Electromyographic permutation entropy quantifies diaphragmatic denervation and reinnervation.

Abstract:
Spontaneous reinnervation after diaphragmatic paralysis due to trauma, surgery, tumors and spinal cord injuries is frequently observed. A possible explanation could be collateral reinnervation, since the diaphragm is commonly double-innervated by the (accessory) phrenic nerve. Permutation entropy (PeEn), a complexity measure for time series, may reflect a functional state of neuromuscular transmission by quantifying the complexity of interactions across neural and muscular networks. In an established rat model, electromyographic signals of the diaphragm after phrenicotomy were analyzed using PeEn quantifying denervation and reinnervation. Thirty-three anesthetized rats were unilaterally phrenicotomized. After 1, 3, 9, 27 and 81 days, diaphragmatic electromyographic PeEn was analyzed in vivo from sternal, mid-costal and crural areas of both hemidiaphragms. After euthanasia of the animals, both hemidiaphragms were dissected for fiber type evaluation. The electromyographic incidence of an accessory phrenic nerve was 76%. At day 1 after phrenicotomy, PeEn (normalized values) was significantly diminished in the sternal (median: 0.69; interquartile range: 0.66-0.75) and mid-costal area (0.68; 0.66-0.72) compared to the non-denervated side (0.84; 0.78-0.90)
at threshold p<0.05. In the crural area, innervated by the accessory phrenic nerve, PeEn remained unchanged (0.79; 0.72-0.86). During reinnervation over 81 days, PeEn normalized in the mid-costal area (0.84; 0.77-0.86), whereas it remained reduced in the sternal area (0.77; 0.70-0.81). Fiber type grouping, a histological sign for reinnervation, was found in the mid-costal area in 20% after 27 days and in 80% after 81 days. Collateral reinnervation can restore diaphragm activity after phrenicotomy. Electromyographic PeEn represents a new, distinctive assessment characterizing intramuscular function following denervation and reinnervation.