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Assessment of vascular reactivity after intracerebral hemorrhage and traumatic brain injury: experimental and clinical validation of the pressure reactivity index

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Autoregulation and in consequence cerebrovascular pressure-reactivity can be lost due to a variety of insults representing a significant risk factor for secondary brain damage. We aimed to explore the use and utility of three indices of cerebral autoregulation in a swine model of intracerebral haemorrhage: PRx, ORx and FRx.

It was possible to continuously assess cerebrovascular autoregulation in 17 swine with an intracerebral haemorrhage on average 12 hours per animal. There were periods where any of the autoregulation indices PRx, ORx and FRx were frankly positive (>0.2), and in three animals the mean PRx of the total monitoring period was >0.2 similar to the case of patients with bad outcome.

FRx correlated highly with ORx (0.96, P = <0.001), but values of both FRx and ORx > 0.2 did not correlate with any microdialysis metabolite. Values of PRx > 0.2 correlated highly (0.65, P < 0.001) with the lactate/pyruvate ratio, values of PRx > 0.3 correlated with glutamate (0.67, P < 0.05), the lactate/pyruvate ratio (0.60, P < 0.01), and PbrO2 (−0.65, P < 0.01). Those findings suggest that, among other parameters of cerebrovascular reactivity, positive PRx coefficients have the highest significance and could be associated with microdialysis alterations during hypoxic events.

In a second step, PRx was calculated in 18 ICH patients and correlated with outcome. PRx is calculated using waves of ICP and MAP in the range of some seconds to two minutes (PRx is usually calculated as a moving correlation, with 5- to 10-s averages, using a time window of 2.5–5 min). We compared PRx with a novel calculation method [low-frequency PRx (L-PRx)], where rapid fluctuations of MAP and ICP are cancelled (waves with frequencies greater than 0.01 Hz). By averaging MAP and ICP data over 1-min periods, we filtered out the frequencies higher than

0.016 Hz that are normally used for PRx calculations. Then, we investigated the range of 0.016–0.0008 Hz. We studied the association between L-PRx and outcome, and compared the optimal cerebral perfusion pressure (CPPopt) produced with L-PRx and the standard CPPopt calculation method.

The averaged PRx values for each patient correlated with L-PRx (P=0.846, p<0.001). CPPopt based on standard PRx was identified in eight patients. In contrast, a CPPopt value based on L-PRx could be found in 12 patients. CPPopt values by both methods correlated strongly with each other (P=0.980, p<0.001). L-PRx had a similar correlation with the NIHSS (0.667, p=0.002) as did PRx (0.563, p=0.015). Because of the small sample size, we cannot conclude that L-PRx is better to prognosticate outcome in ICH patients, but at least that there is probably autoregulatory information in the studied range of 0.016–0.0008 Hz that can be used to predict outcome at least as good as PRx does. CPPopt could be identified in more patients using L-PRx.

In a third step, to test our novel algorithm we used retrospectively 29 head-injured patients requiring continue advanced multimodal monitoring including minutely acquired data of both hemodynamic and ICP and hourly microdialysis. L-PRx correlated significantly with outcome (r = -0.556, p = 0.002) and ICP (r = 0.46, p =0.011). Outcome correlated with glutamate (r = -0.442, p = 0.016) and lactate (r = -0.426, p = 0.021) similarly to other head injury patient series. When averaging daily and hourly data of L-PRx a positive correlation with glutamate was shown (r= 0.549, p = 0.012 and r= 0.169, p = 0.0001 respectively. Very slow changes of ICP and MAP may contain important autoregulation information also in head injured patients. Our novel method "L-PRx" may be an alternative algorithm for clinical prognosis that only requires 1-minute acquired data. MAP and ICP waves with periods of less than 1-2 minutes may not be essential for autoregulation assessment and prognostic information, as it is believed. This new algorithm can be easily applied due to the steadily increasing number of neurocritical care units with minute-by-minute sampling. The range of 0.016–0.0008 Hz should be studied with more detail to determine its role in vascular autoregulation and possible development of secondary brain injury.