# NEUROSTIMULACÍ FACILITOVANÁ REHABILITACE PRO OBNOVU MOTORICKÝCH FUNKCÍ DONÍCH KONČETIN

ŠIMON KOZÁK

CLB A NMC KAR FNKV

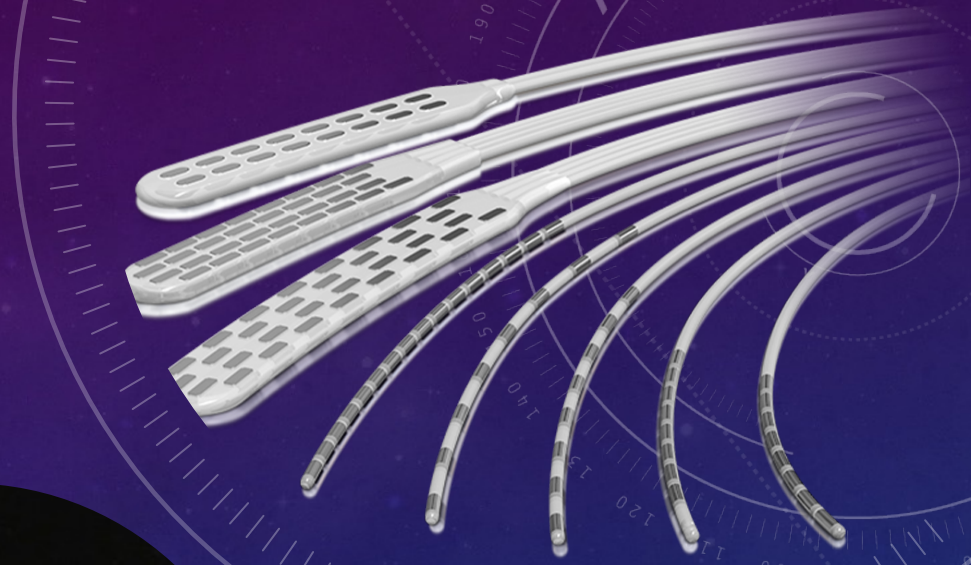

courtesy Gregoire Courtine

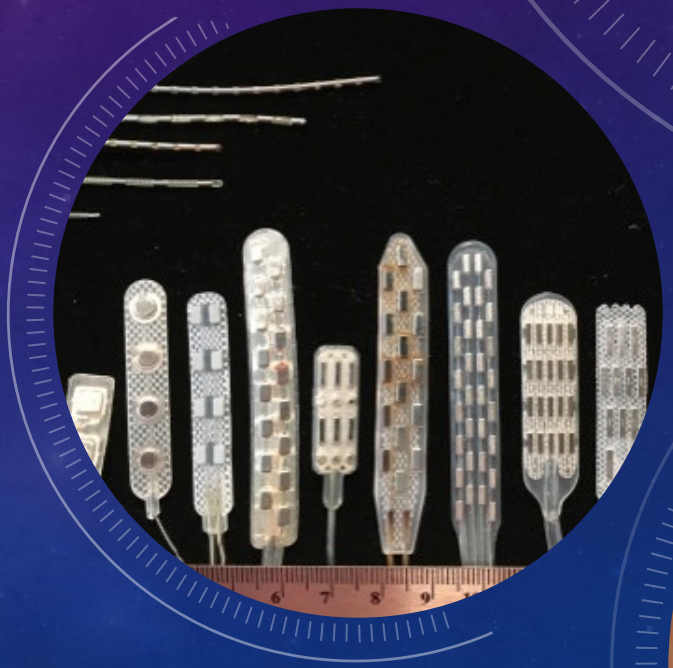
KLINIKA ANESTEZIOLOGIE A RESUSCITACE
3. LF UK a FNKV

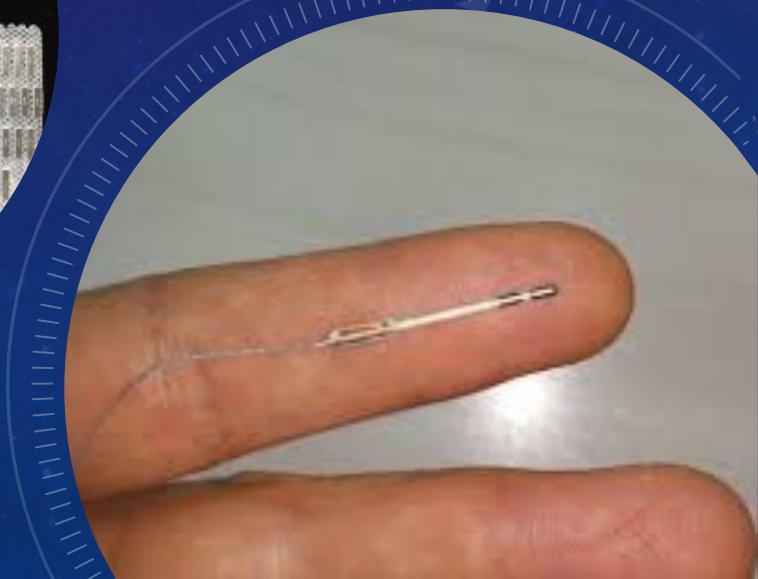
3. LÉKAŘSKÁ FAKULTA
Univerzita Karlova


MOTORIKA PŘED OPERACÍ

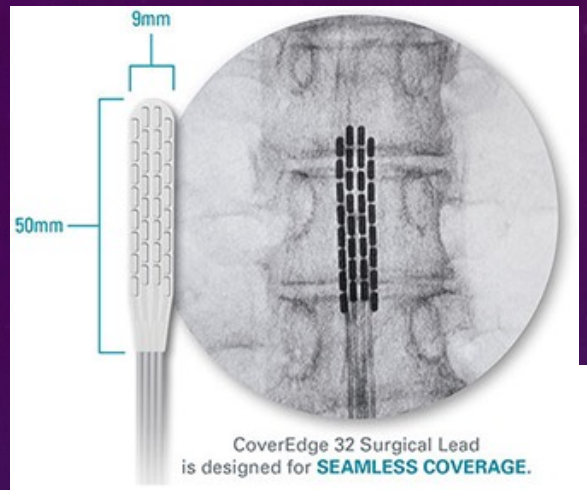
# VÝVOJ NEUROMODULAČNÍ TERAPIE

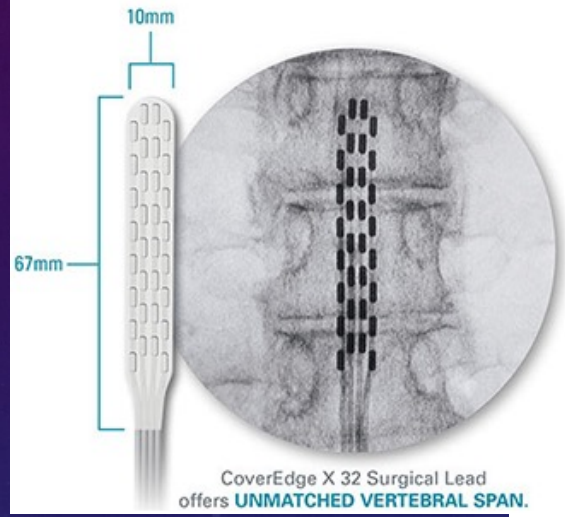


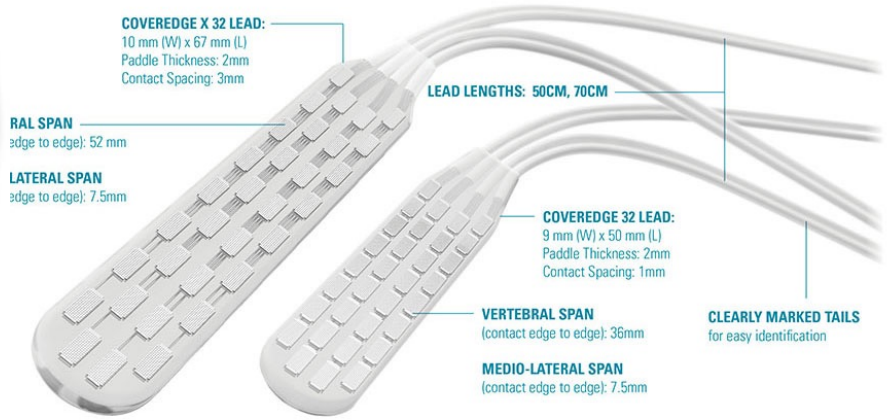




# Unrivaled Percutaneous Lead Options



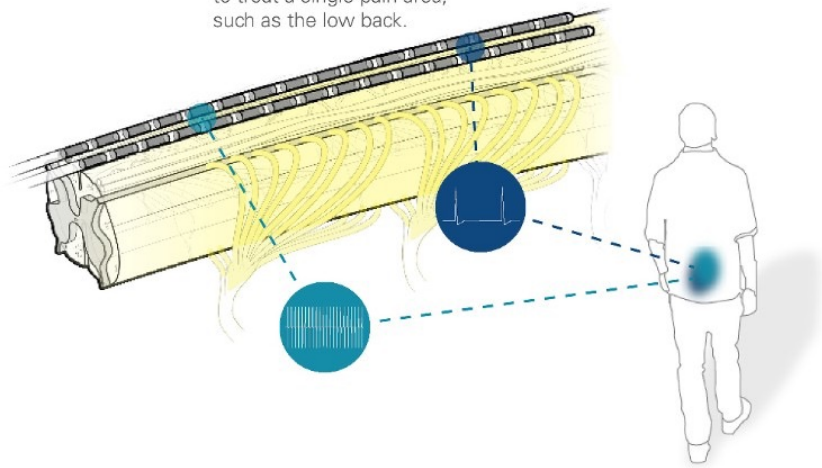




**BOSTON SCIENTIFIC**

| Lead Options | Linear™ ST w/ D4 Splitter | Linear 3-4 w/ D4 Splitter | Linear 3-6 w/ D4 Splitter | Linear | Linear ST | Linear ST w/ W4 Splitter | Linear 3-4 w/ W4 Splitter | Linear 3-4 | Linear 3-6 w/ W4 Splitter | Linear 3-6 | Infinion™ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |  |  |  |
| ts | 4 | 4 | 4 | 8 | 8 | 4 | 4 | 8 | 4 | 8 | 16 |
| ge h) | 1 | 4 | 6 | 1 | 1 | 5 | 11 | 4 | 15 | 6 | 1 |
| h) | 15 | 24 | 30 | 31 | 31 | 31 | 52 | 52 | 66 | 66 | 67 |

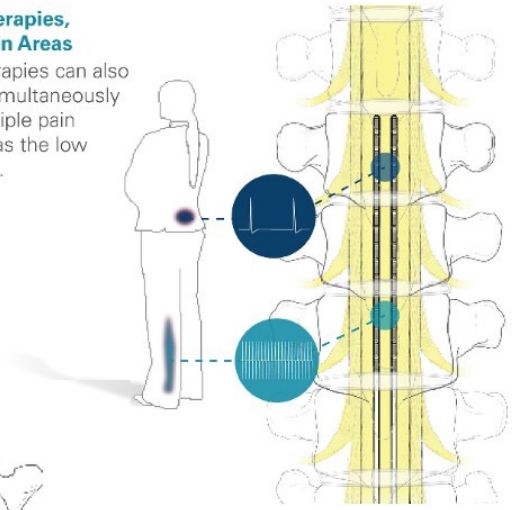
**Multiple Therapies, One Pain Area**

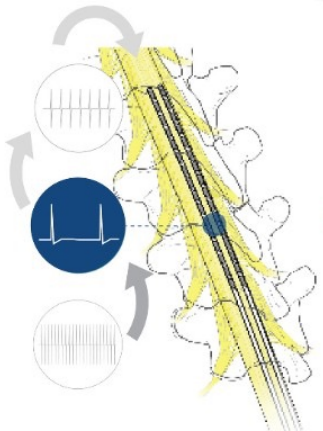
Multiple therapies can be utilized simultaneously to treat a single pain area, such as the low back.



**Multiple Therapies, Multiple Pain Areas**

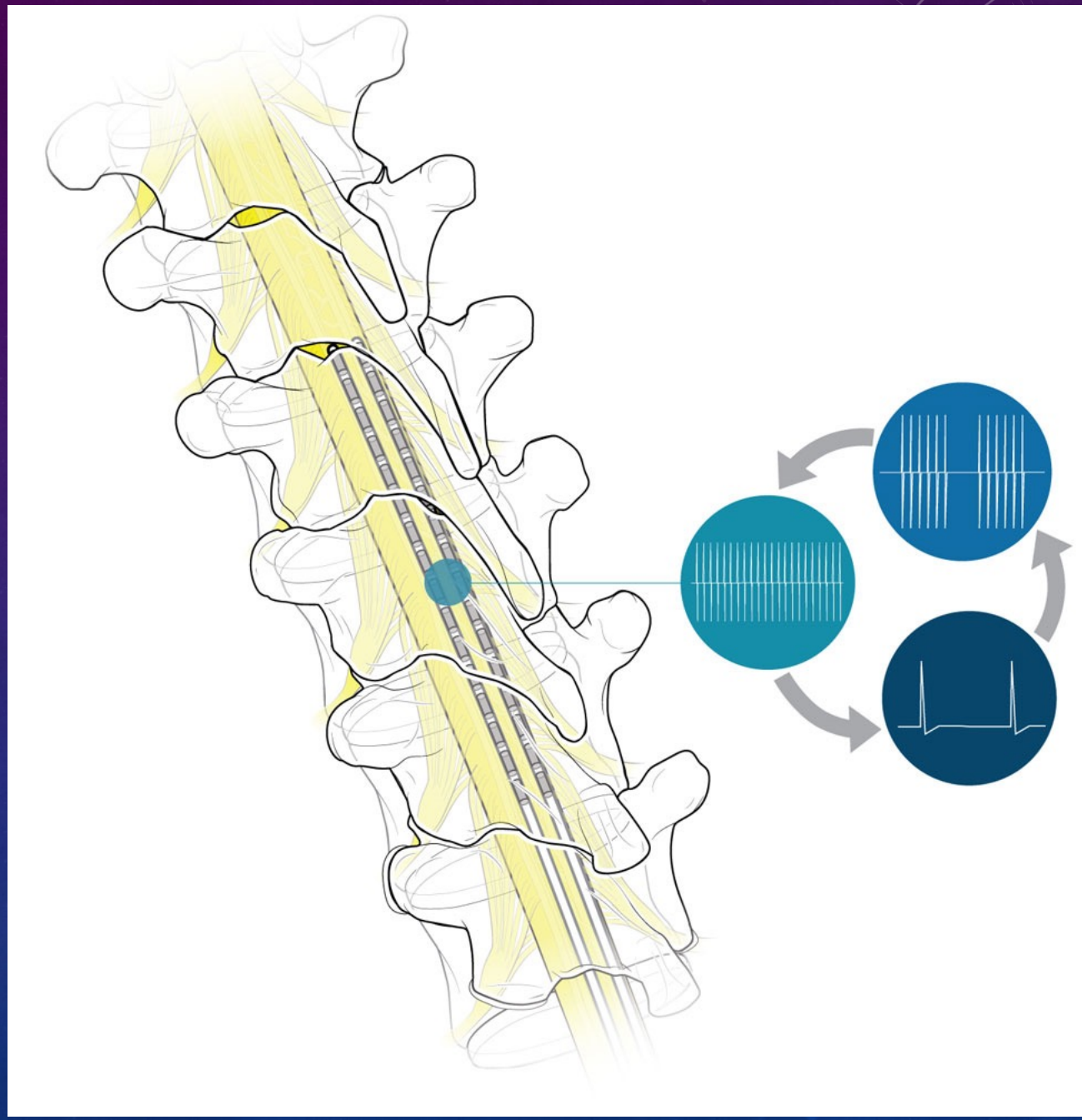
Multiple therapies can also be utilized simultaneously to treat multiple pain areas, such as the low back and leg.

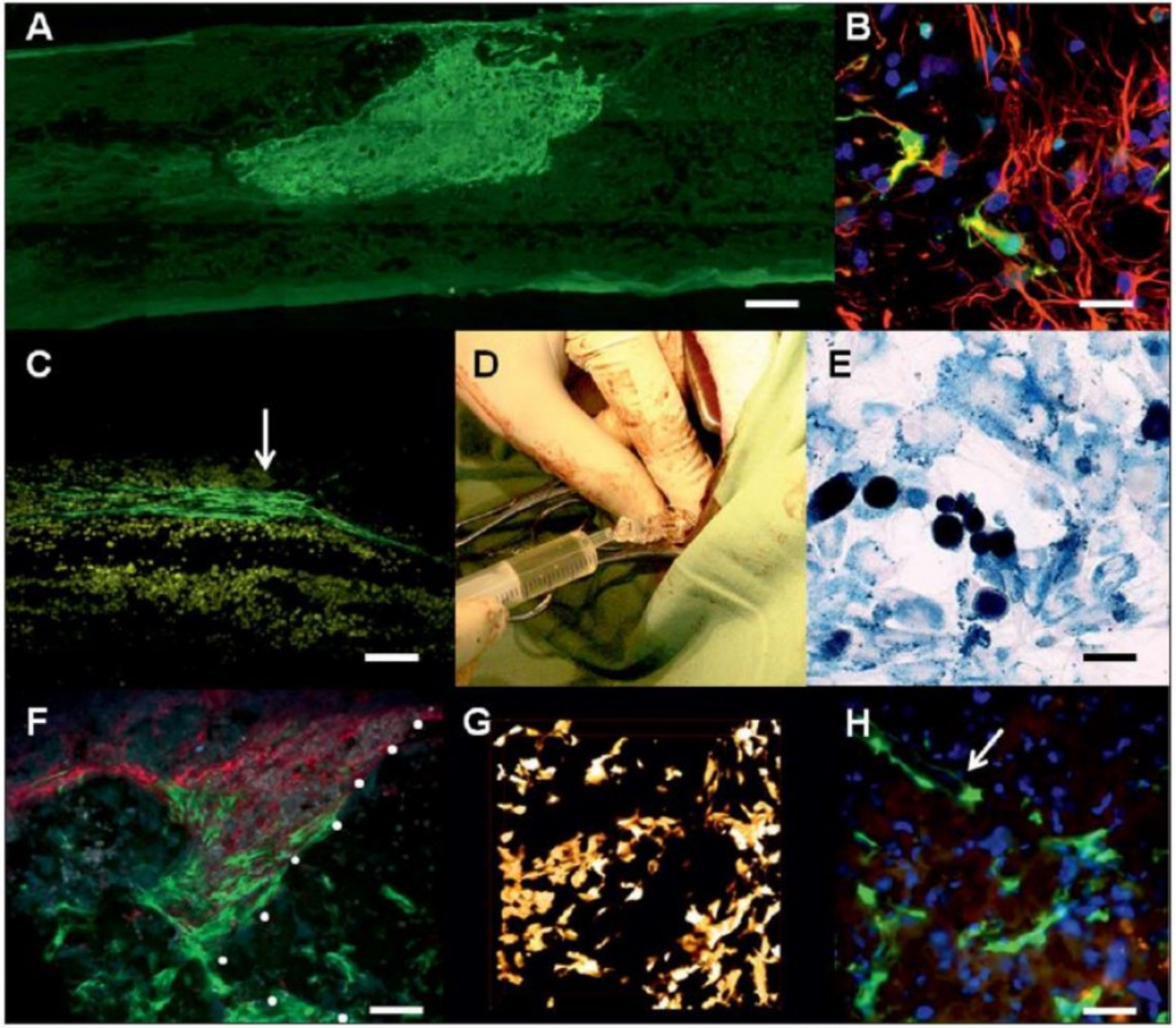




**Multiple Therapies, Sequentially**

Multiple therapies can be utilized sequentially, which may address habituation.






Obr. 4. Různé typy kmenových buněk po experimentální aplikaci do poranění míchy.

d nerves that sends and receives signals

# STIMULAČNÍ TERAPIE

INDIVIDUALS WITH SPINAL CORD INJURY (SCI) CAN FACE DECADES WITH PERMANENT DISABILITIES. **ADVANCES IN CLINICAL MANAGEMENT HAVE DECREASED MORBIDITY AND IMPROVED OUTCOMES.**

NO RANDOMIZED CLINICAL TRIAL HAS DEMONSTRATED THE EFFICACY OF A **REPAIR STRATEGY FOR IMPROVING RECOVERY FROM SCI.**

HERE, WE SUMMARIZE RECENT ADVANCES IN BIOLOGICAL ENGINEERING STRATEGIES TO **AUGMENT NEUROPLASTICITY AND/OR FUNCTIONAL RECOVERY OF SCI THAT ARE PUSHING TOWARD CLINICAL TRANSLATION.**

(GREGOIRE COURTINE, 2018)

# TARGETED NEUROTECHNOLOGY RESTORES WALKING IN HUMANS WITH SPINAL CORD INJURY

Spinal cord injury leads to **severe locomotor deficits** or even complete leg paralysis.

Here we introduce targeted spinal cord stimulation neurotechnologies that enabled voluntary control of walking in individuals who had sustained a spinal cord injury more than four years ago and presented with **permanent motor deficits or complete paralysis despite extensive rehabilitation**.

Within one week, this **spatiotemporal stimulation had re-established adaptive control** of paralysed muscles during overground walking.

After a few months, participants regained voluntary control **over previously paralysed muscles even without stimulation and could walk**.

**These results establish a technological framework for improving neurological recovery and supporting the activities of daily living after spinal cord injury.**

Wagner, F.B., Mignardot, JB., Le Goff-Mignardot, C.G. *et al.* Targeted neurotechnology restores walking in humans with spinal cord injury. *Nature* **563,** 65–71 (2018). https://doi.org/10.1038/s41586-018-0649-2

nature medicine

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Content About Publish

Article | Published: 07 February 2022

# Activity-dependent spinal cord neuromodulation rapidly restores trunk and leg motor functions after complete paralysis

Andreas Rowald, Salif Komi, ... Grégoire Courtine

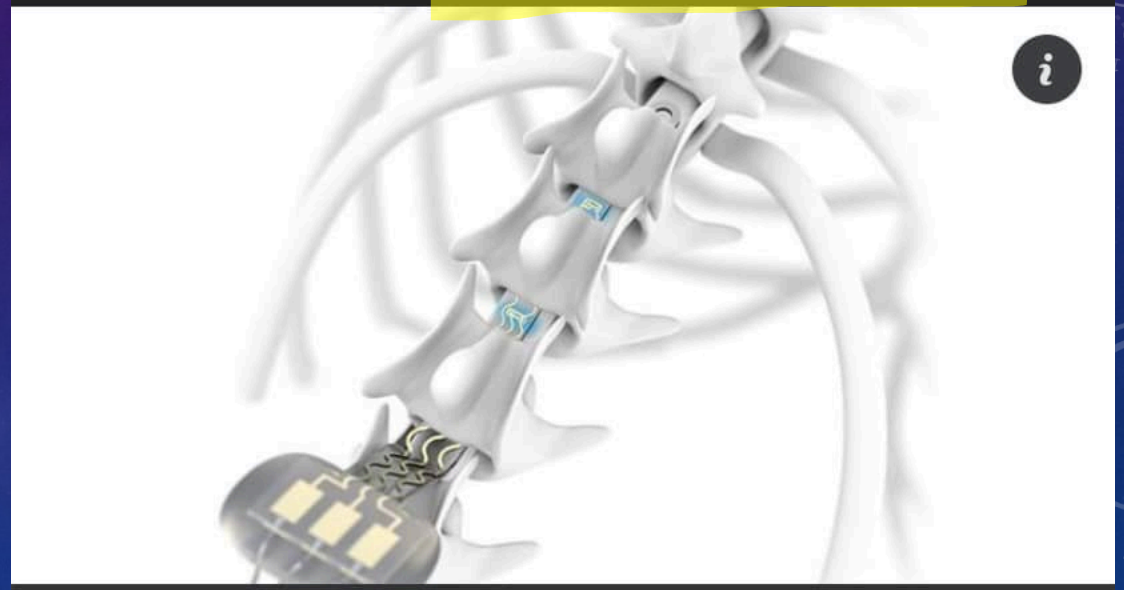
+ Show authors

*Nature Medicine* (2022) | Cite this article

**International Neuromodulation Society**

1 h ·

Nature Medicine has published about clinical research in Switzerland on restoring voluntary leg movement after spinal cord injury in three patients with #paraplegia. The brief article here explains the specialized #spinalcordstimulation technology and has links to the announcement and interviews by the researchers -- who will be giving a plenary lecture May 24 at #INS2022.

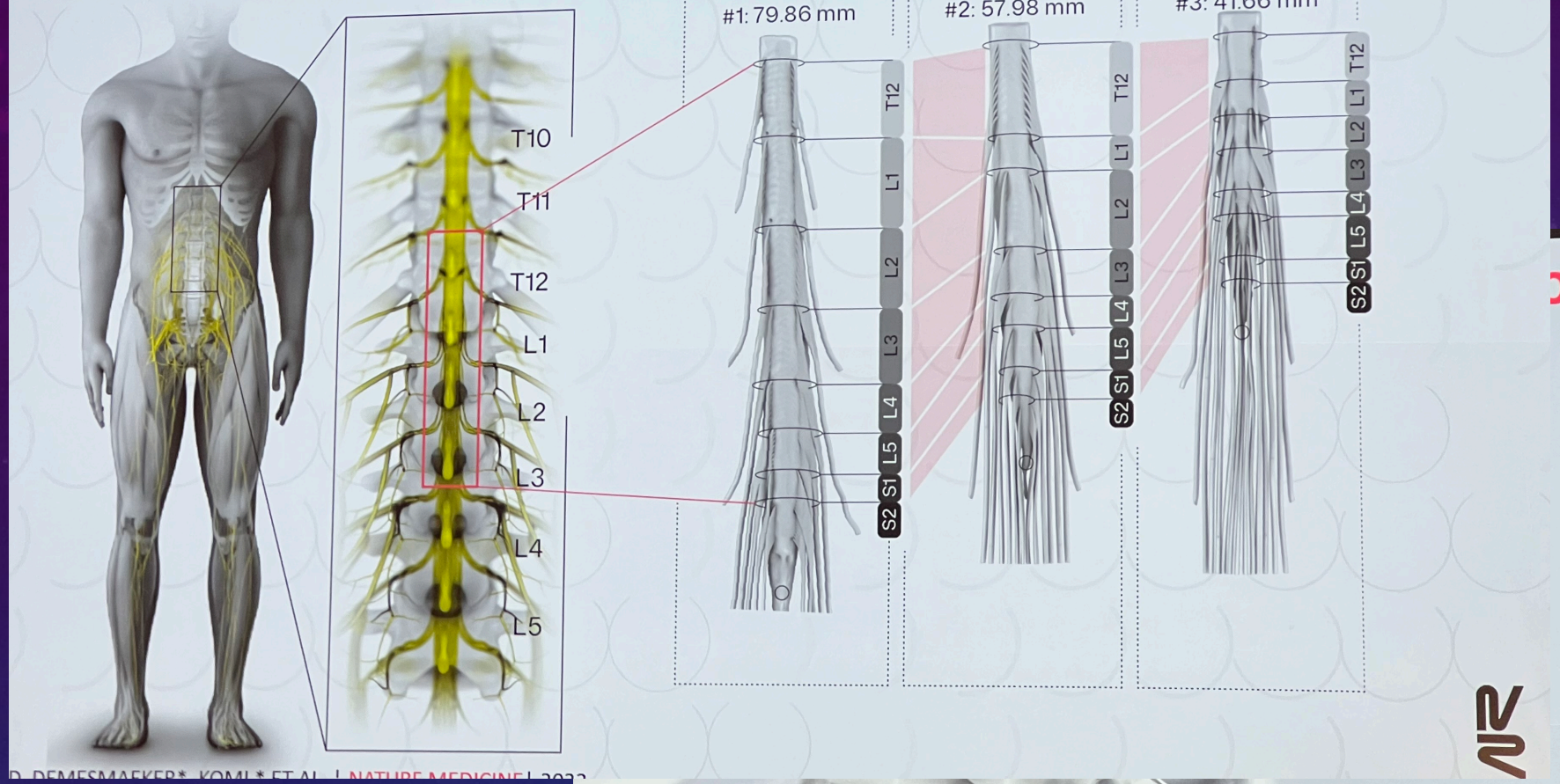


MEDICALDESIGNANDOUTSOURCING.COM

**Paralyzed patients walk, swim and cycle with spinal cord neuromodulation implant - Medical Design and Outsour...**

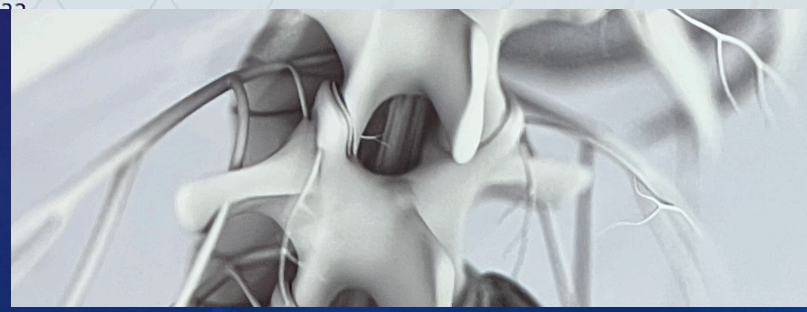

Jocelyne Bloch
Gregoire Courtine
Jocelyne Bloch

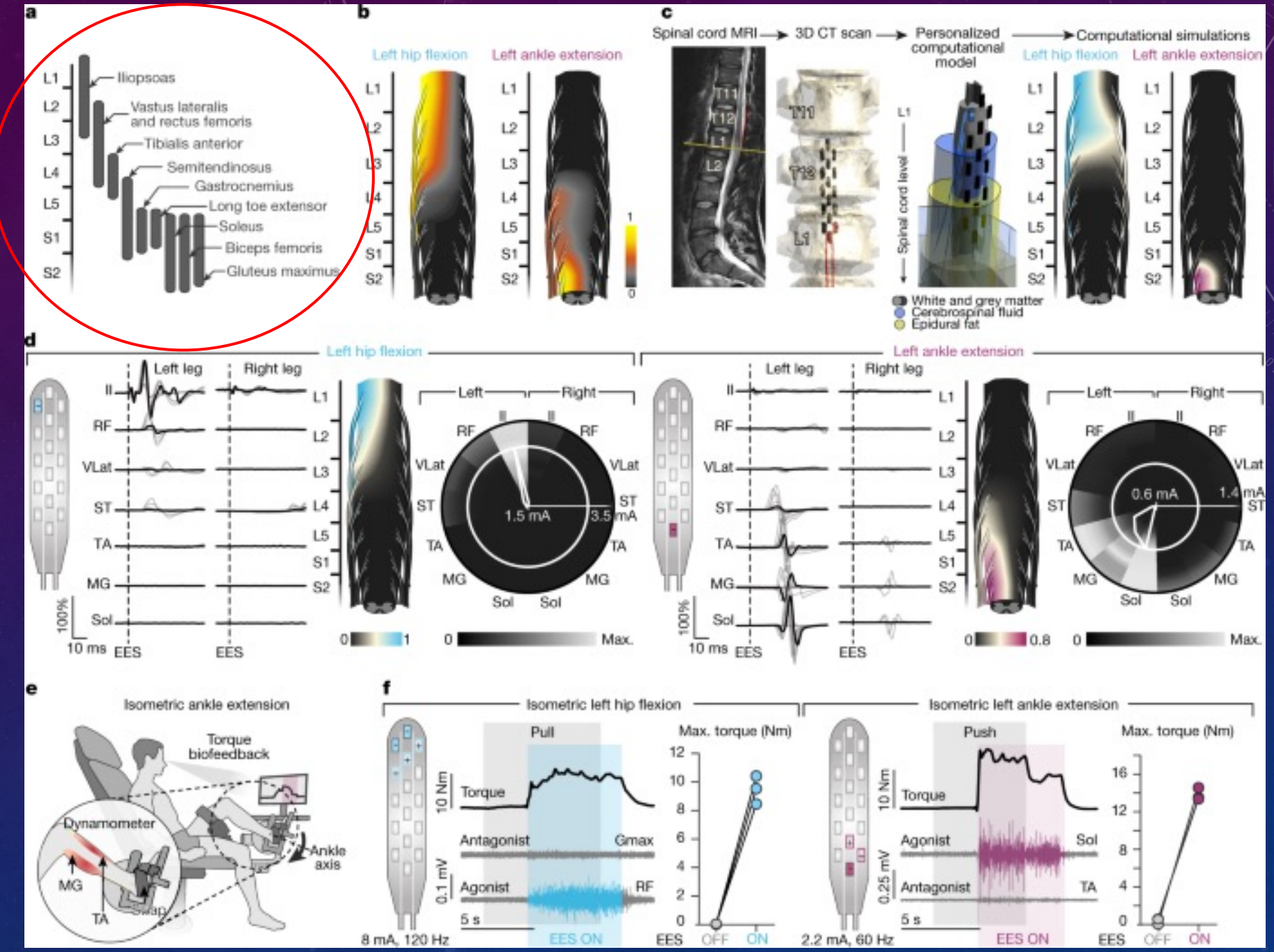
# variability of human spinal cord anatomy



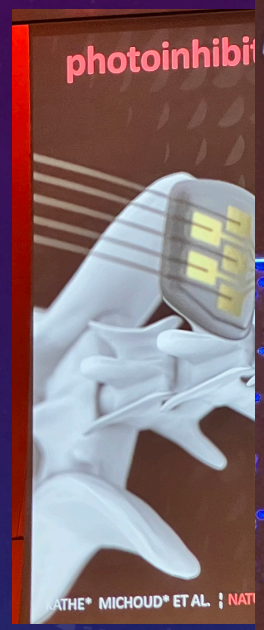

D. DEMESMAEKER*, KOMI* ET AL. | NATURE MEDICINE | 2022

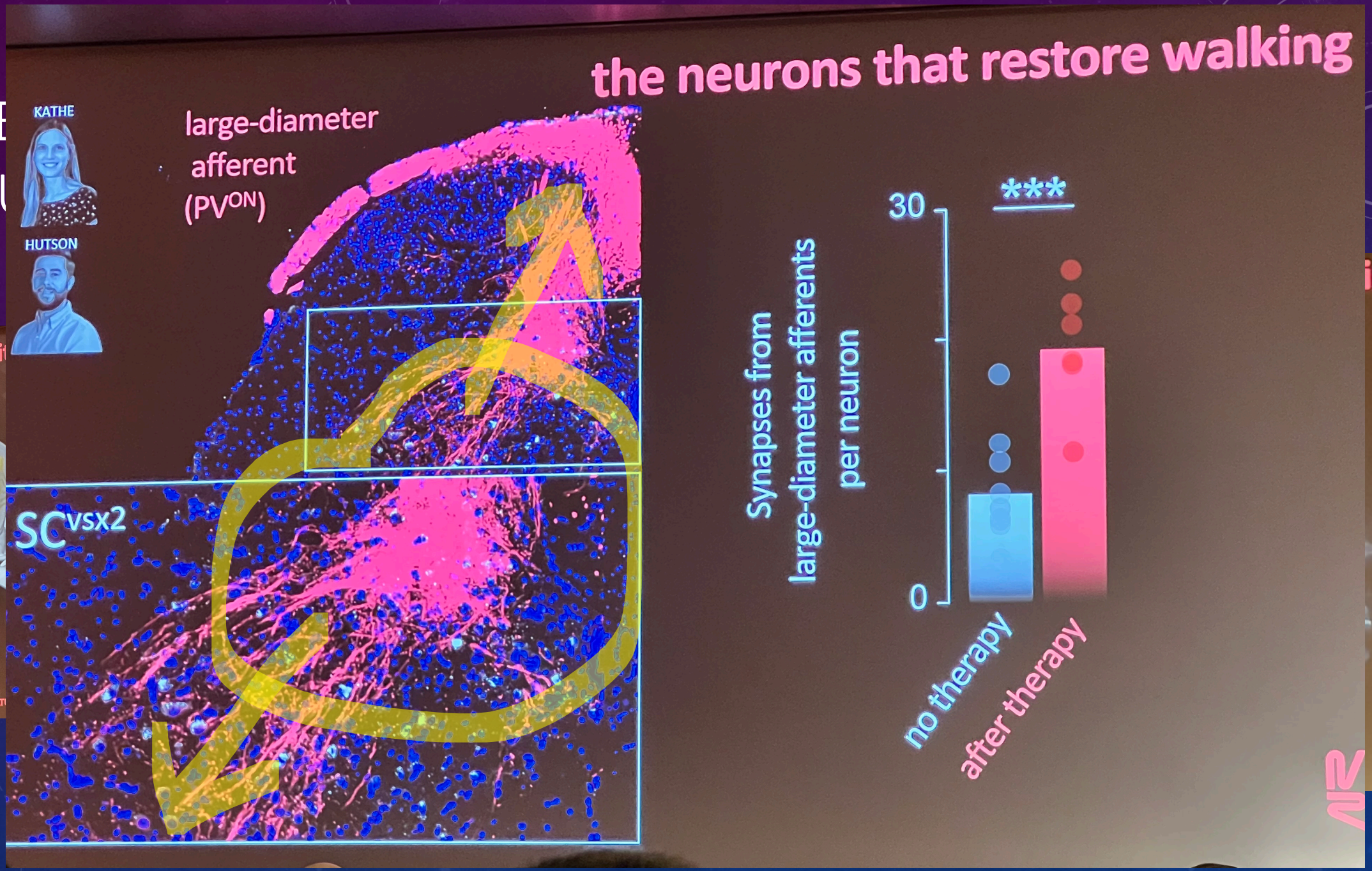
# orsal root entry zones



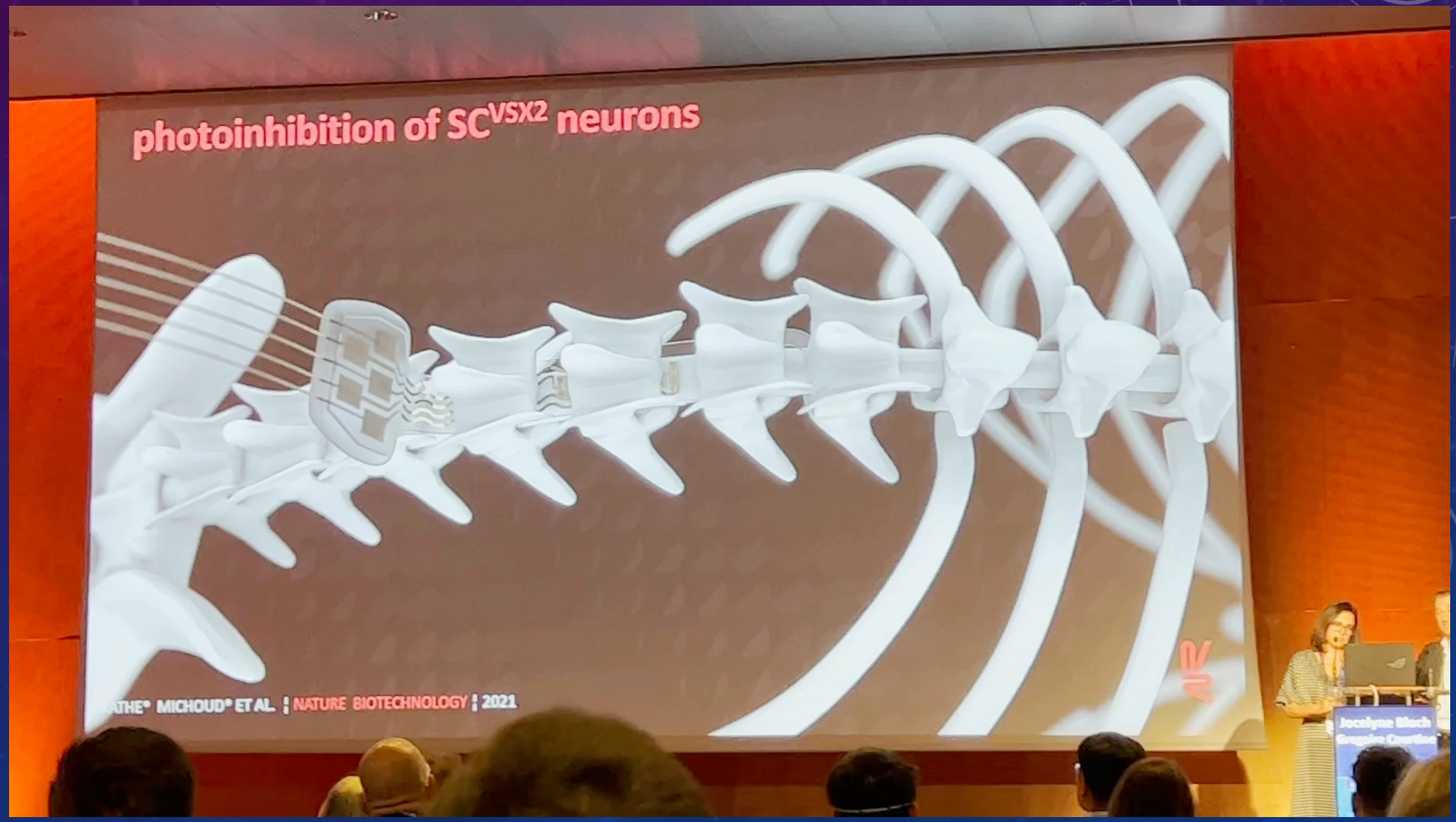

a
L1
L2
L3
L4
L5
S1
S2
Iliopsoas
Vastus lateralis and rectus femoris
Tibialis anterior
Semitendinosus
Gastrocnemius
Long toe extensor
Soleus
Biceps femoris
Gluteus maximus
b
Left hip flexion
Left ankle extension
1
0
c
Spinal cord MRI
3D CT scan
Personalized computational model
Computational simulations
Left hip flexion
Left ankle extension
T11
T12
L1
L2
T11
T12
L1
Spinal cord level
White and grey matter
Cerebrospinal fluid
Epidural fat
d
Left hip flexion
Left ankle extension
Left leg
Right leg
II
RF
VLat
ST
TA
MG
Sol
100%
10 ms
EES
Left
Right
1.5 mA
3.5 mA
0.6 mA
1.4 mA
0
1
Max.
0.8
e
Isometric ankle extension
Torque biofeedback
Dynamometer
Ankle axis
MG
TA
f
Isometric left hip flexion
Isometric left ankle extension
Pull
Push
Max. torque (Nm)
Torque
Antagonist
Agonist
Gmax
RF
Sol
10 Nm
0.1 mV
0.25 mV
5 s
8 mA, 120 Hz
2.2 mA, 60 Hz
EES ON
EES
OFF
ON

SUB
NEU

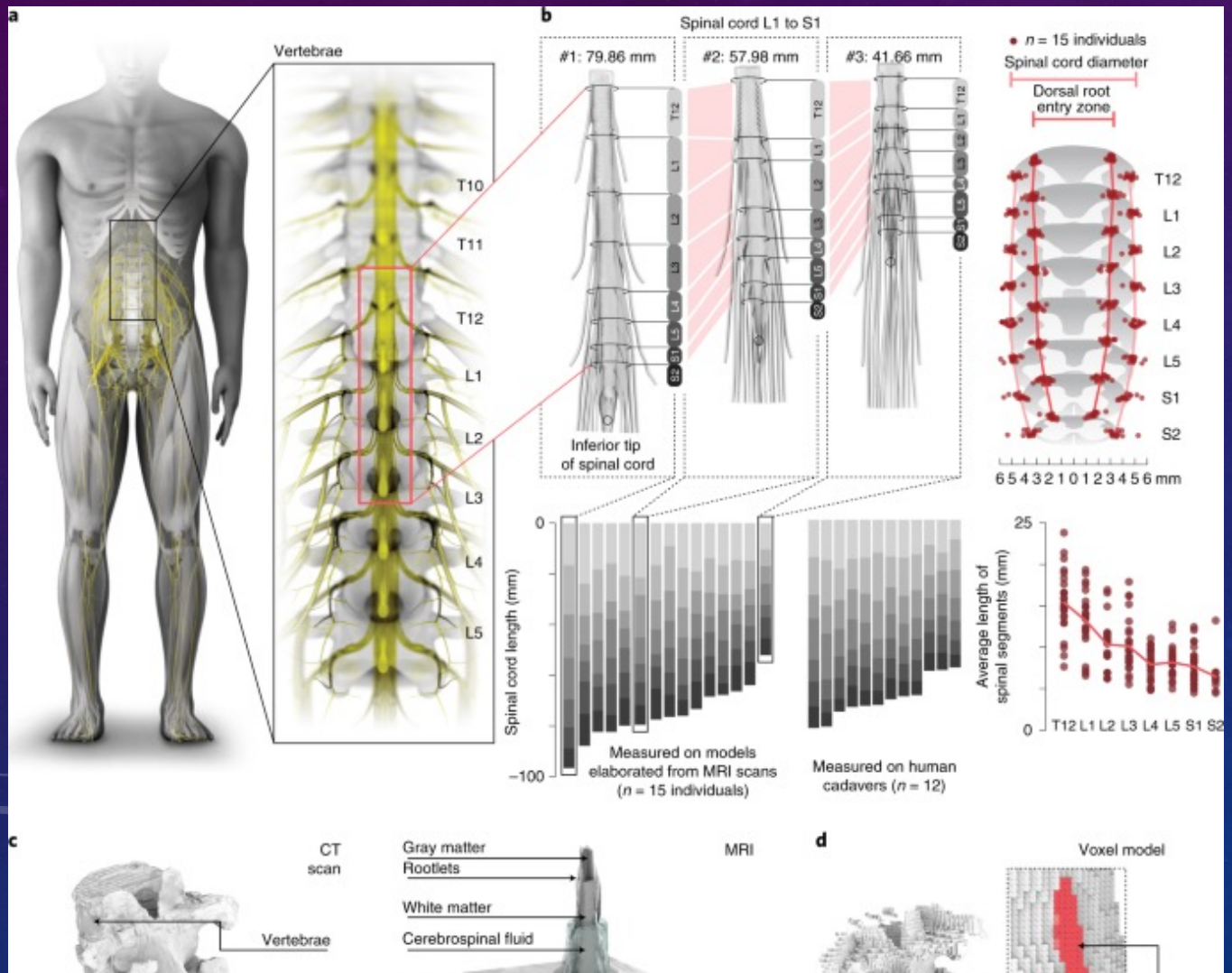

photoinhibit
KATHE* MICHOUD* ET AL.

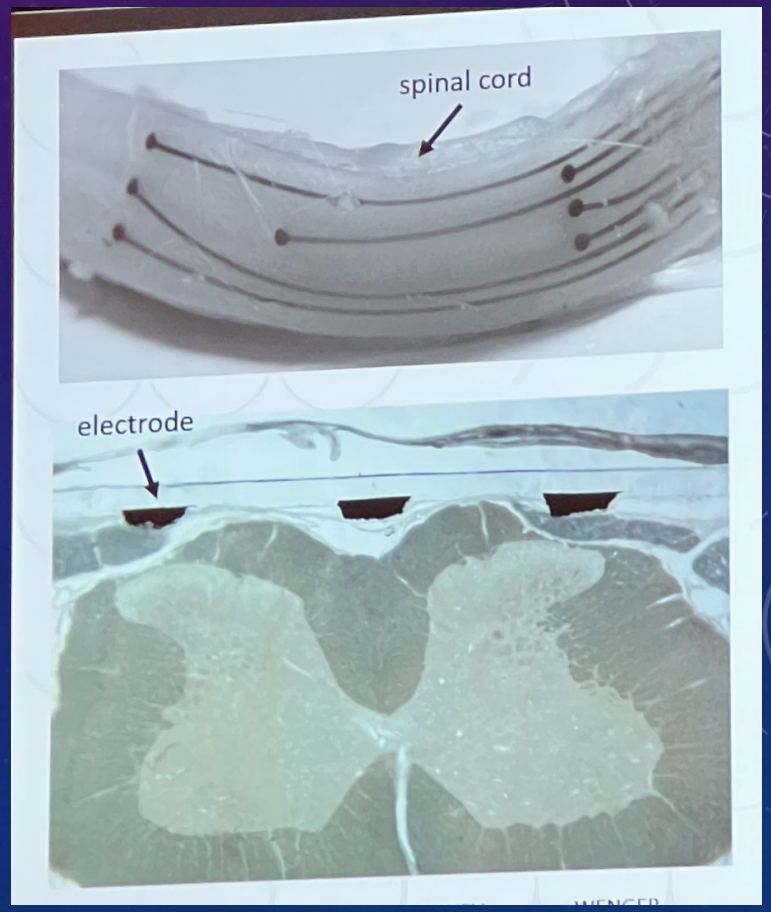

the neurons that restore walking
KATHE
HUTSON
large-diameter
afferent
(PV^ON)
SC^vsx2
Synapses from
large-diameter afferents
per neuron
30
0
***
no therapy
after therapy

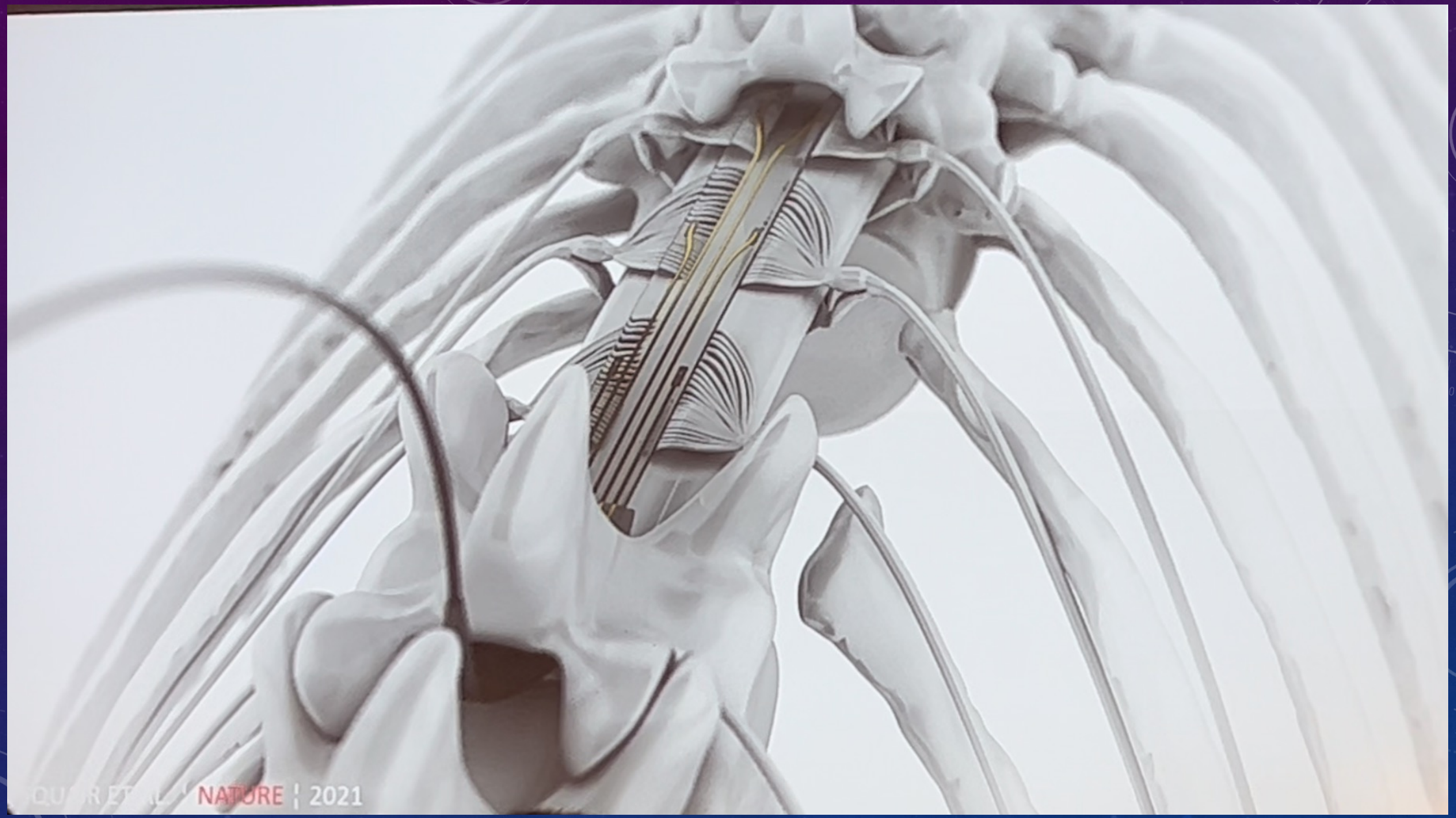
# FLUORESCENČNÍ INHIBICE SC $^{VSX2}$ INTERNEURONŮ BĚHEM EES



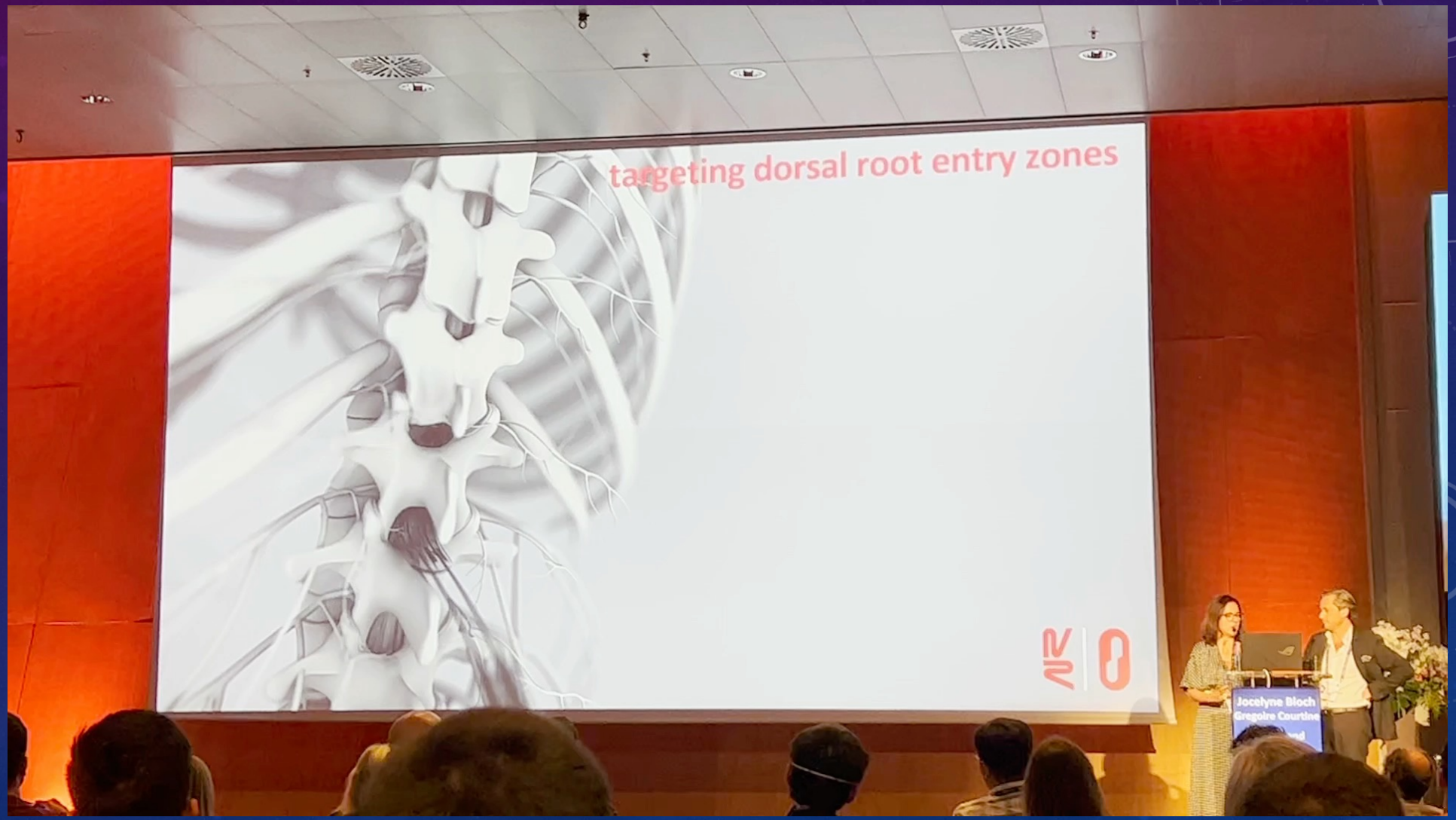
# SPECIÁLNÍ ÚČEL VYŽADUJE SPECIÁLNÍ TECHNOLOGII



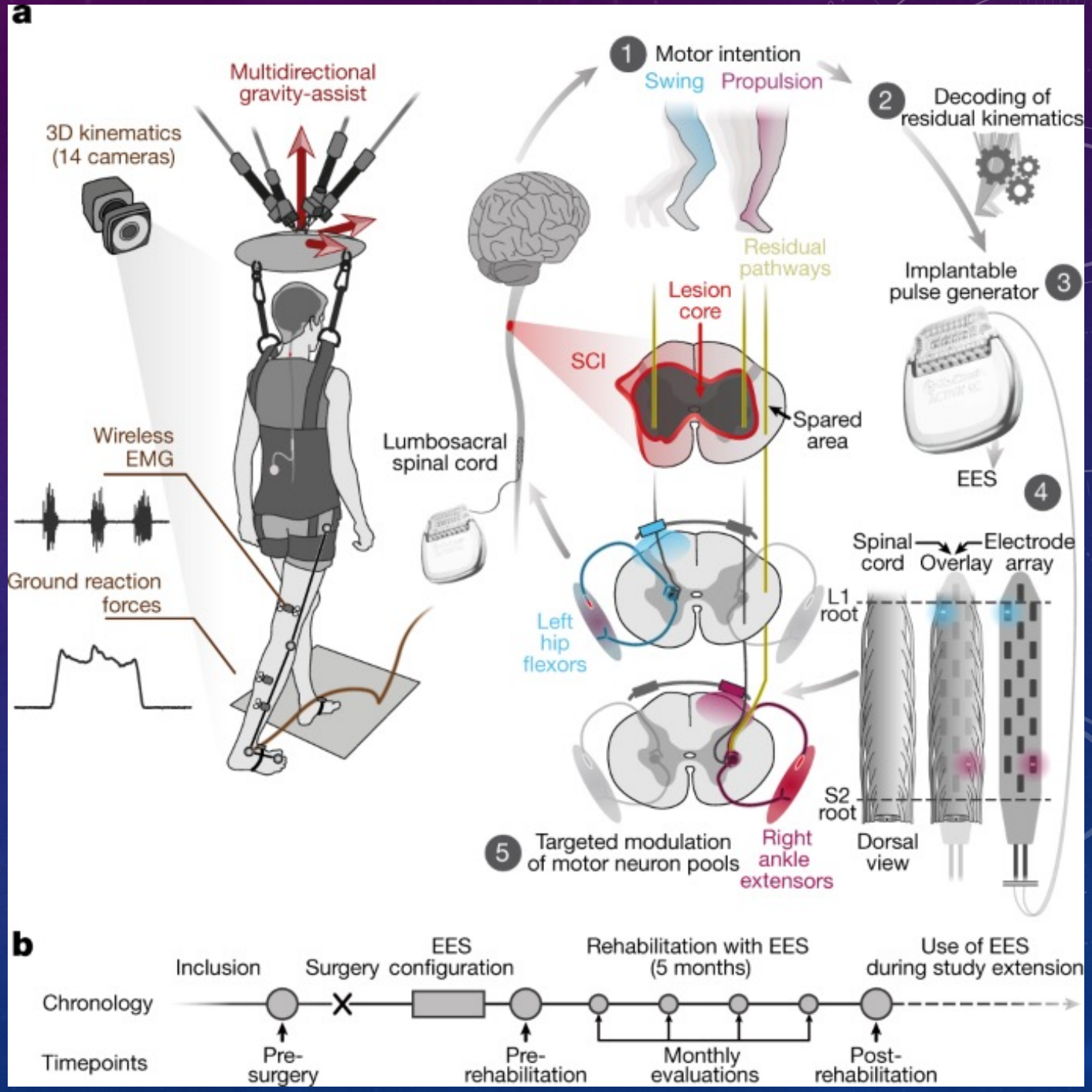




NATURE | 2021

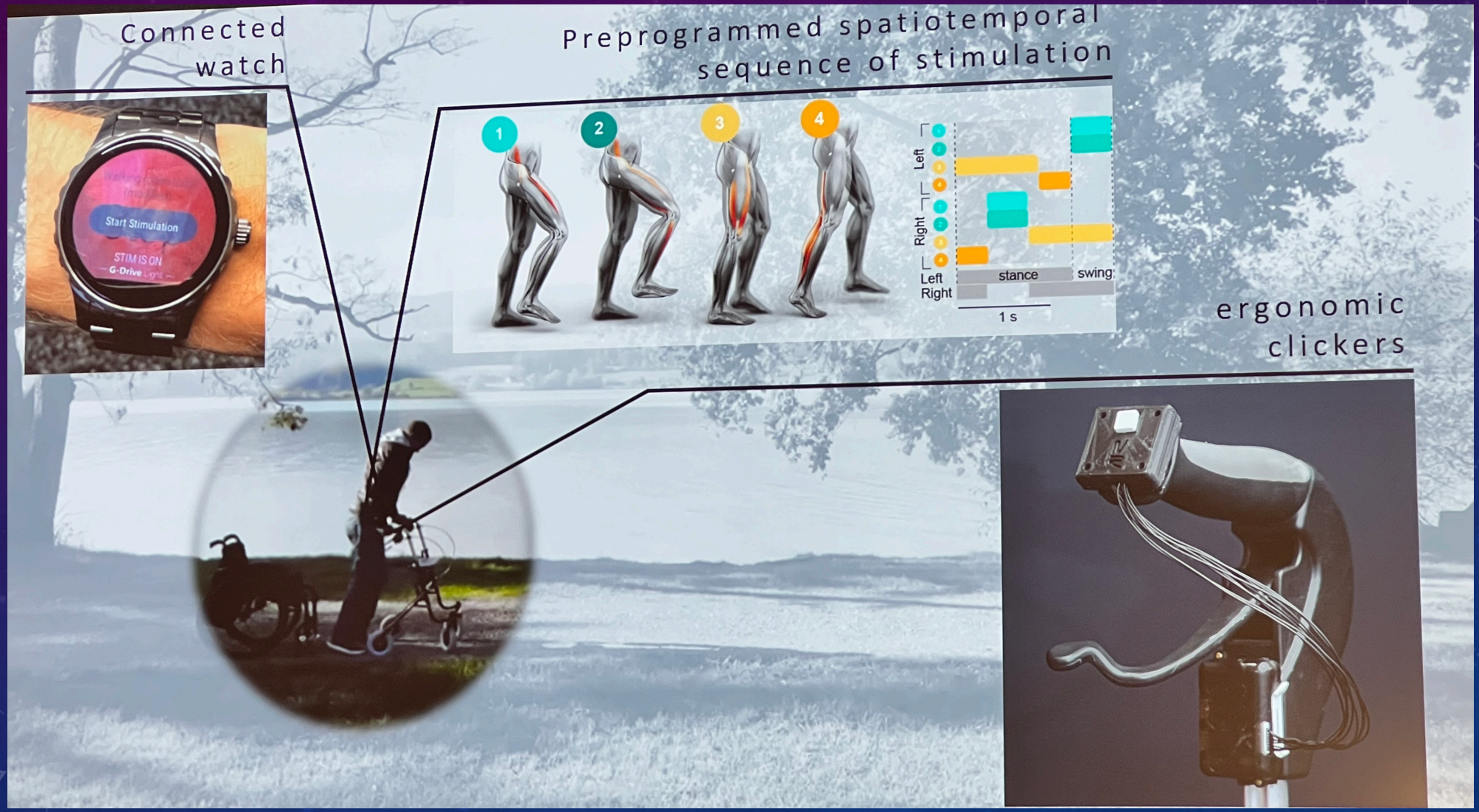
# STIMULATION ON

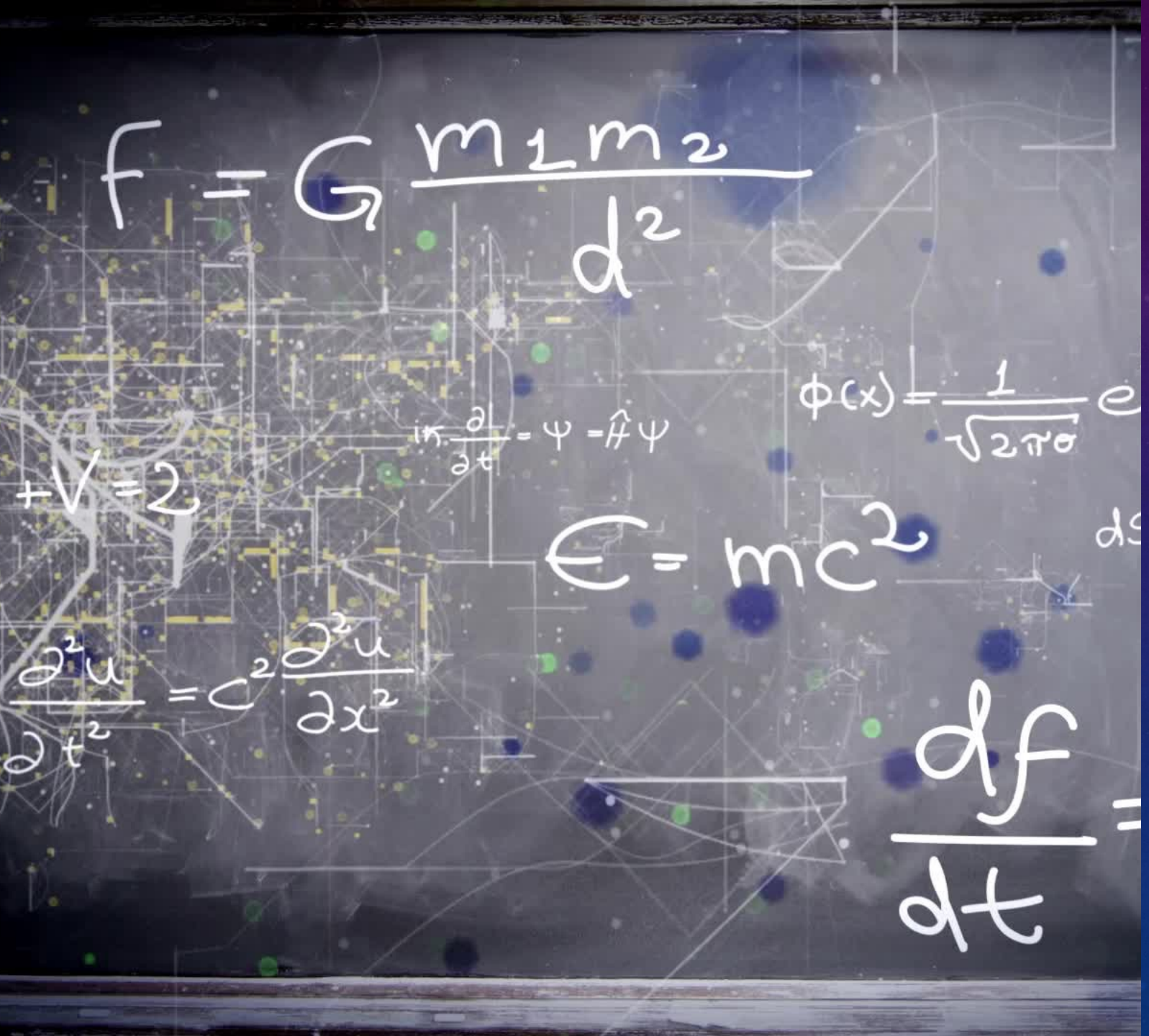


# OPEN LOOP INTERFACE



# PROGRAMMING SPATIOTEMPORAL SPECIFIC EES






# PŘÍTUPY K REŽIMŮM STIMULACE

KONTINUÁLNÍ ES

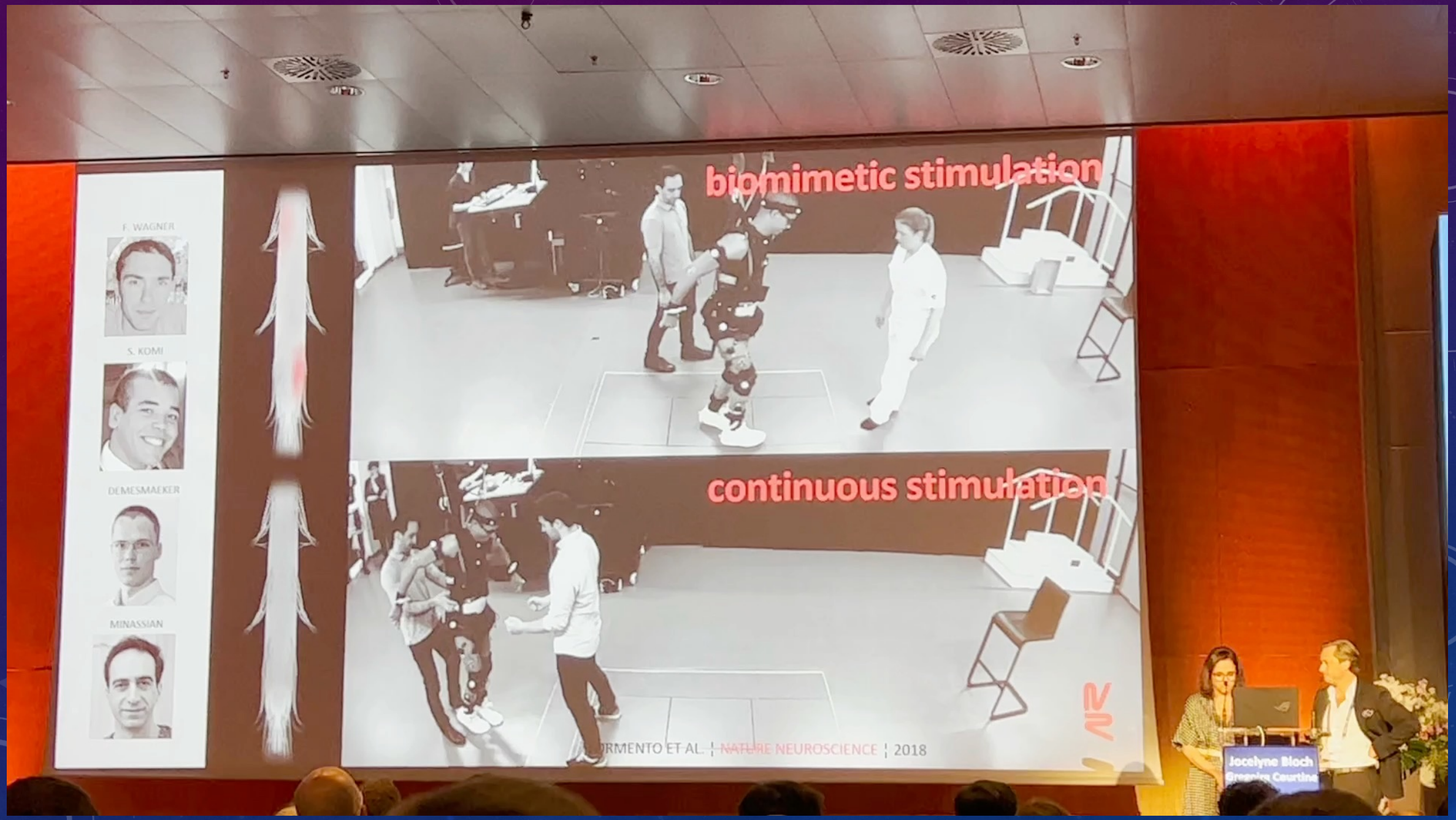
(INTENTIONAL MODULATION )

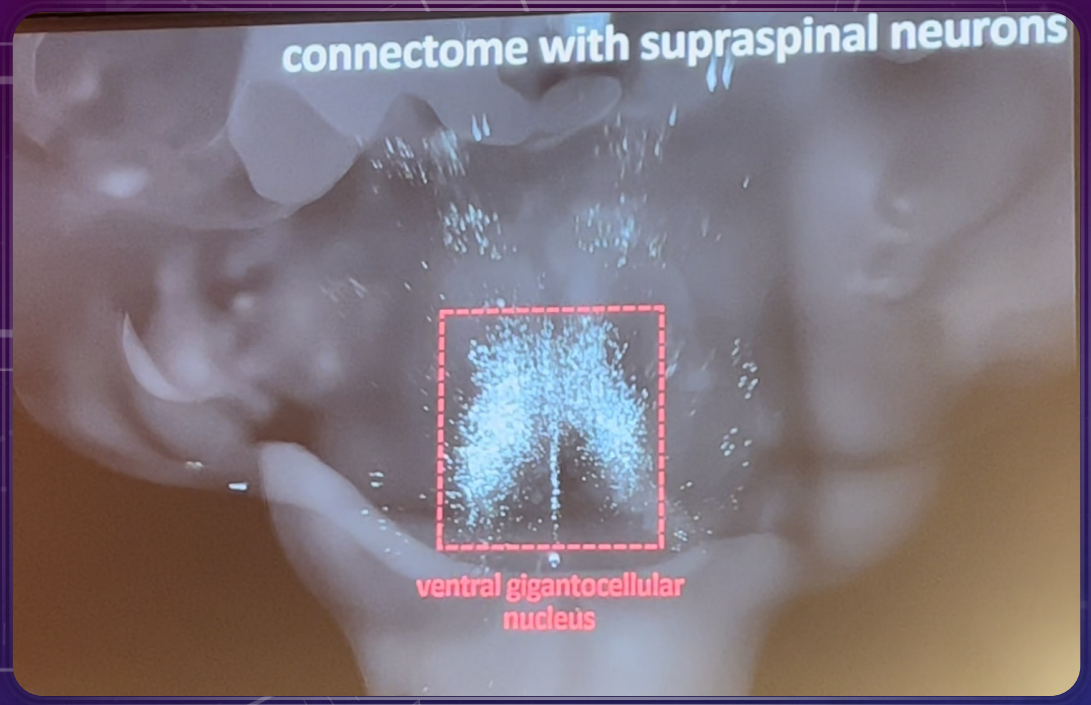
SPATIOTEMPORÁLNÍ ES

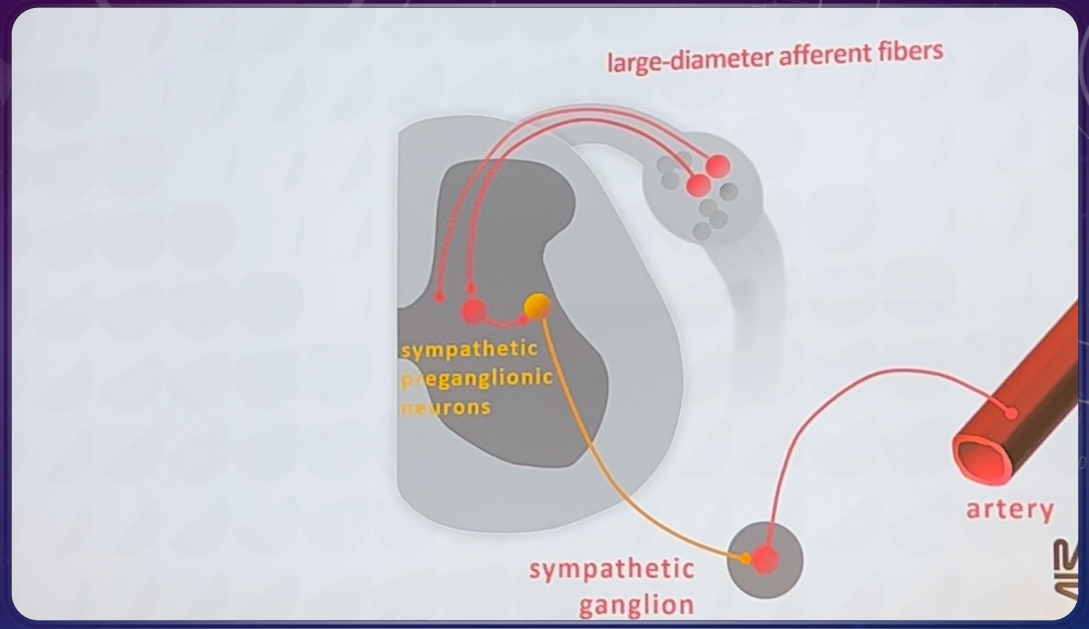
SEKVENČNÍ „BIOMIMETICKÁ

- OPEN LOOP REŽIMY
- CLOSED LOOP REŽIM

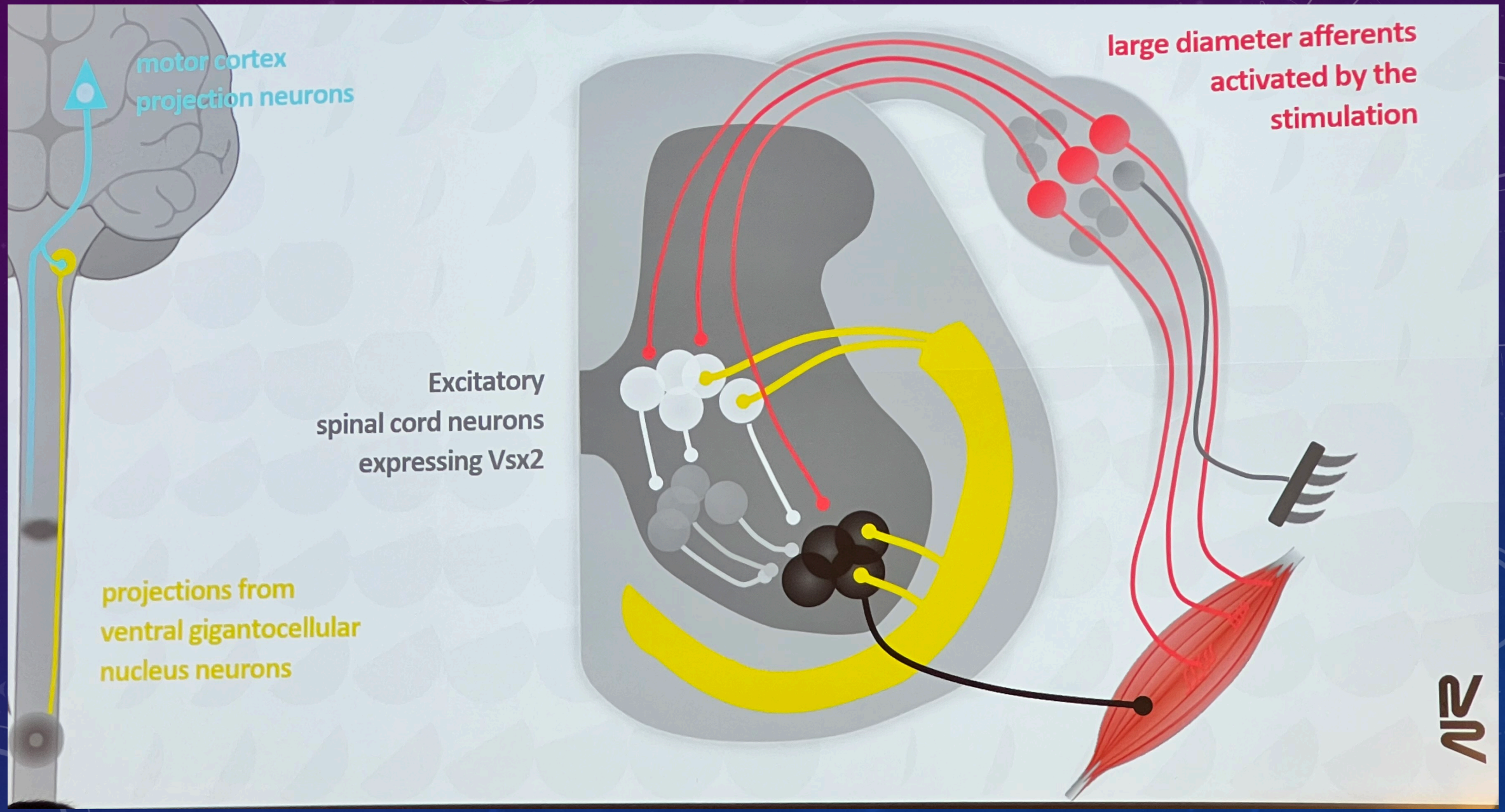
(BRAIN- SPINE INTERFACE)

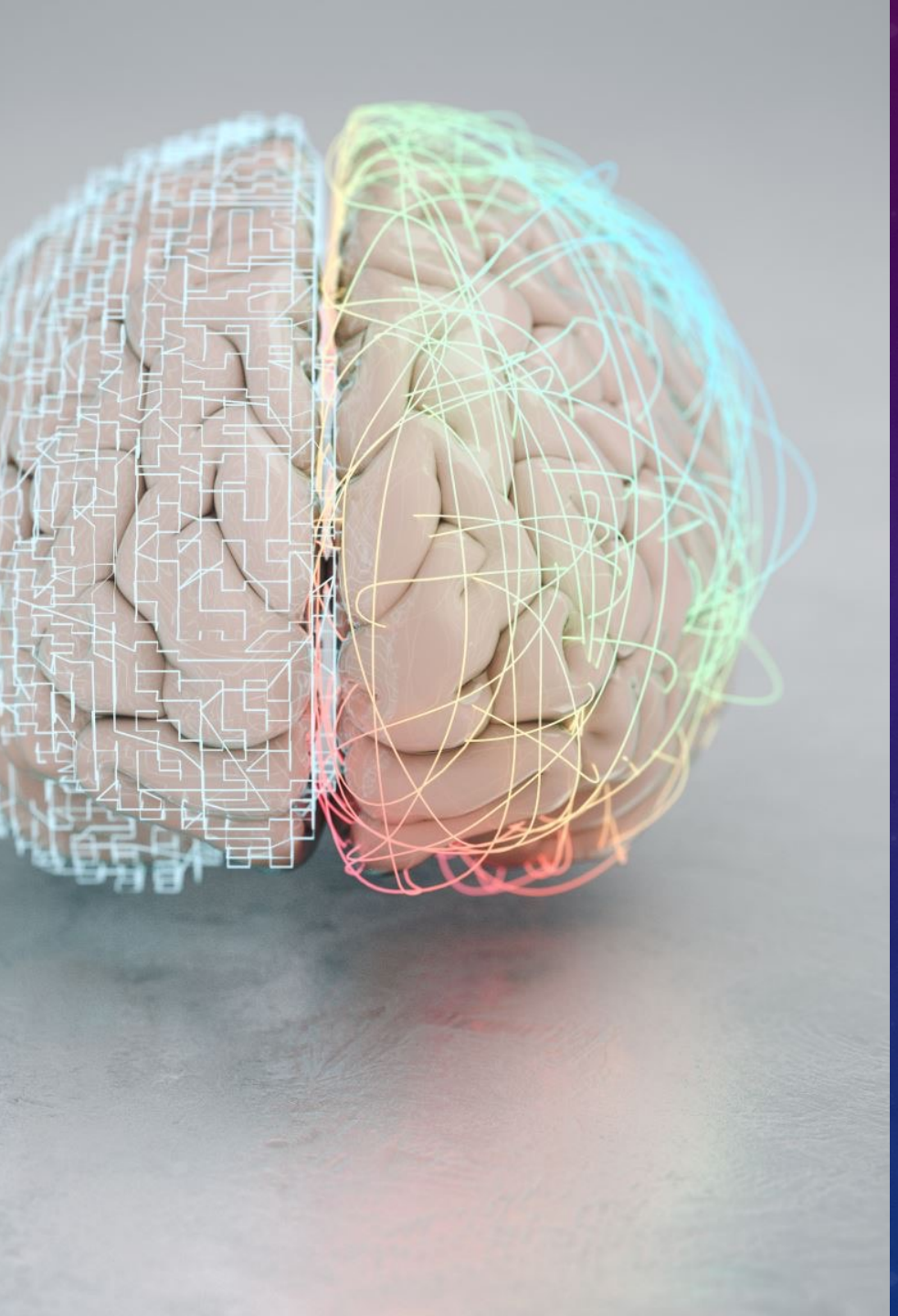

F. WAGNER
S. KOMI
DEMESMAEKER
MINASSIAN
biomimetic stimulation
continuous stimulation
ORMENTO ET AL. ¦ NATURE NEUROSCIENCE ¦ 2018
Jocelyne Bloch




# COLLATERAL FINDINGS: ORTOSTATICKÁ KONTROLA / CONECTOME SUPRASPINÁLNÍ KONTROLY CHŮZE


motor cortex
projection neurons
large diameter afferents
activated by the
stimulation
Excitatory
spinal cord neurons
expressing Vsx2
projections from
ventral gigantocellular
nucleus neurons



# JAK TO FUNGUJE ?

•Stimulace je založena na imitaci přirozených neurofyziologických mechanizmů, tzv**.„ bio- imitace“.**

•Modulace specifických interneuronů ( SC vsx2) regulujících aktivitu konkrétních svalových skupin.

•Modulací těchto oblastí můžeme aktivovat části míchy a simulovat jejich přiroz. aktivaci arteficialní cestou „ jako by to dělal mozek samotný“ ( vč. ascendentních propriocepčních drah! ).

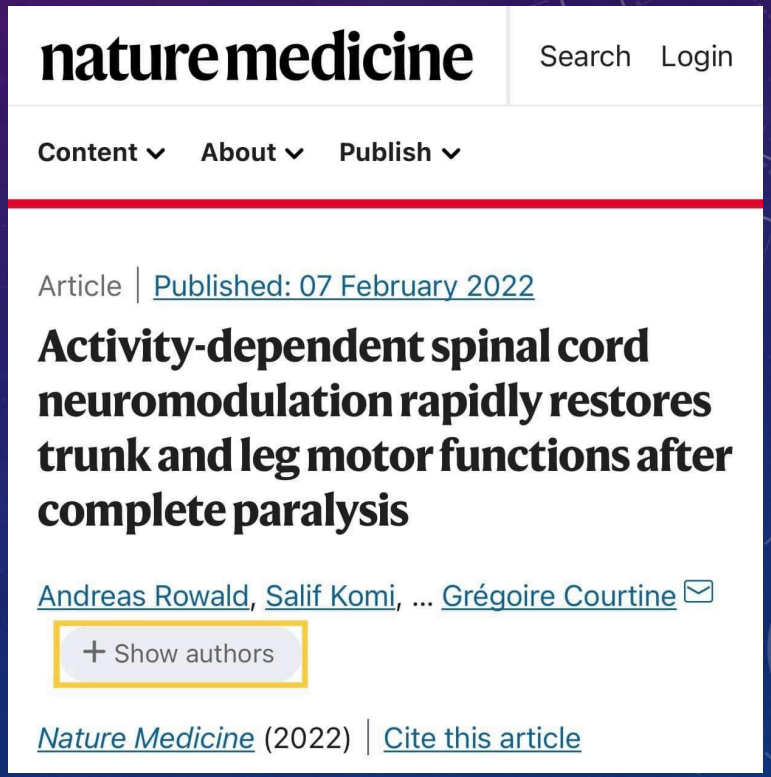
*•Pacienti určí svou pohyb.aktivitu, resp.stim.algoritmus ES (spatiotemporal) svalů trunkálních a dolních končetin, ovladač bezdrátově interaguje s generátorem pacienta, který sekv. aktivuje specifické skupiny neuronů pro jednotlivé svalové skupiny. (Activity specific)*

•Klíčem úspěchu je technologický pokrok posledních dvou dekád dávající možnost dlouhé a široké spinální coverage stimulace s možnostmi **místně i časově specificky aktivovat konkrétní skupiny internn. na exaktních spinálních úrovních. (3D)**

•**Toto nám dává klíčovou možnost kontroly nad neurony odpovědnými za aktivitu konkrétních svalových skupin.**

# JAKÉ JSOU ZÁVĚRY?

AKTIVITĚ ODPOVÍDAJÍCÍ NEUROSTIMULACE MÍŠNÍ OBNOVUJE MOTORICKÉ FUNKCE TRUPU A DOLNÍCH KONČETIN I PO KOMPLETNÍ LÉZI MÍŠNÍ




Rowald, A., Komi, S., Demesmaeker, R. *et al.* Activity-dependent spinal cord neuromodulation rapidly restores trunk and leg motor functions after complete paralysis.*Nat Med* **28,** 260–271 (2022). https://doi.org/10.1038/s41591-021-01663-5

- Epidural electrical stimulation (EES) **targeting the dorsal roots of lumbosacral segments** restores walking in people with spinal cord injury (SCI).
- However, EES is delivered with **multielectrode paddle leads** that were originally designed to target the dorsal column of the spinal cord. (Pain management, SCS)
- Here, we hypothesized that an **arrangement of electrodes targeting the ensemble of dorsal roots involved in leg and trunk movements** would result in superior efficacy, restoring more diverse motor activities after the most severe SCI.

  - Computational Framework (EMG mapping) informed the **optimal arrangement of electrodes** on a new paddle lead and guided its neurosurgical positioning.
  - **Developed software supporting the rapid configuration of activity-specific stimulation programs that reproduced the natural activation of motor neurons underlying each activity.**

Activity-specific stimulation programs enabled these individuals to stand, walk, cycle, swim and control trunk movements.

Neurorehabilitation mediated sufficient improvement to restore these activities in community settings, opening a realistic path to support everyday mobility with EES in people with SCI.


NEUROSTIMULAČNÍ
PINÁLNÍCH (NEJEN ?)
OTORICKÝCH FUNKCÍ

?

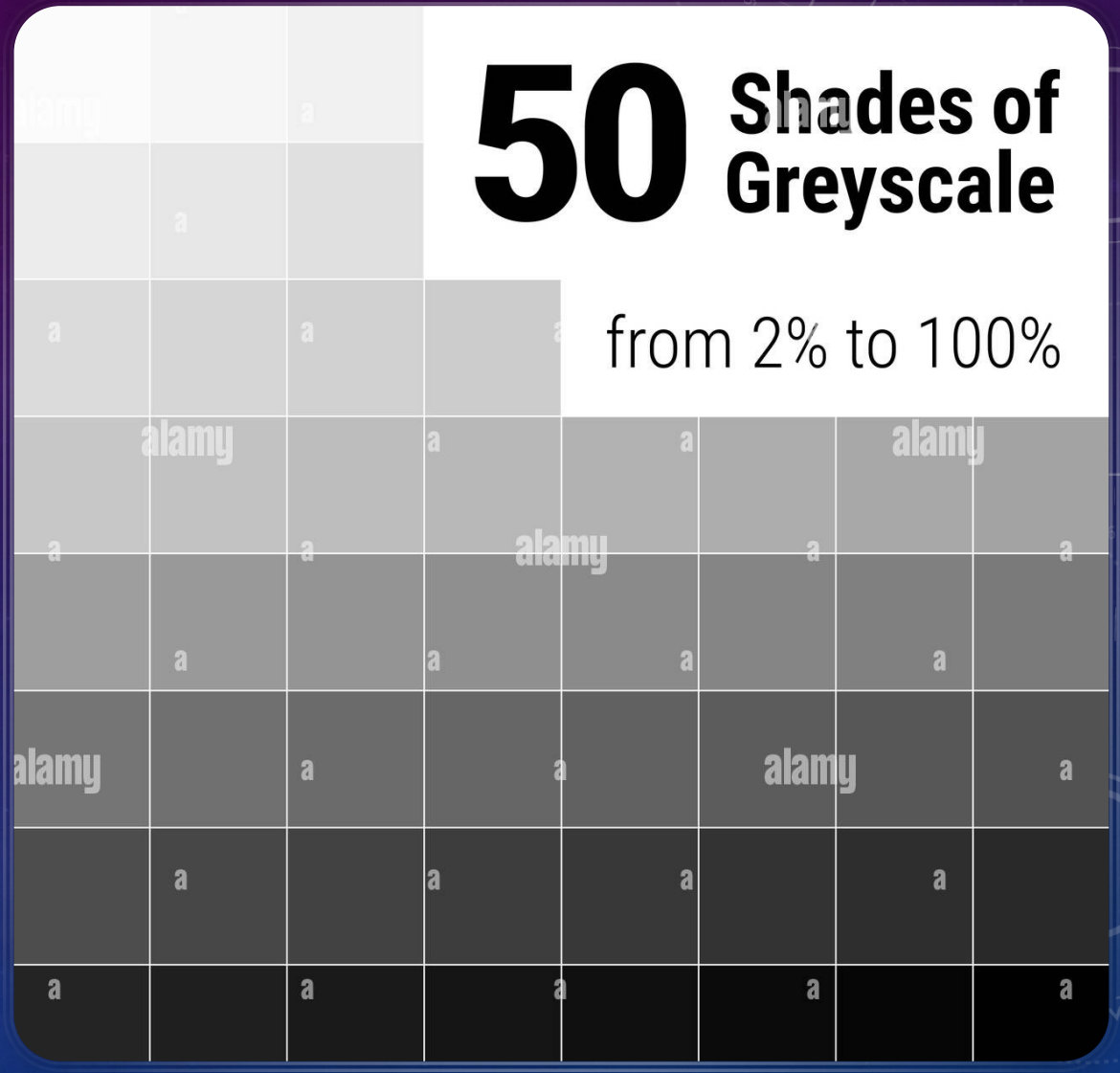
IK

JM“

# 8000 +

- V Česku přibývá asi 250 pacientů s poraněním míchy ročně
- Více než polovina úrazů se přitom stane mladým lidem ve věku do 30 let
- V Česku aktuálně fungují čtyři specializovaná pracoviště (takzvané spinální jednotky)

- **Kolaterální konsekvence socioekonomické,**
  **CAVE: mikro i makroekonomické,**
  **celospolečenské**



INTERNATIONAL STANDARDS FOR NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY (ISNCSCI)

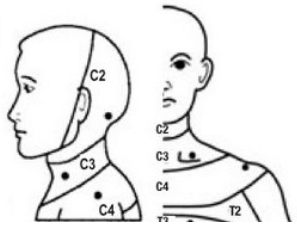
Patient Name _____ Date/Time of Exam _____

Examiner Name _____ Signature _____

RIGHT

MOTOR KEY MUSCLES

SENSORY KEY SENSORY POINTS Light Touch (LTR) Pin Prick (PPR)




| | | | |
|---|---|---|---|
| | | C2 | |
| | | C3 | |
| | | C4 | |
| Elbow flexors | C5 | | |
| Wrist extensors | C6 | | |
| Elbow extensors | C7 | | |
| Finger flexors | C8 | | |
| Finger abductors (little finger) | T1 | | |
| | | T2 | |
| | | T3 | |
| | | T4 | |
| | | T5 | |
| | | T6 | |
| | | T7 | |
| | | T8 | |
| | | T9 | |
| | | T10 | |
| | | T11 | |
| | | T12 | |
| | | L1 | |
| Hip flexors | L2 | | |
| Knee extensors | L3 | | |
| Ankle dorsiflexors | L4 | | |
| Long toe extensors | L5 | | |
| Ankle plantar flexors | S1 | | |
| | | S2 | |
| | | S3 | |
| | | S4-5 | |

UER (Extremity Right)

LER (Extremity Right)

ments (Non-key Muscle? Reason for NT? Pain?):

luntary Anal Contraction (Yes/No)

RIGHT TOTALS

(MAXIMUM) (50) (56)

R SUBSCORES

+ UEL = UEMS TOTAL LER +

25) (25) (50) MAX (25) (25) (50) MAX (56) (56) (112) MAX (56) (56)

UROLOGICAL LEVELS

1-5 for classification as on reverse

R L

1. SENSORY
2. MOTOR

3. NEUROLOGICAL LEVEL OF INJURY (NLI)

4. COMPLETE OR INCOMPLETE? Incomplete = Any sensory or motor function in S4-5

5. ASIA IMPAIRMENT SCALE (AIS)

(In complete injuries only) ZONE OF PARTIAL PRESERVATION Most caudal level with any innervation

SENSORY
MOTOR

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ISNCSCI Algorithm

Help | Resources | Clear this form | Report this form | Excel | Download as Image | Download as PDF | Calculate

Use the * symbol to indicate impairment not due to SCI.

0 * 1 * 2 * 3 *
4 * 5 NT *

Disable down value propagation

RIGHT

MOTOR KEY MUSCLES

SENSORY KEY SENSORY POINTS Light Touch Pin Prick

LEFT

SENSORY KEY SENSORY POINTS Light Touch (LT) Pin Prick (PP)

MOTOR KEY MUSCLES

| | | |
|---|---|---|
| | | C2 |
| | | C3 |
| | | C4 |
| | | C5 Elbow flexors |
| | | C6 Wrist extensors |
| | | C7 Elbow extensors |
| | | C8 Finger flexors |
| | | T1 Finger abductors (little finger) |
| | | T2 |
| | | T3 |
| | | T4 |
| | | T5 |
| | | T6 |
| | | T7 |
| | | T8 |
| | | T9 |

UEL (Upper Extremity Left)

ISNCSCI Algorithm

ALGORITHM SOURCE CODE TEAM NEWS HELP CONTACT US

English 中文

A reliable computational algorithm to score the impairment scale calculations of the ASIA International Standards For Neurological Classification of Spinal Cord Injury (ISNCSCI)

***Version 2.0 (2019 updates):***

***Not to be used for clinical purposes unless verified by a clinician.***

Try it now

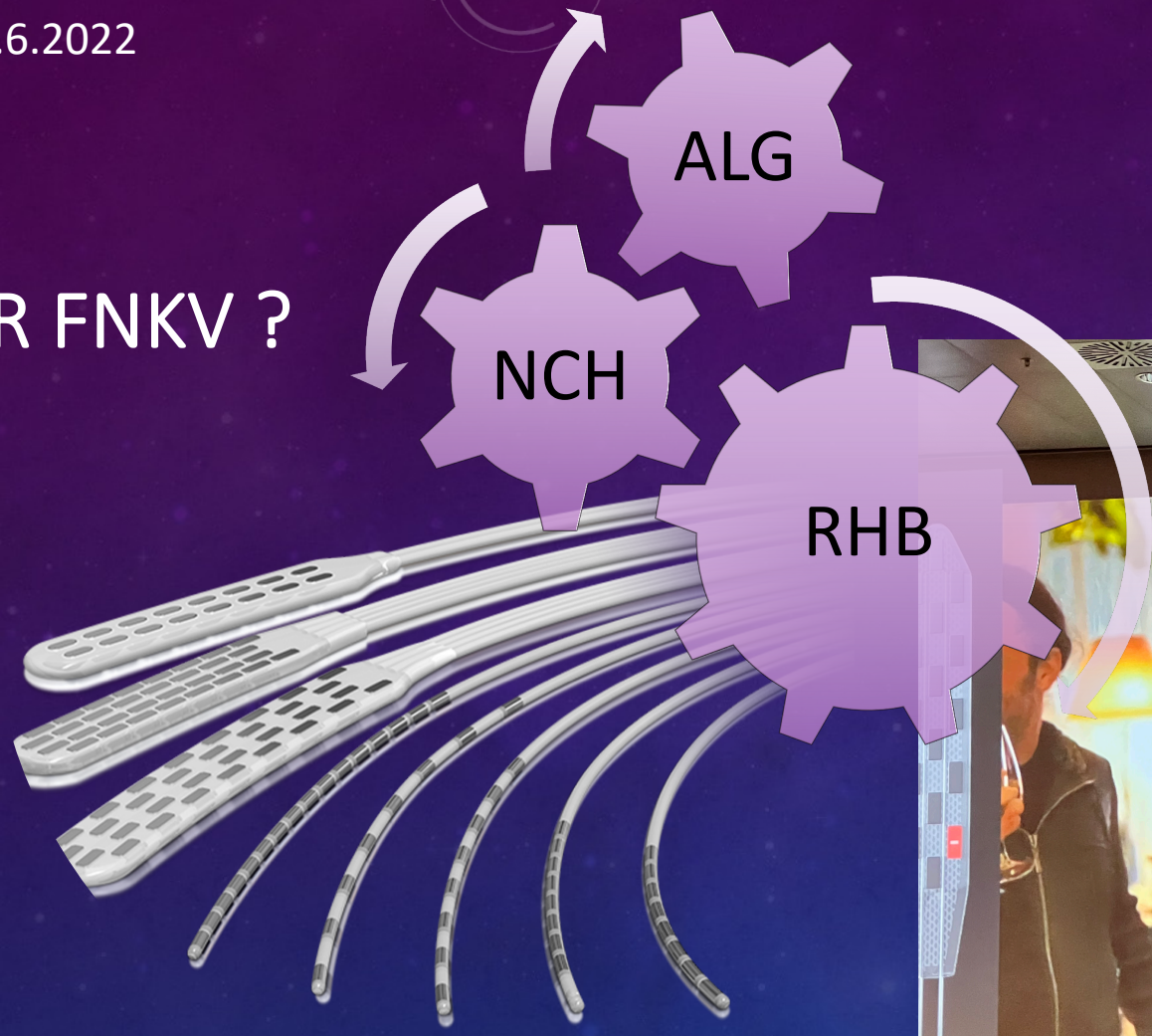
What is ISNCSCI?

The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) is an examination used to score the motor and sensory impairment and severity of a spinal cord injury. The American Spinal Injury Association (ASIA) International Standards Committee is responsible for reviewing and revising the *ISNCSCI* to reflect current evidence.

Retrospekt.: 19.6.2022

# CLB KAR FNKV ?

ALG
NCH
RHB
NEU
PSCH




A care Medical

Boston Scientific

# HYPOTÉZY

- Míra spasticity a míra neuropatie (spektrum SCI)
  - Odpovídající efekty  SCS vs motorická NS
  - Stretch analgetická sval.„mikrostimulace“
- Kritické množství sval.vláken k aktivaci pohybu
  - „Svalový preconditioning“
- Percepce facilitující neuroplasticitu + trigger pohybu
- VR jako adjuvantní metoda neuroplasticity
- Cyklické režimy stimulace
- Režimy stimulace dle aktivity
- Baclofen/ Morfin ith KI nebo vítaná adjuvance
- Věk/ Motivace/ Insitucionalizace/ Kapacity ZZ (Neurorehab)