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Spinal cord injuries

Oral communications

CO24-001-e

Anatomy and physiology of the phrenic nerve and diaphragm in the perspective of diaphragm pacing in quadriplegic patients

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In ventilator-dependent quadriplegics retaining intact C4 phrenic motoneurones, implanted phrenic stimulation (iPS) allows weaning from mechanical ventilation. iPS can also supplement nocturnal ventilation in lower quadriplegics still having a spontaneous ventilatory activity. The anatomy of the phrenic nerve is a major determinant of current and future iPS techniques (intrathoracic, intradiaphragmatic through coeliosocopy, or transvenous). The existence of an accessory phrenic nerve (C5) and the topographic relationship between the phrenic and large vessels (subclavian vein, superior vena cava) are two anatomical particularities that could lead to novel indications (C4 quadriplegia but C5 phrenic component) and techniques (transvenous stimulation). The sensitive function of the phrenic nerve implies that iPS techniques, which require high stimulation intensities, cannot be used in patients with lower or dissociated lesions, because they are painful. Isolated diaphragmatic contractions induce upper rib cage paradox and promote upper airway collapse: this plays a role when discussing tracheotomy closure, and provides a rational to combined hypoglossus-phrenic stimulation. Finally, the diaphragmatic myofibrillar composition determines the strategy and rhythm of post-implantation reconditioning that induces slow fibers homogenization. In conclusion, the anatomy and physiology of the phrenic nerve and the diaphragm are major drivers of the indications, management and future developments of iPS.

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Electrophysiological diaphragmatic exploration in high-level tetraplegia and therapeutic implication

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Approximately 20% of patients with high level of cervical spinal cord injury will need a mechanical ventilation because of interruption between the ventilatory command centers and the phrenic nerves. If there is no phrenic nerve motoneurone involution, phrenic nerve stimulation should permit to leave the ventilator for few hours. At the opposite, when it is destroyed by the lesion, this technique is not indicated. Phrenic nerve pacing needs to have before a diaphragmatic exploration, performed in the physiology exploration department or at bed. This exploration is based on the phrenic nerve stimulations, either magnetic or electric or transcranial magnetic stimulation. During stimulations, motor evoked potentials are recorded as transdiaphragmatic pressure or intratracheal pressure. The results could help to determine if corticodiaphragmatic pathways are normal or if there is an interruption of the ventilatory command and if the phrenic nerve could be stimulated. Those results permit to optimise ventilatory adaptations and phrenic nerve pacing indication.

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Diaphragm pacing: Surgical techniques

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Candidates for diaphragm pacing are those with ventilator insufficiency due to malfunction of the respiratory control center in the brain stem or interruption of the upper motor neurons of the phrenic nerve above the C3 level. Diaphragm pacing through implanted electrodes system has been performed through transthoracic and cervical approaches. More recently, a new device that focuses on the phrenic nerve motor point stimulation on the abdominal portion of the diaphragm has been developed. The Diaphragm Pacing Stimulation (DPS) is performed under four port laparoscopy. It includes four phases: exposure, mapping, implantation, and routing, and takes about 1.5 hours. The initial phase includes mapping each hemi-diaphragm by systematically stimulating it under direct vision to identify the optimal point where stimulation provides maximal contraction of the diaphragm. Electrodes are implanted through a special instrument, two on each side. Once all four electrodes are implanted, they are brought