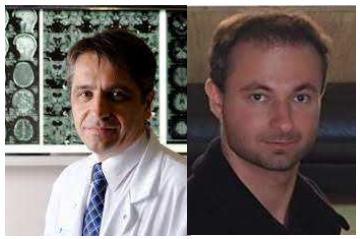


Neurochirurgie



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Merci pour votre attention