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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Electrophysiological diaphragmatic exploration in high-level tetraplegia and therapeutic implication
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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 coelioscopy, 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 myotubular 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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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 phrenic nerve (C5) and the topographic relationship between the phrenic and large vessels (subclavian vein, superior vena cava) has been developed. The Diaphragm Pacing Stimulation (DPS) is performed through a new device that focuses on the phrenic nerve motor point stimulation on the abdominal portion of the phrenic nerve (C5) and the topographic relationship between the phrenic and large vessels (subclavian vein, superior vena cava) 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
out through the epigastric port. Each wire is tunnelled separately, and an addi-
tional indifferent electrode is placed subcutaneously. No drains are left in the
abdomen. The port incisions are then closed and the patient’s wires are placed in
a block to allow for connection to the stimulator. Extubation is routinely planned
in the operating room and the patient goes back to his hospitalization room after a
2-hour monitoring in ICU. He’s usually discharged home the day after surgery.
Laparoscopic DPS is a safe surgical procedure to stimulate diaphragm in selected
patients with ventilator insufficiency.

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Phrenic nerve stimulation in SCI

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Keywords: Spinal cord injuries; Respiratory insufficiency; Ventilators;
Mechanical; Electric stimulation; Respiratory tract infection

Introduction. – Since 30 years, phrenic nerve stimulation in SCI is a physiological
form of ventilation for SCI patients with respiratory insufficiency.

Study design. – Prospective clinical study of two treatments.

Objectives. – To compare mechanical ventilation (MV) with phrenic nerve stim-
ulation (PNS) for treatment of respiratory device-dependent (RDD) spinal
cord-injured (SCI) patients.

Methods. – Prospective data collection of treatment-related data over 25 years.

Results. – Eighty SCI-RDD patients were treated during the study period. Forty
of the patients with functioning phrenic nerves and diaphragm muscles were
treated with PNS; 40 patients with destroyed phrenic nerves were mechanically
ventilated. Respiratory treatment with PNS significantly reduces frequency of
RI. Quality of speech is significantly better with PNS. Nine patients with PNS,
but only 2 with MV, were employed or learned after rehabilitation. Primary
investment in the respiratory device is higher with PNS, but it can be paid off
in our setting within one year because of the reduced amount of single use
equipment, easier nursing, and fewer respiratory infections.

Conclusions. – PNS instead of MV for treatment of SCI-RDD reduces respira-
tory infections, running costs of respiratory treatment, and obviously improves
patients’ quality of life.

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Diaphragmatic reinnervation in tetraplegic chronically ventilated patients

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Cervical spinal cord injury still leads to acute and chronic respiratory insuffi-
ciency. Although electrical stimulation of the phrenic nerve or the diaphragm
remains the current treatment for ventilator-dependent patients, this method
could not be used in case of phrenic nerve motoneuron destruction. Our hypoth-
esis was to test the feasibility of unilateral diaphragm reinnervation by the right
inferior laryngeal nerve.

Five ventilated tetraplegic patients were included. They were hospitalized in
Rouen University Hospital to have right phrenic nerve neurotisation by right
inferior laryngeal nerve. The right vocal cord paralysis was treated by vocal
cord medialisation and reinnervation. One patient was excluded because electrical
stimulation of the right phrenic nerve showed a diaphragmatic response. One
patient died after 6 months of follow-up. The three remaining patients had no
voice or swallowing difficulty after surgery. Regarding the ventilation, diaphrag-
matic exploration showed that at two years of follow-up, it appeared an electrical
diaphragmatic response in all the three patients.

In conclusion, this study demonstrated that diaphragmatic neurotisation by the
right inferior laryngeal nerve is feasible, with no complication. This technique
should now be evaluated in more patients to affirm that it could restore a phrenic
nerve conduction.

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Autonomic dysreflexia (AD): What is it?

Pathophysiology and criteria of diagnosis

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Autonomic dysreflexia is a clinical emergency and commonly occurs in SCI
patients at level T6 and above. This clinical entity is caused by massive sympa-
thetic discharge triggered by noxious stimuli below the level of the SCI (bladder
or colo-rectal distension, high intravesical pressures). Objectively, an increase
in systolic BP greater than 20–30 mmHg is considered a dysreflexic episode.

Individuals with cervical and high thoracic SCI have resting arterial BPs that are
approximately 15 to 20 mmHg lower than able-bodied individuals. The patho-
physiology of AD relies on a phenomenon of vasoconstriction below the level of
the lesion (paroxysmal hypertension) and a vasodilation above leading to throb-
bing headache, profuse sweating, flushing of the face and piloerection above
the level of injury. Other clinical symptoms as anxiety, blurred vision, nasal
congestion can be associated. This massive sympathetic discharge is enhanced
by an increased responsiveness of vasculature to adrenergic agonists, and at
the chronic phase by phenomenon of neuroplasticity (morphologic changes of
sympathetic preganglionic neurons, sprouting in the dorsal roots).

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Different clinical presentations of autonomic dysreflexia and its acute and chronic
consequences on the cardiovascular system

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