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An implantable brain-spine interface restoring lower limb movements in a patient with motor complete spinal cord injury

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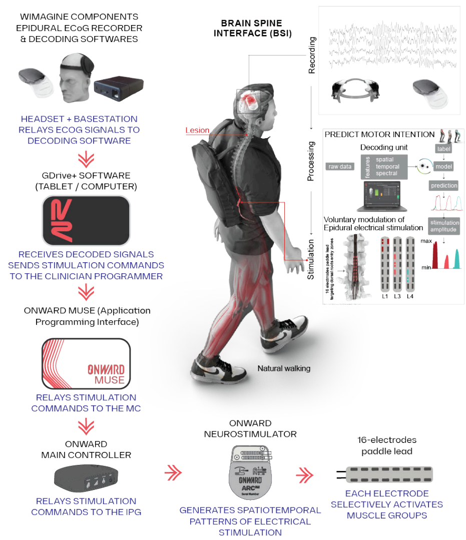
Introduction: A spinal cord injury (SCI) interrupts the communication between the brain and the spinal cord, resulting in sensory, autonomic and motor deficits below the level of the lesion. Applying electrical epidural stimulation (EES) over the lumbosacral region of the spinal cord can reactivate the dormant, yet functional, motor neurons that control lower limb muscles and produce walking. In order to restore voluntary motor control, EES should be controlled by the motor intentions of the patients.

Material, Methods and Results: Here we designed a clinical trial (Think2Go, NCT0624395) to evaluate the effectiveness of an implantable digital bridge (BSI) between the motor intentions recorded at the level of the motor cortex and EES to restore voluntary motor control after complete paralysis. The system is composed of one WIMAGINE® device (64 ECoG electrodes) implanted over the leg sensorimotor cortex to decode motor intentions, connected to the purpose-built ARC^{IM} Lumbar System (Onward medical) delivering EES. The system was implanted in one participant with severe chronic SCI (AIS-A, 39 y.o. female, 6 years post-injury). Raw brain signals were wirelessly streamed and decoded in real-time through classification algorithms, which generated online predictions of motor intentions. We are able to decode motor attempts of different lower limb joints with high accuracy. These intentions were translated into electrical stimulation commands that were wirelessly delivered to the neurostimulator targeting the dorsal roots of the spinal cord.



Conclusion: Within the first 3 days of use after implantation, we were able to calibrate a 3-states decoding model and connect it to primitive movements elicited through EES stimulation, producing brain-controlled stepping with assistance. Subsequently, we could decode up to 6 different movement intentions and link them to specific stimulation programs with high accuracy. The participant used the system during 4 months of rehabilitation including walking, single joint movements and standing exercises. The comparison of motor control performance between BSI^{ON} and BSI^{OFF} conditions, in different clinical tests and with various levels of assistance, demonstrates the effectiveness of the designed system as an implantable brain-spine interface for restoration of voluntary lower limb movements after complete motor paralysis.

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