The effect of fluid infusion strategies and hypertonic saline solution on cortical cerebral microcirculation and markers of glycocalyx damage

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Background

A fluid loading and hyperosmolar solutions might modify the cortical brain microcirculation as well as the endothelial glycocalyx (EG). This study compared short-term effects of liberal fluid loading with a restrictive fluid intake followed by osmotherapy with hypertonic saline (HTS) on cerebral cortical microcirculation and EG integrity in a rabbit craniotomy model.

Methods

In the first phase, experimental rabbits were allocated randomly to receive either less than 2 ml/kg/h (group R, n = 14) or 30 ml/kg/h (group L, n = 14) of balanced isotonic fluids for one hour. In the second phase, animals were randomized to receive 5 ml/kg intravenous infusion of either 3.2% saline (group HTS, n = 14) or 0.9% saline (group NS, n = 13) in 20-min infusion. Microcirculation in the cerebral cortex using sidestream dark-field imaging, morphological index of glycocalyx damage - perfused boundary region (PBR) in sublingual and cortical brain microcirculation and syndecan-1 serum levels were evaluated.

Results

No difference was observed in initial hemodynamic and laboratory parameters between the groups (Table 1).

After fluids, lower cortical brain perfused total vessel density (P = 0.0447), small vessel density (P = 0.0178), and perfused vessel density (P = 0.0286), were observed in group L.

After osmotherapy, no difference was observed between the HTS and NS groups. Syndecan-1serum levels were not different between HTS and NS (P = 0.5174) or from baseline values. Hematocrit corrected syndecan-1 serum levels were also not different between the HTS and NS groups (1.43 ± 0.60 ng/ml vs 1.36 ± 0.49 ng/ml, P = 0.7372) or from baseline values.

A nonsignificant trend toward higher cerebral PBR values (P = 0.0692) and higher hematocrit corrected syndecan-1 serum levels (1.64 ± 0.63 ng/ml vs 1.16 ± 0.31 ng/ml, P = 0.0324) were observed in L group compared to R group.

Conclusions

Liberal fluid loading was associated with altered parameters of cortical cerebral microcirculation and EG integrity.

3.2% saline did not affect cortical cerebral microcirculation or markers of EG integrity.

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Table 1. **Hemodynamic and laboratory data, use of fluids and catecholamines; before and after fluids.** MAP, mean arterial pressure; PaCO₂, arterial tension of carbon dioxide, PaO₂, arterial tension of oxygen; PBR, perfused boundary region. R group, restrictive group; L group, liberal group.

	Baseline			After infusion		
	R group (n = 14)	L group (n = 13)	P	R group (n = 14)	L group (n = 13)	P
MAP (mmHg)	66 ± 7	68 ± 11	0.5172	72 ± 13	77 ± 23	0.5290
pH	7.35 (7.33;7.38)	7.36 (7.35;7.44)	0.5935	7.46* (7.44;7.51)	7.46* (7.41;7.52)	0.8083
PaCO ₂ (mmHg)	50.9 (41.3;55.2)	6.74 (5.51;7.36)	0.6623	38.7* (35.1;40.7)	38.6* (34.1;40.5)	0.4969
PaO ₂ (mmHg)	156 (129;175)	149 (92;175)	0.5281	188* (174;197)	179* (175;195)	0.7524
HCO ₃ ⁻ (mmol/l)	27.4 ± 2.6	27.0 ± 3.6	0.7283	28.0 ± 2.2	26.3 ± 2.9	0.0964
Hemoglobin (g/l)	94.3 ± 6.2	92.2 ± 9.3	0.5036	98.4 ± 6.9*	89.2 ± 7.8	0.0032
Sodium (mmol/l)	140 (139;141)	141 (139;142)	0.4485	138 (137;139)*	140 (139;140)	0.0080
Chlorides (mmol/l)	102 ± 4	101 ± 5	0.5731	100 ± 3	101 ± 3	0.4525
Norepinephrine (ml/h)	0.600 (0.100;1.000)	0.200 (0.000;1.775)	0.8452	0.350 (0.100;0.500)	0.300 (0.100;0.550)	0.9806
Sublingual PBR (µm)	1.93 ± 0.26	2.00 ± 0.22	0.5808	2.05 ± 0.21	2.02 ± 0.26	0.8082

* P < 0.05 vs baseline.

Table 2. **Brain microcirculation parameters after fluids.**

	R group (n = 14)	L group (n = 13)	P
SVD (mm.mm ⁻²)	7.36 ± 1.48	6.27 ± 1.33	0.0816
TVD (mm.mm ⁻²)	9.85 ± 1.37	8.79 ± 0.96	0.0447
PSVD (mm.mm ⁻²)	7.20 ± 1.38	5.83 ± 1.16	0.0178
PVD (mm.mm ⁻²)	9.70 ± 1.37	8.40 ± 1.27	0.0286
PPV (%)	100.0 (98.6;100.0)	98.4 (86.2;100.0)	0.2037
MFI small vessels	3.0 (3.0;3.0)	3.0 (2.9;3.0)	0.3851
DeBacker score (mm ⁻¹)	6.44 ± 1.2	5.77 ± 0.48	0.1172
DeBacker grid crossings	24.4 ± 5.0	21.4 ± 2.2	0.0796

Table 3. **Hemodynamic and laboratory data, use of fluids, catecholamines, sublingual PBR after normal saline or HTS.**

	Before osmotherapy			After osmotherapy		
	HTS group (n = 14)	NS group (n = 13)	P	HTS group (n = 14)	NS group (n = 13)	P
MAP (mmHg)	71.9 ± 13.2	76.5 ± 12.3	0.0530	71.8 ± 16.7	75.2 ± 10.5	0.5395
pH	7.45 (7.41;7.51)	7.48 (7.44;7.52)	0.2541	7.41* (7.38;7.47)	7.42* (7.40;7.49)	0.7203
PaCO ₂ (mmHg)	39.4 (35.1;44.9)	37.8 (33.7;39.4)	0.0900	40.5 (37.5;45.1)	42.1* (39.1;44.9)	0.4667
PaO ₂ (kPa)	186 (178;197)	178 (172;194)	0.1742	183 (170;188)	176 (160;186)	0.5441
HCO ₃ ⁻ (mmol/l)	27.3 ± 2.7	27.0 ± 2.6	0.7298	26.1 ± 2.5*	26.9 ± 4.3	0.5834
Hemoglobin (g/l)	92.0 (91.0;101.0)	94.0 (88.8;99.0)	0.7339	91.5* (87.0;94.0)	93.0 (88.5;103.3)	0.2069
Sodium (mmol/l)	139 ± 2	139 ± 2	0.8388	143 ± 2*	138 ± 1	< 0.0001
Chlorides (mmol/l)	100 (99;102)	100 (99;102)	0.7890	107 (105;108)*	99 (97;102) *	< 0.0001
Serum osmolality (mmol/kg)				302 (300;304)	292 (290;295)	0.0004
Norepinephrine (ml/h)	0.45 (0.30;0.70)	0.20 (0.10;0.43)	0.0840	0.50 (0.40;0.80)	0.50 (0.20;0.73)	0.5597
Sublingual PBR (µm)	2.04 ± 0.23	2.04 ± 0.26	0.9893	1.88 ± 0.54	1.92 ± 0.24	0.8177

* P < 0.05 vs baseline

Table 4. **Brain microcirculation parameters and cortical brain PBR before and after osmotherapy.**

	Before osmotherapy			After osmotherapy		
	HTS group (n = 14)	NS group (n = 13)	P	HTS group (n = 14)	NS group (n = 13)	P
SVD (mm.mm ⁻²)	6.76 ± 1.51	6.93 ± 1.53	0.7933	6.69 ± 1.42	7.16 ± 1.74	0.4606
TVD (mm.mm ⁻²)	9.15 ± 1.18	9.56 ± 1.42	0.4553	9.13 ± 0.78	9.44 ± 1.77	0.5789
PSVD (mm.mm ⁻²)	6.26 ± 1.36	6.85 ± 1.51	0.3308	6.56 ± 1.39	6.90 ± 1.59	0.5713
PVD (mm.mm ⁻²)	8.70 ± 1.44	9.49 ± 1.41	0.2008	8.93 ± 0.64	9.19 ± 1.79	0.6370
PPV (%)	98.5 (85.72;100.0)	100.0 (98.7;100.0)	0.1102	98.9 (97.5;100.0)	100.0 (97.4;100.0)	0.8052
MFI	3.0 (2.8;3.0)	3.0 (3.0;3.0)	0.0106	3.0 (3.0;3.0)	3.00 (2.9;3.00)	0.0326
DeBacker score (mm ⁻¹)	5.95 ± 0.65	6.30 ± 1.32	0.4482	5.91 ± 0.68	6.17 ± 1.24	0.5221
PBR brain (µm)				1.88 ± 0.31	1.90 ± 0.35	0.9284