Carbon dioxide reactivity during prostaglandin E₁ induced hypotension for cerebral aneurysm surgery

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The cerebral vasomotor reactivity to carbon dioxide was studied, using a thermal gradient blood flow meter in 43 patients with intracranial cerebral aneurysm under deliberate hypotension induced by prostaglandin E₁ (PGE₁) infusion. The patients were divided into three groups according to the neurological status. Patients in Groups A and B had subarachnoid haemorrhage due to ruptured cerebral aneurysms. Group A consisted of 23 patients with a neurological grade of I–II and Group B consisted of 11 patients with a grade of III–V. Nine patients with non-ruptured cerebral aneurysm served as controls (Group C). After the dura was opened, local cerebral blood flow (LCBF) was measured. The PGE₁ was started with an initial dose of 0.1 µg · kg⁻¹ · min⁻¹ and the dose was adjusted to maintain MAP at about 70 mmHg. The LCBF and carbon dioxide (CO₂) reactivity were estimated during and after PGE₁ administration. The LCBF did not change among groups throughout the study period. Carbon dioxide reactivity was estimated as follows: absolute; $\Delta\text{LCBF}/\Delta\text{PaCO}_2$, and relative; $\% \Delta\text{LCBF}/\Delta\text{PaCO}_2$ after changing PaCO₂ by increasing minute ventilation. Absolute and relative CO₂ reactivity did not change within groups throughout the study. Absolute CO₂ reactivity values before, during and after, hypotension were 1.07 ± 0.4 , 1.13 ± 0.48 , 1.18 ± 0.6 (ml · min⁻¹ · 100 g⁻¹ · mmHg⁻¹) in Group A, 0.8 ± 0.28 , 0.71 ± 0.25 ,

0.72 ± 0.3 in Group B and 2.13 ± 0.75, 2.17 ± 0.88, 2.06 ± 0.69 in Group C. Relative CO₂ reactivity values before, during and after hypotension were 1.95 ± 0.72, 2.17 ± 0.83, 2.13 ± 0.61 (% · mmHg⁻¹) in Group A, 1.29 ± 0.22, 1.37 ± 0.48, 1.37 ± 0.48 in Group B and 3.58 ± 0.91, 4.17 ± 1.81, 4.03 ± 1.91 in Group C. Carbon dioxide activity was less in Groups A and B than in Group C (P < 0.05) and there was a significant difference between Groups A and B (P < 0.05). There was a close correlation between presurgical neurological status and CO₂ reactivity (before: rs = -0.704, P < 0.01, during: rs = -0.625, P < 0.01, and after deliberate hypotension: rs = -0.618, P < 0.01). The LCBF and CO₂ reactivity were well maintained during PGE₁ infusion in all groups. Outcome was correlated with presurgical neurological status (rs = 0.646, P < 0.01), and the initial cerebral blood flow was correlated with presurgical neurological status (rs = -0.402, P < 0.05). These results suggest that presurgical neurological status is closely correlated with CO₂ reactivity and cerebral blood flow, and that PGE₁ induced hypotension does not change significantly LCBF and CO₂ reactivity.

Key words

ANAESTHESIA: neurosurgical;
ANAESTHETIC TECHNIQUES: hypotensive;
BRAIN: blood flow;
HORMONES: prostaglandin E₁.

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Accepted for publication 22nd November, 1991.

Nous avons étudié la réactivité vasomotrice cérébrale au CO₂, à l'aide d'un débitmètre à gradient thermique, chez 43 patients avec anévrisme cérébral intracranien et sous hypotension contrôlée par une perfusion de prostaglandine E₁ (PGE₁). Les patients ont été classés dans trois groupes selon leur statut neurologique. Les patients des groupes A et B avaient une hémorragie sous-arachnoïdienne suite à des anévrismes cérébraux rompus. Le groupe A comprenait 23 patients avec un grade neurologique I–II et le groupe B comprenait 11 patients avec un grade III–V. Neuf patients avec un anévrisme cérébral non rompu ont servi de contrôles (groupe C). Le débit sanguin cérébral local (LCBF) a été mesuré à l'ouverture de la dure-mère. La PGE₁ a été débutée à une dose initiale de 0,1 µg · kg⁻¹ · min⁻¹ et la dose ajustée pour maintenir une tension artérielle moyenne (MAP) autour de 70 mmHg. Le LCBF et la réactivité au CO₂ ont été estimés pendant et après l'administration de PGE₁. Le LCBF a été constant entre les groupes pour la

durée de l'étude. La réactivité au CO₂ a été estimée comme suit absolue : $\Delta\text{LCBF}/\Delta\text{PaCO}_2$ et relative : $\%\Delta\text{LCBF}/\Delta\text{PaCO}_2$ après avoir changé la PaCO₂ en augmentant la ventilation minute. Les réactivités relatives et absolues au CO₂ n'ont pas changé entre les groupes pour la durée de l'étude. Les valeurs de réactivité absolue au CO₂ avant, pendant et après l'hypotension étaient de $1,07 \pm 0,4$, $1,13 \pm 0,48$, $1,18 \pm 0,6 \text{ ml} \cdot \text{min}^{-1} \cdot 100 \text{ g} \cdot \text{mmHg}^{-1}$ pour le groupe A, $0,8 \pm 0,28$, $0,71 \pm 0,25$, $0,72 \pm 0,3$ pour le groupe B et $2,13 \pm 0,75$, $2,17 \pm 0,88$, $2,06 \pm 0,69$ pour le groupe C. Les valeurs de réactivité relative au CO₂ avant, pendant et après l'hypotension étaient de $1,95 \pm 0,72$, $2,17 \pm 0,83$, $2,13 \pm 0,61 \text{ \%} \cdot \text{mmHg}^{-1}$ pour le groupe A, $1,29 \pm 0,22$, $1,37 \pm 0,48$, $1,37 \pm 0,48$ pour le groupe B et $3,58 \pm 0,91$, $4,17 \pm 1,81$, $4,03 \pm 1,91$ pour le groupe C. La réactivité au CO₂ était moindre pour les groupes A et B que pour le groupe C ($P < 0,05$), et il y avait une différence significative entre les groupes A et B ($P < 0,05$). Il y avait une étroite corrélation entre le statut neurologique préchirurgical et la réactivité au CO₂ (avant : $r_s = -0,704$, $P < 0,01$; pendant $r_s = -0,625$, $P < 0,01$ et après l'hypotension contrôlée : $r_s = -0,618$, $P < 0,01$). Le LCBF et la réactivité au CO₂ ont été bien maintenus pendant la perfusion de PGE₁ pour tous les groupes. L'issue était en corrélation avec le statut neurologique préchirurgical ($r_s = 0,646$, $P < 0,01$) et le débit sanguin cérébral initial était en corrélation avec le statut neurologique préchirurgical ($r_s = -0,402$, $P < 0,05$). Ces résultats suggèrent que le statut neurologique préchirurgical est en corrélation étroite avec la réactivité au CO₂ et avec le débit sanguin cérébral, et que l'hypotension induite par la PGE₁ n'altère pas le LCBF et la réactivité au CO₂ de façon significative.

Deliberate hypotension has been used in cerebral aneurysm surgery to reduce the risk of premature rupture and to facilitate surgery.^{1,2} However, it is necessary to preserve the carbon dioxide (CO₂) reactivity during induced hypotension, because it is common clinical practice to hyperventilate the lungs to reduce cerebral blood flow and volume in patients with increased intracranial pressure.

Subarachnoid haemorrhage (SAH) itself leads to impaired autoregulation of cerebral blood flow.³⁻⁵ Pickard *et al.* reported that there was a risk of postoperative neurological deficit in patients with impaired autoregulation.⁶ Several intravenous drugs such as trimethaphan (TMP), nitroglycerine (TNG), adenosine and sodium nitroprusside (SNP) have been used to induce hypotension but it is difficult to identify a preferable drug.

We have previously reported that prostaglandin E₁ (PGE₁) maintained local cerebral blood flow (LCBF) during cerebral aneurysm surgery.⁷ In the previous study, however, we did not evaluate the effect of PGE₁ on CO₂ reactivity. In the present study, we investigated CO₂ reactivity in patients with non-ruptured and ruptured

cerebral aneurysms using prostaglandin E₁ (PGE₁) to induce hypotensive anaesthesia.

Methods

The experimental protocol was approved by the committee on human studies at the Osaka Police Hospital and informed consent was obtained from each patient or appropriate relative. The series comprised 43 patients undergoing craniotomy for cerebral aneurysm surgery. The neurological status was graded by the Hunt and Kosnik scale⁸ at the time of admission to the operating theatre. The patients were divided into three groups according to their neurological grade. Group A consisted of 23 patients who had neurological grade I–II. Group B consisted of 11 patients who had poorer neurological grades of III–V and Group C consisted of nine patients who had non-ruptured cerebral aneurysms and served as controls. Fifty-three patients with non-ruptured cerebral aneurysms were identified by cerebral angiography but LCBF could be measured in only nine because the thermal gradient blood flow probe was removed immediately after aneurysm clipping. The diagnosis of subarachnoid haemorrhage (SAH) was confirmed by computerized tomography, four-vessel cerebral angiography, and cerebrospinal fluid examination. The timing of operation was based on the clinical condition, aneurysm location and the medical condition of the patients; early surgery was defined as surgery within three days of SAH and late surgery: > four days of SAH. The outcome of patients was graded by the Glasgow Outcome Scale (GOS) at discharge⁹ by two independent neurosurgeons. The GOS is defined as follows: I – good recovery, II – moderate disability, III – severe disability, IV – vegetative state, V – death. Anaesthesia was induced with thiopentone ($4 \text{ mg} \cdot \text{kg}^{-1}$), muscle relaxation was produced with pancuronium ($0.1 \text{ mg} \cdot \text{kg}^{-1}$). Fentanyl 0.1 mg , supplemented with isoflurane 1–1.5% and lidocaine $1 \text{ mg} \cdot \text{kg}^{-1}$ were administered before tracheal intubation. After intubation, ventilation was maintained mechanically.

Anaesthesia was maintained with fentanyl ($2 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$) and nitrous oxide 70% in oxygen. A radial artery catheter was used for continuous monitoring of arterial blood pressure and arterial blood sampling. Arterial blood gases were analyzed with an gas automatic blood gas analyzer (ABL II, Radiometer, Denmark). A venous cannula was introduced into the femoral vein for infusion of PGE₁.

Cerebral aneurysm clipping was performed at various times depending on the clinical severity of patients after ruptured aneurysm. In patients with low neurological grade, ventricular drainage was performed immediately after opening the dura. A thermal gradient blood flow meter probe (Biomedical Science Co. Tokyo, Japan.) was

placed on the middle frontal gyrus, distal to the point of intended brain retraction.

The measurement of blood flow was based on changes in heat conductivity of the tissue in response to altered blood flow. The gradient is maximum when no blood is passing through the cerebral cortex (V_0) and cortical blood flow increases; the temperature difference decreases in proportion to flow. Tissue blood flow (F) was calculated by the following formula from the electromotive force (V) of the thermocouple generated by temperature changes: $F = k(1/V - 1/V_0)$ in which k is constant.^{10,11} Control measurements were made just before the administration of PGE₁. An initial dose of $0.1 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ of PGE₁ was given and subsequent dosing was adjusted to maintain MAP at about 70 mmHg. The LCBF and CO₂ reactivity were obtained at 60 min after the start of PGE₁ infusion and at 60 min after its discontinuation which was at the completion of cerebral aneurysm clip ligation. The PaCO₂ was changed by increasing minute ventilation and arterial blood samples were obtained before and after the changes of ventilation settings. The PaCO₂ value was measured by an automatic blood gas analyzer.

Absolute CO₂ reactivity was defined as the unit change in LCBF per unit change in PaCO₂ ($\text{ml} \cdot \text{min}^{-1} \cdot 100 \text{ g}^{-1} \cdot \text{mmHg}^{-1}$). Relative CO₂ reactivity values were obtained by dividing the value for the percentage of change in the LCBF by the value for the change in PaCO₂, $\% \Delta \text{LCBF} / \Delta \text{PaCO}_2$ ($\% \cdot \text{mmHg}$).

Statistical analysis

Data are expressed as mean $\pm$ SD. The relation between outcome and presurgical neurological status was evaluated with Spearman Rank coefficient test. Statistical analysis of age and total dose of PGE₁ administered was performed with Student's *t* test. Haemodynamic and LCBF were compared with one-way analysis of variance and Bonferroni correction to define differences within group and between groups. Statistical analysis of relative and absolute CO₂ reactivity was performed with two-way analysis of variance and Bonferroni correction. The evaluation of correlation between presurgical neurological status and relative CO₂ reactivity was performed with the Spearman Rank coefficient test. The relationship between neurological grade and initial cerebral blood flow was evaluated with the Spearman Rank coefficient test. $P < 0.05$ was considered statistically significant.

Results

Table I shows demographic data of the patients studied. There were no differences of age among groups. The dose of PGE₁ required to induce hypotension was not different between Groups A and B, but was lower in Group C than in Groups A and B ($P < 0.01$).

FIGURE 1 Correlation between presurgical neurological status and local cerebral blood flow before deliberate hypotension.

There was a close correlation between the initial cerebral blood flow and presurgical neurological status ($r_s = -0.402$, $P < 0.05$) (Figure 1) and the latter correlated with outcome ($r_s = 0.646$, $P < 0.01$). After the start of PGE₁ administration, MAP decreased but LCBF and HR did not change throughout the study (Table II). Carbon dioxide reactivity, absolute (Table III) and relative (Table IV) was related to neurological status and was greater in Group C than in Group A which was greater than in Group B ($P < 0.05$). Reactivity was not affected by PGE₁ infusion in any group at any time.

There was a close correlation between presurgical neurological status and relative CO₂ reactivity (before: $r_s = -0.704$, $P < 0.01$, during: $r_s = -0.625$, $P < 0.01$, and after PGE₁ infusion: $r_s = -0.618$, $P < 0.01$) (Figure 2).

Discussion

The purposes of this study was to evaluate the effects of PGE₁ induced hypotension on LCBF and CO₂ reactivity during cerebral aneurysm clipping, and to determine the correlation between presurgical neurological status and CO₂ reactivity. LCBF and CO₂ reactivity were preserved in each patient throughout the study. Relative CO₂ reactivity was closely correlated with the presurgical neurological status (before: $r_s = -0.704$, $P < 0.01$, during: $r_s = -0.625$,

TABLE I Patient's backgrounds

No.	Age	Sex	Aneurysm location	Total dose of PGE ₁ (µg)	Outcome	NS	Timing of operation
<i>Group A</i>							
1	50	F	MCA	1750	I	I	L
2	41	F	IC	400	I	I	L
3	61	F	BA	700	IV	I	L
4	21	M	AcomA	790	I	I	L
5	76	F	AcomA	720	I	I	L
6	48	M	IC	600	II	I	L
7	44	M	IC	1120	I	I	L
8	55	M	MCA	930	I	I	L
9	56	M	MCA	725	I	I	L
10	55	M	MCA	612	I	I	L
11	26	F	AcomA	680	I	I	L
12	57	M	MCA	350	I	I	L
13	48	F	AcomA	450	I	I	E
14	80	M	IC	1260	I	II	E
15	47	F	IC	1360	I	II	E
16	60	M	AcomA	680	I	II	L
17	68	F	IC	1653	II	II	E
18	59	F	IC	500	I	II	E
19	81	F	AcomA	432	I	II	E
20	26	F	AcomA	415	I	II	L
21	48	M	MCA	925	III	II	E
22	73	F	AcomA	432	III	II	E
23	43	M	MCA	330	III	II	E
mean	52			774.5*			
SD	±15			±405.5			
<i>Group B</i>							
1	76	F	MCA	500	I	III	E
2	63	F	AcomA	400	IV	III	E
3	78	F	IC	333	II	III	E
4	48	M	MCA	580	IV	III	E
5	41	F	MCA	975	IV	IV	E
6	41	F	MCA	1500	IV	IV	E
7	55	F	IC	870	IV	IV	E
8	44	F	IC	1500	III	IV	E
9	50	F	IC	440	V	IV	E
10	40	M	MCA	500	V	IV	E
11	57	F	MCA	380	V	V	E
mean	56			725.3*			
SD	±12			±432.0			
<i>Group C</i>							
1	48	M	MCA	330	I	0	L
2	54	F	IC	380	I	0	L
3	56	M	AcomA	350	I	0	L
4	72	F	IC	260	I	0	L
5	72	F	IC	330	IV	0	L
6	58	F	AcomA	400	I	0	L
7	63	F	MCA	280	I	0	L
8	78	M	AcomA	600	I	0	L
9	57	F	AcomA	580	I	0	L
mean	62			390			
SD	±9			±121.6			

AcomA: anterior communicating artery, IC: internal carotid artery, MCA: middle cerebral artery, BA: basilar artery. Outcome was graded with Glasgow outcome scale. Presurgical neurological status (NS) was graded with Hunt and Kosnik scale. L: late surgery, E: early surgery.

* $P < 0.01$ compared with Group C.

TABLE II

	<i>Just before PGE₁ start</i>	<i>During PGE₁ infusion</i>	<i>After PGE₁ Discontinuation</i>
<i>Group A</i>			
MAP (mmHg)	107.7 ± 11.5	75.5 ± 4.8†	91.8 ± 11.4†
HR (min ⁻¹)	78.9 ± 7.9	77.5 ± 7.5	79.1 ± 9.6
LCBF (ml · 100 g ⁻¹ · min ⁻¹)	54.7 ± 9.9	57.5 ± 13.2	51.9 ± 12.1
<i>Group B</i>			
MAP (mmHg)	107.3 ± 9.7	73.2 ± 4.6†	88 ± 12.9†
HR (min ⁻¹)	82.6 ± 11.9	85.5 ± 8.9	82.7 ± 6.9
LCBF (ml · 100 g ⁻¹ · min ⁻¹)	51.2 ± 11.9	47.9 ± 10.2	50.2 ± 11.7
<i>Group C</i>			
MAP (mmHg)	110.3 ± 9.0	72.7 ± 6.6†	97.6 ± 11.3*
HR (min ⁻¹)	78.8 ± 6.1	81.1 ± 8.8	84.1 ± 8.4
LCBF (ml · 100 g ⁻¹ · min ⁻¹)	56.1 ± 10.9	53.8 ± 9.7	55.3 ± 7.1

MAP mean arterial pressure, HR: heart rate, LCBF: local cerebral blood flow.

**P* < 0.05, †*P* < 0.01, compared with just before start.

TABLE III

	<i>Just before start of PGE₁</i>	<i>60 min after start of PGE₁</i>	<i>60 min after PGE₁ discontinuation</i>
<i>Group A</i>			
Absolute CO ₂ reactivity (ml · 100 g ⁻¹ · min ⁻¹ · mmHg ⁻¹)	1.07 ± 0.4*†	1.13 ± 0.48*†	1.18 ± 0.6*†
ΔPaCO ₂ (mmHg)	11 ± 4.1	9.9 ± 4.1	11.8 ± 4.4
(kPa)	1.47 ± 0.55	1.32 ± 0.55	1.57 ± 0.59
<i>Group B</i>			
Absolute CO ₂ reactivity (ml · 100 g ⁻¹ · min ⁻¹ · mmHg ⁻¹)	0.8 ± 0.28*	0.71 ± 0.25*	0.72 ± 0.3*
ΔPaCO ₂ (mmHg)	10.7 ± 3.8	9.5 ± 3.6	10.8 ± 2.9
(kPa)	1.43 ± 0.51	1.27 ± 0.48	1.44 ± 0.39
<i>Group C</i>			
Absolute CO ₂ reactivity (ml · 100 g ⁻¹ · min ⁻¹ · mmHg ⁻¹)	2.13 ± 0.75	2.17 ± 0.88	2.06 ± 0.69
ΔPaCO ₂ (mmHg)	11.1 ± 3.9	11.7 ± 4.5	11.3 ± 3.8
(kPa)	1.48 ± 0.52	1.56 ± 0.6	1.51 ± 0.51

Mean ± SD.

**P* < 0.05 compared with Group C.†*P* < 0.05 compared with Group B.

TABLE IV Relative CO₂ reactivity (% · mmHg⁻¹)

Just before start of PGE ₁	60 min after start of PGE ₁	60 min after PGE ₁ discontinuation
Group A		
1.95 ± 0.72*†	2.17 ± 0.83*†	2.13 ± 0.61*†
Group B		
1.29 ± 0.22*	1.37 ± 0.48*	1.37 ± 0.48*
Group C		
3.58 ± 0.91	4.17 ± 1.81	4.03 ± 1.91

Mean ± SD.

**P* < 0.05 compared with Group C.†*P* < 0.05 compared with Group B.

P < 0.01, and after deliberate hypotension: *r*_s = -0.618, *P* < 0.01). Initial cerebral blood flow correlated with presurgical neurological status (*r*_s = -0.402, *P* < 0.05). The CO₂ reactivity demonstrated was greater in Group C than in Groups A and B (*P* < 0.05), and there was a difference between Groups A and B (*P* < 0.05). Thus, patients with poorer preoperative neurological grade had decreased CO₂ response.

Recent technological developments allow several methods of measuring cerebral blood flow. We employed the thermal gradient blood flow meter, because of its ability to register LCBF changes continuously without delay. Values of LCBF measured in this study were comparable to previous reports with other methods^{12,13} and CO₂ reactivity values were in good agreement with previous reports in cerebral aneurysm patients using a thermal conductivity probe for the measurement of LCBF.^{14,15} The probe of thermal gradient blood flow meter was placed on the middle frontal gyrus and LCBF was measured in a boundary zone between anterior and middle cerebral arteries.¹⁶

After SAH, clinical presentation is dependent on the severity of haemorrhage. Patients with ruptured cerebral aneurysms may still have a poor outcome in spite of modern neuroanaesthetic and microsurgical techniques.¹⁷ The outcome of patients in the present study correlated well with presurgical neurosurgical status (*P* < 0.01) which suggests that the outcome of patients after aneurysm surgery can be predicted by the presurgical neurological status.

The use of intraoperative hypotension during aneurysm surgery is controversial. Subarachnoid haemorrhage causes a decrease in cerebral blood flow^{18,19} and there is concern that the use of deliberate hypotension may further decrease cerebral blood flow and result in ischaemic brain damage. Most patients with ruptured cerebral aneurysms develop abnormal autoregulation suggesting that they may be more susceptible to cerebral blood flow reduction during hypotension than normal individuals.^{20,4} However,

FIGURE 2 Correlation between relative CO₂ reactivity and presurgical neurological status before, during and after deliberate hypotension.

in our study, local cerebral blood flow demonstrated no difference between non-ruptured cerebral aneurysm cases and ruptured cerebral aneurysm cases. We measured LCBF in 53 patients with non-ruptured cerebral aneurysms, but the probe of thermal-gradient blood flow meter was removed immediately after aneurysm clipping and in only nine cases could we measure LCBF after discontinuation of PGE₁. There was a close correlation between presurgical neurological status and initial cerebral blood flow (*P* < 0.05).

McDowall¹⁶ concluded that the margin of safety of cerebral ischaemia was reduced by the use of induced hypotension. He suggested that induced hypotension should be used only when it may benefit the patient and only by those with appropriate training and experience.

It has been reported that CO₂ responsiveness is totally or partly preserved even in severe cerebral apoplexy.²¹ However, using the intraarterial ¹³³Xenon, Ishii reported that in most patients CO₂ responsiveness was disturbed and that impairment of autoregulation was correlated with clinical status, cerebral blood flow and vasospasm.²² Voldby *et al.* studied CO₂ responsiveness in 29 patients during hyperventilation within the first 13 days after aneurysm rupture.²³ They reported a decrease in cerebral blood flow of 1 to 4% per mmHg reduction of PaCO₂ regardless of the clinical condition. Cerebrovascular reactivity to hypocapnia was generally preserved in patients with SAH, although it was often reduced. In our study, CO₂ reactivity was correlated with presurgical neurological status before, during and after deliberate hypotension, but even in patients with the poorest neurological status (Hunt and Kosnik Scale grade V), carbon dioxide reactivity was not abolished. PGE₁ induced hypotension preserved CO₂ reactivity in each group throughout this study.

Hunt *et al.* recommended early operation in patients of

grade I and II clinical status, preferably within 24 hr of admission. Their survival rate was 96% in grade I and 85% in II.⁸

In this study, aneurysm surgery was performed at various times depending on the clinical severity. The safety of deliberate hypotension during aneurysm surgery depends on the preservation of autoregulation. Hitchcock reported that the incidence of postoperative neurological deficits was higher in patients subjected to intraoperative hypotension below 60 mmHg of MAP and that it correlated with the duration of hypotension.²⁴

In conclusion, this study demonstrated a close correlation between presurgical neurological status and CO₂ reactivity before and during PGE₁ administration and after its discontinuation. Using thermal gradient blood flow meter, LCBF and CO₂ reactivity were preserved during PGE₁ induced hypotension. These results suggest that presurgical neurological status has a close correlation with CO₂ reactivity and cerebral blood flow, and PGE₁ induced hypotension does not change LCBF and CO₂ reactivity.

Acknowledgement

We wish to thank Professor Toru Hayakawa, Department of Neurosurgery, Osaka University Medical School, for technical advice.

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