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REGIONAL COOLING FOR REDUCING BRAIN TEMPERATURE AND INTRACRANIAL PRESSURE

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Abstract – Objective: To evaluate the effectiveness of regional cooling for reducing brain temperature (BrTe) and intracranial pressure (ICP) in patients where conventional clinical treatment has failed. **Method:** Regional cooling was carried out using ice bags covering the area of the craniectomy (regional method) in 23 patients. The BrTe and ICP were determined using a fiber optic sensor. Thirteen patients (56.52%) were female. The ages ranged from 16 to 83 years (mean of 48.9). The mean APACHE II score was 25 points (11–35). The patients were submitted, on mean, to 61.7 hours (20–96) of regional cooling. **Results:** There was a significant reduction in mean BrTe ($p<0.0001$–from 37.1ºC to 35.2ºC) and mean ICP ($p=0.0001$–from 28 mmHg to 13 mmHg). **Conclusion:** Our results suggest that mild brain hypothermia induced by regional cooling was effective in the control of ICP in patients who had previously undergone decompressive craniectomy.

KEY WORDS: intracranial hypertension, intracranial pressure, cerebral hypothermia, brain edema, brain injuries.

Resfriamento cerebral regional para redução da temperatura e pressão intracraniana

Resumo – Objetivo: Avaliar a eficácia do resfriamento regional na redução da temperatura cerebral (TeCe) e pressão intracraniana (PIC) após falha das medidas clínicas convencionais de tratamento. **Método:** O resfriamento cerebral foi realizado com bolsas com gelo, colocadas sobre a área de craniectomia (método regional) em 23 doentes. A TeCe e PIC foram verificadas com sensor de fibra óptica. Treze (56,52%) eram do sexo feminino. A idade variou de 16 a 83 anos (média 48,96). A pontuação média no índice APACHE II foi 25 pontos (11–35). Os doentes foram submetidos, em média, a 61,7 horas (20–96) de resfriamento regional. **Resultados:** Houve uma redução significativa da TeCe média ($p<0,0001$–de 37,1ºC para 35,2ºC) e da PIC média ($p=0,0001$–de 28 mmHg para 13 mmHg). **Conclusão:** Nossos resultados sugerem que o resfriamento regional foi eficaz no controle da PIC nos doentes submetidos, previamente, a craniectomia descompressiva.

PALAVRAS-CHAVE: hipertensão intracraniana, pressão intracraniana, hipotermia induzida, edema encefálico, traumatismos encefálicos.

Intracranial hypertension (ICH), associated with various neurologic diseases, is responsible for high morbid-mortality[1]. The ideal treatment for ICH is focused on a combined analysis of the hemodynamic and cerebral metabolism. However, there is no single system of treatment that can be used for all patients.

At the beginning of the 1990s, the works of Clifton et al.[2], Marion et al.[3] and Shiozaki et al.[4] demonstrated the safety and possible benefits of mild to moderate hypothermia in the treatment of patients with severe traumatic brain injury (TBI).

Since that time, mild to moderate hypothermia has been one of the measures adopted for the treatment of acute ICH, particularly in patients where other conventional measures have failed[5]. However Clifton et al.[6] did not demonstrate any significant difference in mortality between the group submitted to hypothermia and that submitted to normothermia, after six months of TBI. At

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present, hypothermia for the treatment of various acute cerebral disorders is based on the individual experience[7,8]. Despite the progressive consolidation of hypothermia as a therapy, a number of questions still need to be answered.

We therefore present our results with the use of brain hypothermia induced by regional cooling for the control of intracranial pressure (ICP).

METHOD

The Research Project was approved by the Research Ethics Committee of the Hospital São Joaquim da Real e Benemérita Sociedade Portuguesa de Beneficência de São Paulo (CEPesp 236/04) and the Research Ethics Committee of the Hospital São Paulo–Federal University of São Paulo–Escola Paulista de Medicina (CEP 0421/06).

The study included patients with acute ICH refractory to clinical treatment (Table 1) and decompressive craniectomy; who have been submitted to at least 12 hours of regional cooling (restricted to the cephalic segment), in an intensive care unit (ICU).

The ICP and brain temperature (BrTe) were continually monitored in all the patients, using a fiber optic catheter. The sedation schemes (Table 2) were adjusted to attain and maintain level 6 on the Ramsay Scale.

Cerebral cooling was achieved using ice bags covering the area of the craniectomy (regional method). The total cerebral cooling time was dependant on the improvement demonstrated in the Ct scans and the stabilization of the ICP during the rewarming phase. The patients were submitted, on mean, to 61.7 hours (20–96 hours) of regional cooling.

The following variables were evaluated in the "pre" and "post" hypothermia periods: cardiac frequency (CF), mean arterial pressure (MAP), central venous pressure (CVP), ICP, cerebral perfusion pressure (CPP), $PaCO_2$, $SataO_2$ and BrTe. The start time of the cerebral cooling was used as the reference for the study of "pre" and "post" variables. The $PaCO_2$ was not corrected according to temperature ("α-stat" strategy).

The "pre" variables corresponded with the last records, for each item, determined prior to the start of cooling. The "post" variables consisted of the mean for the values determined, for each item, in the 48 hours following the start of hypothermia. The effectiveness of hypothermia in the control of ICH was evaluated by the variation in "pre" and "post" ICP values.

The evolution of the patients was classified according to the Glasgow Outcome Scale (GOS) at the moment of discharge from the ICU. No subsequent evaluation was carried out in the present study. The APACHE II scores, time of cerebral cooling and length of stay in the ICU were calculated.

Casuistic

Cerebral hypothermia was induced in 23 patients during the period of July 1997 to December 2003. Thirteen patients (56.52%) were female. The ages ranged from 16 to 83 years (mean 48.9). Regarding to the cause of the brain lesion, six patients were victims of severe TBI (26.09%), ten presented complications following subarachnoid hemorrhage (SAH) (43,48%), four had suffered severe acute ischemic stroke (17.39%), two presented exacerbation of tumor edema (,69%) and one presented extensive intracerebral hemorrhage (4.34%). The interval between neurological deterioration and the beginning of hypothermia was, on mean, 21.4 hours (2–106 hours).

Statistical analysis

The quantitative variables were presented descriptively, in tables containing mean, standard deviation, median, minimum and maximum values. The pre and posthypothermia means were compared with the paired student-t test.

Values of $p<0.05$ were considered statistically significant and signed with an asterisk.

RESULTS

Table 3 shows the values of the variables for 23 patients in the pre and post hypothermia period. Table 4

Table 1. Clinical treatments of the intracranial hypertension.

1.	General measures–respiratory, hemodynamic, biochemical and temperature control.
2.	Postural care–Lying position, elevated to 30 degrees, with centered head position.
3.	Sedation and analgesia + Neuromuscular blocker.
4.	Optimized ventilation.
5.	Hyperosmolar substance – Manitol 20% (0.25 g to 0.5 g/kg/dose). Hypertonic saline solutions were not used in the present study.
6.	Increase in arterial pressure to maintain the pressure of cerebral perfusion – Noradrenalin (0.05 to 2.0 μg/kg/min).

Table 2. Medications most used in each pharmacological group.

1.	Hypnotic = Propofol 1% (initially 1–2 mg/Kg and continuous infusion 0.3–4 mg/Kg/h).
2.	Benzodiazepines = Midazolam (initially 0.05-0.1 mg/Kg and continuous infusion 0.5–1.5 μg/Kg/min).
3.	Opioid = Fentanyl (initially 1.0–3.0 μg/Kg and continuous infusion 2.0–6.0 μg/Kg/h).
4.	Neuromuscular blocker = Atracurium (initially 0.3–0.6 mg/Kg and continuous infusion 3–5 μg/Kg/min).

Table 3. Values of the variables studied, for each patient, in the pre and post regional cooling period.

Case	BrTe (ºC)		ICP (mmHg)		CPP (mmHg)		CF (bpm)		MAP (mmHg)		CVP (cm H_2O)		$SataO_2$ (%)		$PaCO_2$ (mmHg)	
Nº	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	35.3	35.2	35	19	75	83	66	77	110	102	15	15	99.4	98.9	25.2	22.1
2	36.8	34.2	64	14	52	80	100	73	116	94	9	10	100	98.5	18.5	22.6
3	38.9	34.4	49	6	71	91	64	51	120	97		11	99.9	99	33.9	24.4
4	37.5	33.6	36	21	24	66	81	76	60	87	9	5	99.5	98.4	36	30.9
5	38.1	35.6	18	13	52	85	89	76	70	98	5	8	96.9	99.1	35.3	37.3
6	38.6	34.7	30	5	70	91	78	68	100	96	7	7	98.7	98.1	36.5	31.4
7	37.5	36.6	21	10	84	70	80	87	105	80	5	8	99	98.2	31.5	34.9
8	36.4	35.4	23	10	57	85	71	63	80	95	7	4	99.8	98.2	33	38.3
9	36.8	34.1	22	10	73	85	110	94	95	95	8	14	97.9	98.7	36.8	28.1
10	36.1	34.4	26	11	49	67	88	94	75	78	11	10	100	99	23.2	28.9
11	37.7	36.8	21	19	54	79	62	55	75	98	12	8	99	98.8	32.6	36
12	36.8	34.7	22	5	68	85	65	57	90	90	1	8	95.7	97.6	25.5	40
13	38.0	33.9	24	14	61	80	97	66	85	94	9	9	99.7	97.4	40.4	36.6
14	36.4	35.5	38	16	62	76	118	98	100	92	13	11	99.2	98.7	47.3	43.9
15	36.4	35.2	21	3	64	78	48	63	85	81		12	94.7	95.9	40.9	45.9
16	38.7	35.7	19	3	69	97	83	71	88	99	7	13	99	98.8	29	39.3
17	36.7	35.3	20	16	60	76	62	59	80	92	15	12	99.3	97.5	44.1	38.4
18	36.7	34.1	45	13	35	60	59	53	80	72	8	13	99.5	98.3	27.7	41.9
19	36.4	35.6	21	18	64	85	52	61	85	103	13	15	97.8	98.3	44.3	37.4
20	36.2	34.4	38	51	67	39	85	66	105	90	12	8	95	96.9	40.8	44.5
21	36.5	35.6	22	5	58	72	53	49	80	77	10	13	100	98.5	25	28.4
22	38.3	37.3	19	2	46	99	62	57	65	101	11	12	95.9	97.2	29.7	32.2
23	37.3	37.6	19	10	61	72	74	97	80	82	15	8	99.9	98.5	34.5	39
Mean	37.1	35.2	28	13	60	78	76	70	88	91	10	10	98.5	98.2	33.6	34.9

CF: cardiac frequency; CPP: cerebral perfusion pressure; CVP: central venous pressure; ICP: intracranianal pressure; MAP: mean arterial pressure; $PaCO_2$: parcial pression CO_2; $SataO_2$: arterial saturation O_2; BrTe: brain temperature.

shows the mean, standard deviation, median, minimum and maximum value of the variables studied in the pre and posthypothermia period, as well as the results of the paired Student-t test.

There was a significant reduction ($p<0.0001$) in mean BrTe, from 37.1ºC (35.3ºC–38.9ºC), prior to cooling, to 35.2ºC (33.6ºC–37.6ºC) in the post-hypothermia period (Table 4, Fig 1).

There was a significant drop ($p=0.0001$) in mean ICP from 28 mmHg (18–64 mmHg), in the pre-cooling period, to 13 mmHg (2 mmHg–51 mmHg) in the postcooling period (Table 4, Fig 2). During the pre-cooling period, 19 of the 23 (82.60%) patients presented ICP higher than or equal to 20 mmHg and only two patients (8.69%) maintained an ICP over 20 mmHg after cooling.

There was a significant increase ($p=0.0001$) in mean CPP, from 60 mmHg (24–84 mmHg) in the pre-cooling period, to 78 mmHg (2 mmHg–39 mmHg) in the post-cooling period (Table 4, Fig 3). In the pre-cooling period, 18 of the 23 (78.26%) patients presented CPP lower than or equal to 70 mmHg, while only four patients (17.39%) maintained CPP below 70 mmHg after cooling.

The control variables (CF, MAP, CPV, $SataO_2$ and $PaCO_2$) did not present statistically significant alterations between the pre and post-hypothermia periods (Table 4).

Table 5 shows the APACHE II scores, length of stay in the ICU, and evolution. The mean risk of death, calculated based on the APACHE II score, was 51.3%. Ten patients (43.47%) died while in the ICU. The GOS score for the 13 surviving patients was: four patients (30.76%) with a GOS of 4 or 5 points, eight patients (61.53%) with a GOS of 3 points, and one patient (7.69%) with a GOS of 2 points.

Table 4. Measure of the variables in the pre and post regional cooling periods.

Variable		Mean*	Standard deviation	Median	Minimum value	Maximum value	Student-t test
BrTe (ºC)	Pre	37.13	0.95	36.8	35.3	38.9	p<0.0001*
	Post	35.21	1.08	35.2	33.6	37.6	
ICP (mmHg)	Pre	28.39	11.86	22	18	64	p=0.0001*
	Post	12.78	10.06	11	2	51	
CPP (mmHg)	Pre	59.83	13.21	61	24	84	p=0.0001*
	Post	78.22	12.92	80	39	99	
CF (bpm)	Pre	75.96	18.57	74	48	118	p=0.0425
	Post	70.04	15.19	66	49	98	
MAP (mmHg)	Pre	88.22	15.86	85	60	120	p=0.4338
	Post	91.00	8.75	94	72	103	
CVP (cm H_2O)	Pre	9.62	3.67	9	1	15	p=0.6148
	Post	10.05	3.14	10	4	15	
$SataO_2$ (%)	Pre	98.51	1.70	99.2	94.7	100	p=0.2552
	Post	98.20	0.79	98.4	95.9	99.1	
$PaCO_2$ (mmHg)	Pre	33.55	7.43	33.9	18.5	47.3	p=0.3508
	Post	34.89	6.84	36.6	22.1	45.9	

CF: cardiac frequency; MAP: mean arterial pressure; CPP: cerebral perfusion pressure; $PaCO_2$: parcial pression CO_2; CVP: central venous pressure; $SataO_2$: arterial saturation O_2; ICP: intracranianal pressure; BrTe: brain temperature.

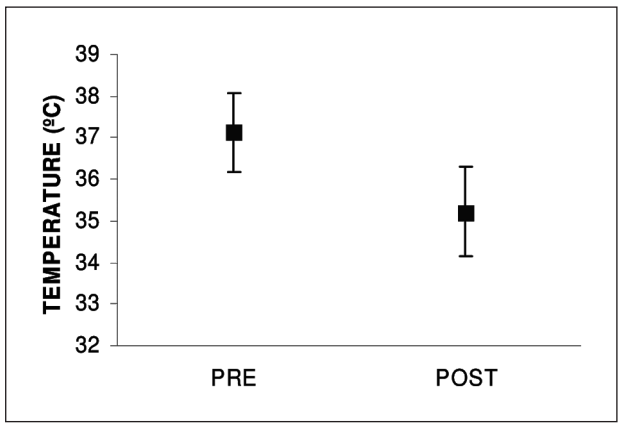

Fig 1. Graph showing the mean brain temperature (ºC) and standard deviation in the pre and post regional cooling periods.

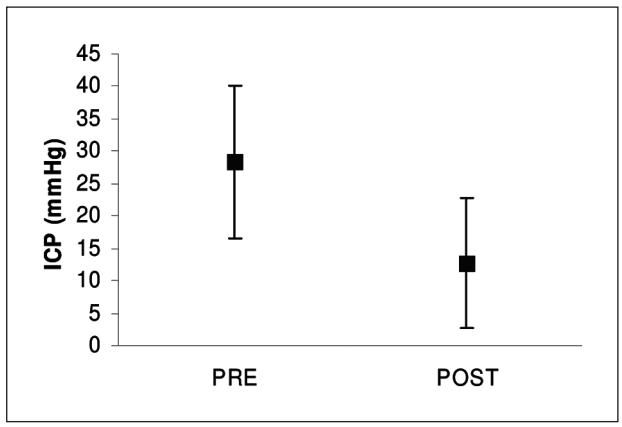

Fig 2. Graph showing the mean intracranial pressure (mmHg) and standard deviation in the pre and post regional cooling periods.

DISCUSSION

The pathogenics alterations caused by primary brain lesion are extensive and complex. In general, they determine a series of biochemical reactions which result in the: liberation of excitatory neurotransmitters and production of inflammatory agents, cytokine, metabolites of arachidonic acid, nitric oxide, free radicals (reperfusion) and activity of the intracellular pathways which cause programmed cell death (apoptosis).

Hypothermia influences virtually all biochemical reactions caused by the primary brain lesion[9]. The biochemical action can be explained by the physical properties involved. Biological reactions are catalyzed by enzymes and the characteristics of the environment (pH, temper-

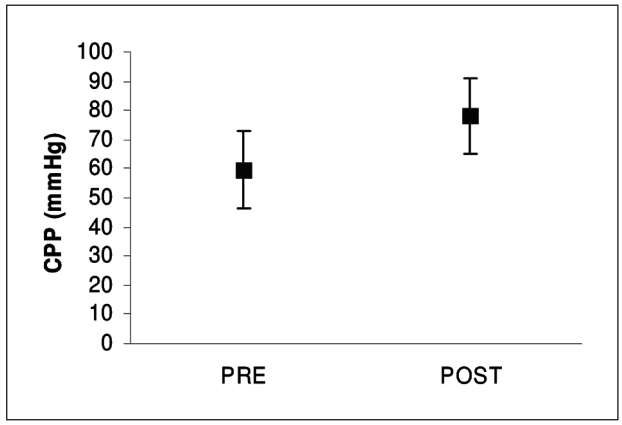

Fig 3. Graph showing the mean cerebral perfusion pressure (mmHg) and standard deviation in the pre and post regional cooling periods.

Table 5. APACHE II score, risk of death and evolution of each patient.

Case Nº	APACHE II	Risk of death (%)	Stay in ICU (days)	GOS
1	31	69,5	8	1
2	31	69,5	6	1
3	22	34,1	31	5
4	32	72,5	7	1
5	26	52,3	19	3
6	22	38	26	3
7	19	28,3	11	4
8	29	80,8	16	1
9	27	56	78	2
10	18	25,5	29	3
11	29	63	39	3
12	30	66,3	44	1
13	24	45,1	17	3
14	28	59,5	5	1
15	35	80,3	48	1
16	19	28,3	18	3
17	19	28,3	16	4
18	20	31,4	98	3
19	33	75,3	8	1
20	28	59,5	12	1
21	24	45,1	18	3
22	28	59,5	11	1
23	11	10,9	20	5
Mean	25	51,3	25,4	–

ICU: intensive care unit; GOS: Glasgow outcome score.

ature, pressure, among others) directly influence the enzyme activity.

The enzymes demonstrate an adequate performance within a narrow temperature range around 37ºC. The increase or reduction in temperature directly affects the speed of the biological reactions. This variation is determined by the temperature coefficient (Q_{10}), i.e. the Q_{10} of the brain is approximately 2.3, therefore an alteration of 10º C in the temperature will lead to a 2.3-fold increase or decrease in brain metabolism[10].

In the central nervous system, around 70% of the energy produced in the form of ATP is used in the processes of active transport and nervous excitation. The lack of energy compounds compromises the function of the pumps and ionic pathways which control the efflux of potassium ions (K^+) and influx of calcium ions (Ca^{2+}), sodium ions (Na^+) and water. Thus, cellular edema, activation of phospholipases and proteases result in irreversible lesion of the membranes, and death of the cell.

Hypothermia can stabilize the intracellular environment, through the adequate functioning of the ionic pumps and pathways. Cooling causes reduction in energy demand and a relative increase in the concentration of energy compounds (ATP) which are probably used in the maintenance of active transport.

The ability to maintain the potential of the cell membrane reduces the ionic permeability, and the activity of the Na^+/K^+ and Na^+/Ca^{2+} ion pumps determine the functional evidences of the strategy of saving energy during the cooling[11]. Thus, hypothermia hinders the influx of Ca2+ and the consequent activation of proteolytic enzymes.

The clinical application of cerebral hypothermia began with the pioneering work of neurosurgeon Temple Fay, in 1938, but the program was abandoned during the Second World War[12].

From the 1950s, studies on profound cerebral hypothermia beginning. Despite the promising results in experimental models[13], the practical application led to various complications (hemodynamic and hydroelectrolytic disturbances, alterations in coagulation and increased in infections) and was rapidly suspended.

In the 1980s, experimental studies demonstrated the

beneficial effects of mild to moderate cerebral hypothermia in the treatment of acute brain lesions, and enabled the application of new cerebral cooling techniques. Prandini et al.[14] used surface cooling, with ice packs applied over the area of the craniectomy to induce cerebral hypothermia in provoked ischemic lesion in rabbits brain. The experimental results suggested that the induction of mild hypothermia (around 34ºC) exerts a neuroprotective and therapeutic effect, following severe acute ischemic brain lesion.

At the beginning of the 1990s, three isolated clinical trails demonstrated the benefits of mild to moderate therapeutic hypothermia in severe TBI[2-4].

Following these trials, systemic hypothermia began to be used in others clinical situations: severe acute ischemic stroke[15-17], subarachnoid hemorrhage[8], fulminating hepatitis and anoxia-ischemic encephalopathy[8,18]. Our study was also comprised of patients with refractory ICH, with different causes, and a predominance of traumatic and vascular lesions.

However, the results of the further multicentric study did not confirm the initial findings. Clifton et al. carried out a randomized, prospective multicentric controlled study of 392 patients with severe TBI (GCS≤8). They did not find any significant difference in mortality between the group submitted to hypothermia and the group submitted to normothermia, after six months of TBI. They recorded a significant reduction in ICP with the hypothermia group, but associated with a higher tendency to infections[6].

A possible explanation for the disassociation between the results is the lack of standardization of the method[19]. In recent years, different techniques, objectives and evaluation criteria have been used and compared, indiscriminately.

Thus, we should consider the following aspects of the technique, which are important for analyzing the results of the therapeutic hypothermia: intensity of cooling; the cooling method used; the site at which the temperature is determined; the start and time of maintenance, and the rewarming strategy.

Intensity of cooling

For every 1ºC drop in temperature there is a reduction in the cerebral metabolism of around 6%[10]. Meanwhile, an increase in temperature of just 1ºC to 2ºC will worsen the primary lesion and increase tissue necrosis[20].

Induced hypothermia is classified according the temperature achieved. The accentuated body cooling, for prolonged periods, is associated with high rates of morbidmortality.

The majority of authors adopt a body core temperature between 32ºC and 33ºC, which characterizes the hypothermia as moderate and increases the risk of complications. This choice was made because the initial experimental and clinical trials indicate that a potent neuroprotective action is obtained at this temperature. As Tokutomi et al.[21] we opted for mild cerebral hypothermia (up to 34.0ºC) as the target temperature in our treatment scheme.

Cooling method

The choice of cooling method was another important technical aspect. This decision directly influenced the intensity and speed of hypothermia induction.

The techniques are divided into:

(1) Surface cooling
  (a) Blankets[2,3,6,15,16,21]
  (b) Ice packs or immersion in cold water[15,22]
  (c) Cooling helmet[7,22]
(2) Deep cooling
  (a) With cold solutions
  - Intravenous infusion[8,23]
  - Gastric washing[3,6]
  - Peritoneal washing[24]
  - Nasopharyngeal cooling[22]

  (b) Closed intravascular system[16]

The cooling techniques were associated, in the majority of instances, with the circulation of cooled air leading to a decrease in environmental temperature to around 18ºC.

However, the brain temperature is not constant. The cerebral metabolism is responsible for the production of heat, and the loss occurs through conduction, convection and radiation.

The conduction of heat occurs through the tissues. In normal conditions, this mechanism contributes shortly to temperature control, as the intact cranium is an important barrier (thermal isolator). In convection, heat loss occurs as a result of the CBF and arterial blood temperature.

Gentilello[25] describes in detail, the physical mechanisms of heat loss or transfer. Heat conduction occurs though contact between the two masses. The transfer rate depends on the temperature gradient, interface, size of the contact area and thermal conductivity of the material. The transfer is also affected by the distance that the heat needs to travel, i.e. the thickness of the skin and subcutaneous tissue.

Heat can also be transferred to the environment in the form of electromagnetic waves, which do not require contact with any mass or fluid. Radiation is proportional to the fourth power of the temperature gradient, surface area of the body and characteristics of the heat emission itself.

This principles form the basis of our choice of surface cooling using ice bags, to induce regional hypothermia in patients submitted to decompressive craniectomy. In this specific group of patients, removal of part of the cranium enabled the adoption of a new strategy for cerebral cooling. In the area of the craniectomy, there is a reduction in thermal isolation, which facilitates heat loss by conduction, convection and radiation.

Site of temperature determination

The body temperature fluctuates throughout the day, and varies according to regions. Disease can exacerbate the temperature gradients. Therefore, the body temperature observed in different regions does not reflect the intracranial temperature. The sites for determining temperature can be divided into:

(1) Surface: axiliary region[26]

(2) Deep

(a) Core: esophagus[27], urinary bladder[3,15,16], internal jugular vein[28], lower cava vein[16], pulmonary artery[18], rectum[5,21,22] and tympanic membrane[27,18]

(b) Intracranial: lateral ventricle[22], brain[3,5,7,21,26] and epidural space[22]

The determination of body core temperature is used generally for the control of patients admitted to the ICU. A difference between core and brain temperature (brain-core temperature gradient) was observed in patients with acute brain lesion. The BrTe tends to be 1ºC higher than the core temperature.

Rumana et al.[28] demonstrated that this difference in temperature tends to increase in situations that compromise the CPP. They observed that in episodes where there is a drop in CPP, to levels of 20 mmHg a 50 mmHg, the brain-body core gradient can reach 2.1ºC. Henker et al.[29], also observed that the difference between brain and core temperature can be as high as 2.0ºC.

The BrTe should act as a guide for therapeutic interventions in patients with acute brain lesion, and serve as a control for cooling until the desired temperature is reached. Various different sensors were developed to monitor BrTe, the majority of which are coupled to ICP sensors.

Start and duration

The best moment to induce hypothermia depends on the objectives to be reached. It is likely that therapeutic window remains only for a few hours, in order to obtain the neuroprotective action of the cerebral hypothermia[30]. In this situation, cooling may be used as a temporary strategy (a bridge) until the definitive treatment can be carried out[8]. In our study, the regional cooling was maintained for around 61.7 hours (20–96 hours) for the control de ICP. In the majority of the studies reviewed, the maintenance span of hypothermia was 24 to 48 hours. Despite these differences, we believe that our favorable results are related to the rapid reduction in BrTe, provided by the regional cooling, and the more prolonged maintenance of the hypothermia.

Strategy in the rewarming phase

The rewarming phase consisted of a new challenge specially for patients submitted to systemic hypothermia. Two strategies may be used: passive or active rewarming.

The passive form is based on the endogenous generation of heat, resulting in a gradual increase in central temperature. However, this strategy prolongs the total time of hypothermia and can, in theory, increase the harmful effects.

Active rewarming was used in the majority of studies. The temperature was raised using a blanket, lamps, and heated solutions. The speed of rewarming varied between 0.5ºC every two hours[3] and 1.0ºC per day for three days[4].

The increase in ICP is the most feared complication in the rewarming phase, but it is not the only one[15]. We should remember that hyperthermia increases the neuronal lesion and worsens the development of patients with severe brain lesion.

To avoid these complications, Schwab et al.[15] recommend the use of slow rewarming for the control of the ICP and CPP, in patients with extensive acute ischemic stroke submitted to moderate hypothermia.

Our technique enabled gradual and passive rewarming of the brain, with the intermittent application of ice packs to the area of the craniectomy (regional method), to avoid an abrupt elevation in BrTe.

In conclusion, despite the limited number of patients, our results suggest that mild cerebral hypothermia, induced by regional cooling, was effective in the control of intracranial pressure in patients who had previously undergone decompressive craniectomy. However, cerebral hypothermia, for the treatment of various acute cerebral lesions, continues to be used based on the experience of each author, and on the results of isolated clinical series. In our understanding, the best explanation for the discrepancy in the results observed in the literature is the lack of clearly-defined criteria for the indication, induction, maintenance and suspension of cerebral hypothermia, which led to a comparison of the results obtained by different methods.

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