Selective brain cooling (SBC)

Systemic hypothermia, the method used in almost all major clinical trials, is limited by the time to target temperature, the depth of hypothermia, and complications, problems that may be solved by selective brain cooling.

see Prophylactic Hypothermia for severe traumatic brain injury.

Selective brain cooling (SBC) can occur in hyperthermic humans despite the fact that humans have no carotid rete, a vascular structure that facilitates countercurrent heat exchange located at the base of the skull in some mammals.

Emissary and angular veins, upper respiratory tract, tympanic cavity and cerebrospinal fluid are major components of SBC system in humans. The efficiency of SBC is increased by evaporation of sweat on the head and by ventilation through the nose, but it is surprising to find out that mammals do not display SBC during exercise hyperthermia. What is the explanation then for the SBC at high body temperatures?

The hypothesis of Irmak et al., is that selective brain cooling protects the brain from thermal damage in a long-standing manner by allowing adaptive mechanisms to change the craniofacial morphology appropriate for different environmental conditions. Since the brain can only be as big that can cool, it is not surprising to find a lower (below 1300 cm(3)) cranial volume in Australian Aborigines with respect to the one (over 1450 cm(3)) in Eskimos. In addition to lower brain volume, other craniofacial features such as thick everted lips, broader nasal cavity and bigger paranasal sinuses that provide more evaporating surfaces seem to be anatomical variations developed in time for an effective SBC in hot climates. It was reported previously that these biological adaptations result from the tissues of neural crest origin. Among the crest derivatives, leptomeninges, skeletal and connective tissues of the face and much of the skull seem to be structures upon which environment operates to produce more convenient craniofacial morphology for an effective SBC.

Selective brain cooling seems to be a mechanism leading to adaptive craniofacial diversity observed in different geographical regions. Thus, SBC is necessary for long-term biological adaptation, not for protecting the brain from acute thermal damage [1)].

In experimental models of neuronal damage, therapeutic hypothermia proved to be a powerful neuroprotective method.

In clinical studies of traumatic brain injury (TBI), this very distinct effect was not reproducible. Several metaanalysis draw different conclusions about whether therapeutic hypothermia can improve outcome after TBI. Adverse side effects of systemic hypothermia, such as severe pneumonia, have been held responsible by some authors to counteract the neuroprotective effect. Selective brain cooling (SBC) attempts to take advantage of the protective effects of therapeutic hypothermia without the adverse side effects of systemic hypothermia.

Case series

2006

Qiu et al., present the results of a study in which noninvasive selective brain cooling (SBC) was achieved using a head cap and neckband. Ninety patients with severe TBI were divided into a normothermia control group (n=45) and a SBC group (n=45), whose brain temperature was maintained at 33-35 degrees C for 3 days using a combination of head and neck cooling. At 24, 48 and 72h after injury, the mean intracranial pressure (ICP) values of the patients who underwent SBC were lower than those of the normothermia controls (19.14+/-2.33, 19.72+/-1.73 and 17.29+/-2.07 mmHg, versus 23.41+/-2.51, 20.97+/-1.86, and 20.13+/-1.87 mmHg, respectively, P<0.01). There was a significant difference in the neurological recovery of the two groups at the 6-month follow-up after TBI. Good neurological outcome (Glasgow Outcome Scale score of 4 to 5) rates 6 months after injury were 68.9% for the SBC group, and 46.7% for the control group (P<0.05). There were no complications resulting in severe sequelae. In conclusion, the noninvasive SBC described here is a safe method of administering therapeutic hypothermia, which can reduce ICP and improve prognosis without severe complications in patients with severe TBI [2)].

Sixty-six in-patients were randomized into three groups. In one group, brain temperature was maintained at 33 - 35 degrees C by cooling the head and neck (SBC); in a second group, mild systemic hypothermia (MSH; rectal temperature 33 - 35 degrees C) was produced with a cooling blanket; and a control group was not exposed to hypothermia. Natural rewarming began after 3 days. Mean intracranial pressure 24, 48 or 72 h after injury was significantly lower in the SBC group than in the control group. Mean serum superoxide dismutase levels on Days 3 and 7 after injury in the SBC and MSH groups were significantly higher than in the control group. The percentage of patients with a good neurological outcome 2 years after injury was 72.7%, 57.1% and 34.8% in the SBC, MSH and control groups, respectively. Complications were managed without severe sequelae. Non-invasive SBC was safe and effective [3)].

Case reports

2016

Three different methods of SBC were applied in a patient who had severe traumatic brain injury TBI with recurrent increases of intracranial hypertension refractory to conventional forms of treatment:

(1) external cooling of the scalp and neck using ice packs prior to hemicraniectomy

(2) external cooling of the craniectomy defect using ice packs after hemicraniectomy

(3) cooling by epidural irrigation with cold Ringer solution after hemicraniectomy.

External scalp cooling before hemicraniectomy, external cooling of the craniectomy defect, and epidural irrigation with cold fluid resulted in temperature differences (brain temperature to body temperature) of - 0.2°, - 0.7°, and - 3.6°C, respectively. ICP declined with decreasing brain temperature.

Previous external cooling attempts for SBC faced the problem that brain temperature could not be lowered without a simultaneous decrease of systemic temperature. After hemicraniectomy, epidural irrigation with cold fluid may be a simple and effective way to lower ICP and apply one of the most powerful methods of cerebroprotection after severe TBI [4].

Animal studies

2015

Adult male Sprague-Dawley rats (mean weight = 300 g; n = 25) were subjected to brain injury using a modified Marmarou method. Immediately after the onset of TBI, rats were randomized into three groups. Selective brain cooling was applied around the head using ice packages. Intracranial Temperature (ICT) and ICP were continuously measured at 0, 30, 60, 120, and 180 minutes and recorded for all groups. Group 1 (n = 5) was normothermia and was assigned as the control group. Group 2 (n = 10) received moderate hypothermia with a target ICT of between 32°C - 33°C and Group 3 (n = 10) was given a deeper hypothermia with a target ICT of below 32°C.

All subjects reached the target ICT by the 30th minute of hypothermia induction. The ICT was significantly different in Group 2 compared to Group 1 only at the 120th minute ($P = 0.017$), while ICP was significantly lower starting from the 30th minute ($P = 0.015$). The ICT was significantly lower in Group 3 compared to Groups 1 and 2 starting from the 30th minute ($P = 0.001$ and $P = 0.003$, respectively). The ICP was significantly lower in Group 3 compared to Group 1 starting from 30th minute ($P = 0.001$); however, a significant difference in ICP between Group 3 and Group 2 was observed only at the 180th minute ($P = 0.047$).

Results of this study indicate that selective brain cooling is an effective method of decreasing ICP in rats; however, the deeper hypothermia caused a greater decrease in ICP three hours after hypothermia induction [5].

2013

Anesthetized male Sprague-Dawley rats were divided into two major treatment groups. Immediately after the onset of fluid percussion TBI, a craniectomy window of 6 × 8 mm was made at the right parietal, and a cold water bag (0°C-1°C or 5°C-6°C) was applied locally for 30 min. Additional groups of rats were used as craniectomy and craniectomy + FPI controls. Physiological parameters, such as brain and colonic temperature, mean arterial pressure, and heart rate, were monitored during FPI. Functional motor outcomes were evaluated using the inclined plane test (maximal grasp angle). Cellular infarction volume was calculated using triphenyltetrazolium chloride staining. Apoptosis and neuronal marker-positive cells in the cortex were measured by immunofluorescence staining. All functional and morphologic parameters were assessed 72 h after injury.

Compared with the craniectomy + FPI control groups, the groups treated with 5°C-6°C local cold water therapy showed significant attenuation of the FPI-induced motor deficits, weight loss, and cerebral infarction but no effect on colonic temperature. The FPI-induced apoptosis and neuronal loss were also significantly reduced by local cooling.

The results suggest that local cooling with 5°C-6°C cold water therapy may ameliorate TBI in rats by reducing infarction volume, neuronal cell loss, and apoptosis, resulting in improved functional

outcome. They propose that the use of local cooling at the craniectomy site after FPI might have clinical benefits in the future [6].

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