中国药理学与毒理学杂志 2006 年 8 月; **20**(4):288 – 294
Chin J Pharmacol Toxicol 2006 Aug; **20**(4):288 – 294

Protective effect of baicalin on inflammatory injury following transient focal cerebral ischemia-reperfusion in rats

OUYANG Chang-Han, WU Ji-Liang*
(*Department of Pharmacology, Xianning College, Xianning* 437100, *China*)

Abstract: **AIM** To investigate if the protective effect of baicalin on cerebral injury induced by transient focal ischemia is related to modulation of expressions of inflammatory cytokines or adhesive molecules. **METHODS** Transient focal cerebral ischemia injury model in rats was induced by occlusion of the right middle cerebral artery for 2 h, followed by 24 h reperfusion. The infarct volume and neurological deficit were determined by TTC staining and the scoring method of Longa *et al*. The expression of intracellular adhesion molecule-1 (ICAM-1), neutrophils infiltration, and myeloperoxidase (MPO) activity in brain were measured by immunohistochemistry, hematoxylin-eosin staining, and spectrophotometer, respectively. Semiquantitative RT-PCR was employed to assess the expression of inducible nitric oxide synthase (iNOS) mRNA. The level of interleukin-1 (IL-1) in brain was assayed by radioimmunoassay. The expression of nuclear factor-κB (NF-κB) protein was evaluated by Western blot. **RESULTS** After transient cerebral ischemia, MPO activity and the expression of ICAM-1 in the periphery of ischemic cortex were significantly increased. Increase in iNOS mRNA and NF-κB protein expression was also shown in the ischemic area. Treatment with baicalin markedly reduced brain infarct volume and neurological deficit induced by ischemic insult, inhibited MPO activity, inflammatory cell infiltration, as well as expression of ICAM-1, iNOS and NF-κB, and decreased IL-1 level. **CONCLUSION** Baicalin may play a protective effect on cerebral ischemic injury through inhibiting the expression and release of the inflammatory mediators after cerebral ischemia.

Key words: baicalin; cerebral ischemia; intracellular adhesion molecule-1; nitric oxide synthase; NF-kappa B; interleukin-1

CLC number: R285
Document code: A
Article ID: 1000-3002(2006)04-0288-07

Stroke, frequently encountered following vascular disorders or clinical practices, is a leading cause of death and permanent disability in the developed countries, for which there is currently no effective treatment. Several mechanisms of neuronal injury after stroke have been proposed, and especially the generation of oxygen free radicals, chemokines and proinflammatory mediators in the penumbra during the reperfusion phase are thought to play a major role in the delayed progression of injury occurring at the periphery of the infarct area[1,2]. Soon after ischemia, several inflammatory cascades are initiated, and astrocytes, microglia and vascular endothelial cells become rapidly activated leading to inflammatory cell infiltration and release of proinflammatory cytokines and rapid up-regulation of adhesion molecules. They induced infiltration of recruited inflammatory cells and neuronal injury. Accordingly, numerous studies have been done in relation to a possibility of oxygen free radical scavengers and anti-inflammatory drugs as therapeutic agents for the neuronal damage by ischemia. Among them, the use of polyphenolic compounds has been studied, and there have been promising results[3].

Baicalin (7-glucuronic acid, 5, 6-dihydroxyflavone), a polyphenolic flavonoid compound, isolated from the dried root of *Scutellaria baicalensis* Georgi, has been widely used in traditional Chinese herbal medicine to treat allergic and inflammatory diseases. Researches have shown that baicalin possesses multiple

Received date: 2005-09-15 **Accepted date**: 2006-02-15
Biography: OUYANG Chang-Han (1975 –), male, native of Hanchuan, Hubei Province, PhD, main research field is cardiovascular and cerebrovascular pharmacology.
* Corresponding author. E-mail: xywjl@163.com Tel: (0715)8269518

pharmacological activities, such as decreasing blood pressure, inhibiting lipid peroxidation, blocking calcium channel, and anti-inflammatory effects[4-6]. These pharmacological findings highlight the therapeutic potential of the drug for the treatment of cardiac and cerebrovascular diseases even though the mechanisms by which baicalin exert its effects are unclear. Recently, our and other some studies have demonstrated that baicalin has a protective effect against tissue injuries induced by ischemia-reperfusion (I-R), amyloid-β protein, glutamate or inflammatory factors[7-9]. However, to date, evidences regarding baicalin′s effects on ischemic brain injury is still limited. Baicalin has been reported to suppress inflammatory response *in vitro* models. To clarify the possible mechanisms by which baicalin protects brain from ischemic injury, we have assessed intracellular adhesion molecule-1 (ICAM-1) and inducible nitric oxide synthase (iNOS) expression, neutrophil infiltration and proinflammatory cytokines release following transient focal cerebral ischemia and aimed to offer a new drug of therapy for ischemic diseases.

1 MATERIALS AND METHODS

1.1 Drugs and reagents

Baicalin (purity >95%), was purchased from National Institute for the Control of Pharmaceutical and Biological Products (Beijing). It was dissolved in normal saline before use; nimodipine injection (Bayer Company, Germany); myeloperoxidase (MPO) activity assay kit (Jiancheng Biology Institute, Nanjing, China); interleukin-1 (IL-1) assay kit (Bioengineering Institute, Beijing, China); Trizol reagent, Takara RT-PCR kit (Yafa Bioengineering Co., Wuhan, China).

1.2 Animal treatment

Male Wistar rats (Certificate № 97004), weighing 230 – 280 g, were purchased from Experimental Animal Center, Tongji Medical College. The rats were treated ip twice with normal saline, baicalin or nimodipine at 30 min before ischemia and again 12 h after reperfusion, respectively. Five groups were studied: sham-operated group; I-R model group; baicalin 60 and 120 $mg\cdot kg^{-1}$ groups; nimodipine 0.7 $mg\cdot kg^{-1}$ group.

1.3 Establishment of focal cerebral ischemia model

Focal cerebral ischemia was induced by transient middle cerebral artery (MCA) occlusion in the right hemisphere as previously described[10]. Briefly, after the rats were anesthetized with chloral hydrate (350 $mg\cdot kg^{-1}$, ip), a midline incision through the neck was made to expose the right common carotid artery, the external carotid artery (ECA) and the internal carotid artery (ICA). A 4-0 monofilament nylon suture (ϕ 0.24 mm), its tip had been blunted by heating near a flame and coated with poly-*L*-lysine, was inserted into the ECA and advanced into the ICA to occlude the origin of the MCA. After 2 h of ischemia, the suture was removed and the animals were allowed to recover. The body temperature of the rats was maintained at 36.5 – 37.5℃ during the surgery by a heating lamp.

1.4 Neurological deficit evaluation and infarct volume measurement

Neurological deficits were evaluated after 24 h reperfusion using a 5-point scoring system according to the method of Longa *et al*[10]. At the end of each experiment, the animal was sacrificed and the brains were removed rapidly for tissue slicing. Five 2 mm thick coronal slices were stained with 2% 2, 3, 7-triphenyltetrazolium chloride, then fixed with 10% formalin solution (pH 7.4). In each section, the cortical and subcortical infarcted area was measured from planimetric analysis of digitized image. The infarct volume was calculated by multiplying the sum of infarct areas of 5 sections with their thickness 2 mm. In order to minimize the effects of edema on infarction size calculations, the area of uninfarcted tissue in the ischemic hemisphere was measured and subtracted from the area of the

contralateral hemisphere.

1.5 Western blot analysis for nuclear factor-κB (NF-κB)

Protein in the various samples was extracted and purified by Trizol reagent, and the concentration was determined according to the Bradford method[11]. An aliquot of 20 μg of protein from each sample was separated on 12% SDS-polyacrylamide gel electrophoresis. After transfer to PVDF membrane, blots were probed with primary antibidies (anti-p65 antibody, 1∶600 dilution), followed by incubation with HRPO-conjugated secondary antibody (1∶800 dilution). NF-κB proteins were visualized by enhanced chemiluminescence and the relative amount was obtained after normalization with β-actin in the same lane.

1.6 MPO activity and IL-1 level

Twenty-four hours after reperfusion, rats were sacrificed and the brains were rapidly removed and separated into right and left hemisphere on ice. Tissue samples, obtained from the surrounding region of the MCA distribution in the ipsilateral hemisphere was isolated and store at −70℃ for later biochemical analysis. The spectrophotometer and radioimmunoassay methods were used to assay MPO activity and IL-1 level according to the description of the assay kits, respectively.

1.7 Immunohistochemistry for ICAM-1

After 24 h reperfusion, the rats were anesthetized again and perfused with normal saline solution, followed by 4% paraformaldehyde. Brain ischemic penumbra area was removed and post-fixed in the same fixative and cytoprotected in 25% sucrose solution. The brain tissues were embedded in paraffin blocks and sectioned at 8 μm thickness for hematoxylin-eosin (HE) staining or 20 μm for immunohistochemical study.

The expression of ICAM-1 protein in brain was visualized by immunohistochemical assay kit, as recommended by the manufacturer. Briefly, endogenous peroxidase activity of the sections were blocked with H_2O_2. Then, the sections were incubated with the rabbit anti-rat ICAM-1 polyclonal antibody (Boster Biotechnology Co., Wuhan, China), biotinylated goat anti-rabbit IgG, and avidin-biotin-peroxidase complex in turn. After stained by DAB, the sections were observed under light microscopy. Photos were taken and quantitative analysis was conducted with image analysis system in 5 fields of each slide. The negative controls were performed without the primary antibodies.

1.8 RT-PCR analysis for iNOS

Total RNA from different samples was isolated and purified by Trizol reagent. Total RNA 1 μg was reverse-transcribed using the RT-PCR kit according to the manufacturer′s protocol. PCR was performed in a 25 μL reaction mixture containing 100 $nmol \cdot L^{-1}$ of each primer for iNOS (sense, 5′- TCCCGAAACGCTACACTTCC-3′; antisense, 5′-AACGTGGGGTTGTTGCTGAA-3′) or β-actin (sense, 5′-CCTCTATGCCAACACAGTGC-3′; antisense, 5′-GTACTCCTG CTTGCTGATCC-3′). The PCR primers used for detection of iNOS and β-actin yielded cDNA products of 520 bp and 211 bp, respectively. The conditions for PCR were one cycle of denaturing at 94℃ for 5 min, followed by 32 cycles of 94℃ for 45 s, 56℃ for 45 s, 72℃ for 1 min with a final extension at 72℃ for 7 min. PCR products were electrophoresed on a 2% agarose gel and photographed. Digitized photographs were assessed with gel imaging software and the relative value of iNOS compared to β-actin was calculated in each sample.

1.9 Statistical analysis

All data were expressed as $\bar{x} \pm s$. One way ANOVA was made by SPSS software to assess statistical significance between drug groups and various related control groups.

2 RESULTS

2.1 Effects of baicalin on cerebral infarct volume and neurological deficit

Transient occlusion of the MCA produced a well-delineated infarction involving the cortex

Tab 1. Effects of baicalin on cerebral infarct volume and neurological deficit score after cerebral ischemia (2 h)-reperfusion(24 h) (I-R)in rats

Group	Dose/ mg·kg^{-1}	Infarct volume/mm^3			Neurological deficit score
		Cortex	Sub-cortex	Total	
Sham	–	–	–	–	–
I-R model	–	172 ± 34	46 ± 17	218 ± 41	2.4 ± 0.9
Baicalin	60	123 ± 38 *	36 ± 15	160 ± 46 *	1.6 ± 0.5
	120	113 ± 42 *	32 ± 12	146 ± 54 *	1.4 ± 0.6 *
Nimodipine	0.7	122 ± 29 *	34 ± 14	156 ± 39 *	1.5 ± 0.5

Cerebral I-R injury model was induced by middle cerebral artery occlusion. Baicalin and nimodipine were given ip twice at 30 min before ischemia and again 12 after reperfusion. Sham and I-R rats received normal saline 0.5 mL·kg^{-1} according to the same protocol. $\bar{x} \pm s$, $n = 6$. $^{*}P < 0.05$, compared with I-R rats.

and the subcortical area at 24 h after reperfusion. After treatment with baicalin or nimodipine, the total and cortical infarct area was markedly reduced, but the subcortical infarct area was not reduced, compared with the I-R group. The neurological deficit was also ameliorated by baicalin (Tab 1).

2.2 Effect of baicalin on the expression of NF-κB protein

As shown in Fig 1 A and B, although the expression of NF-κB protein was weak in cortex of sham-operated rats, it has been obviously induced in cortex of I-R rats. After treated with baicalin, the expression of NF-κB protein was significantly reduced, compared with I-R rats.

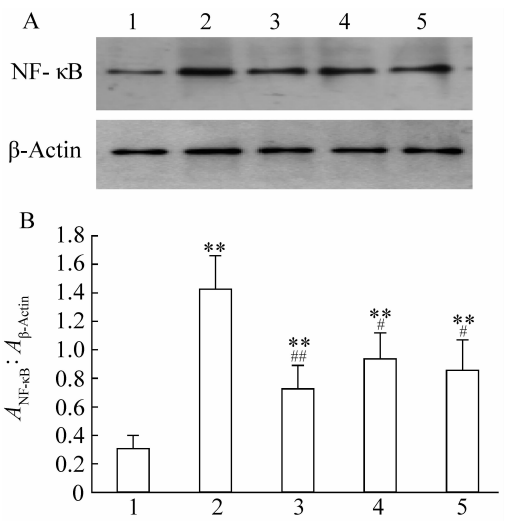

Fig 1. Effect of baicalin on expression of nuclear factor-κB (NF-κB) protein in cerebral cortex after I-R in rats. Lane 1: sham; lane 2: I-R; lane 3: baicalin 120 mg·kg^{-1}; lane 4: baicalin 60 mg·kg^{-1}; lane 5: nimodipine 0.7 mg·kg^{-1}. See Tab 1 for rat treatments. $\bar{x} \pm s$, $n = 4$. $^{**}P < 0.01$, compared with sham-operated rats; $^{\#}P < 0.05$, $^{\#\#}P < 0.01$, compared with I-R rats.

2.3 Effect of baicalin on neutrophil infiltration

Transient cerebral ischemia led to a massive increase in MPO activity in ischemic cortex, from (7.0 ± 2.0) to (15.0 ± 4.0) nmol·min^{-1}·g^{-1} wet tissue ($n = 6$, $P < 0.01$). After treatment with baicalin 120 mg·kg^{-1}, the activity of MPO was significantly reduced to (10.0 ± 2.3) nmol·min^{-1}·g^{-1} wet tissue ($n = 6$, $P < 0.05$, compared with I-R group). HE staining showed that baicalin ameliorated markedly the infiltration of inflammatory cell in ischemic area (Fig 2).

2.4 Effect of baicalin on the expression of ICAM-1 and iNOS mRNA

The expression of ICAM-1 in the endothelium was detected by immunohistochemistry, and the outline of brown-stained microvessels was shown. In the sections of sham-operated rat brain, brown-stained vessels were not found. After ischemia 2 h and reperfusion 24 h, the number and intensity of ICAM-1 positive vessels in the ischemic cortex apart from the ischemic core increased significantly. After treatment with baicalin, the expression of ICAM-1 on the microvascular endothelium was down-

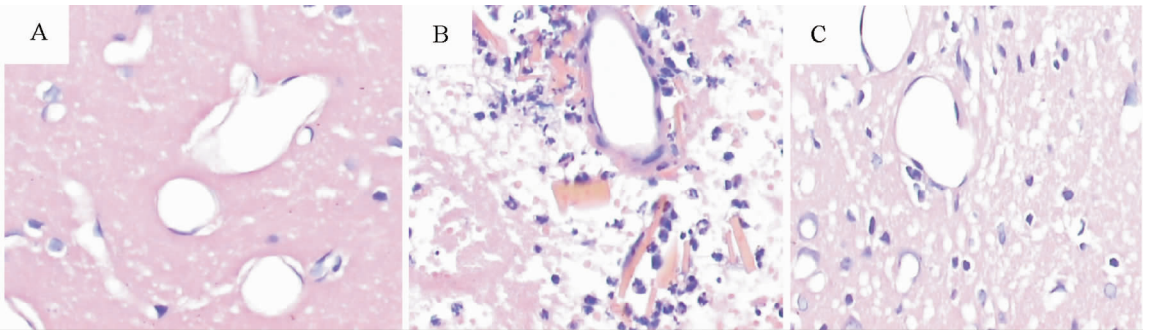

Fig 2. Representative photographs of cerebral cortex after I-R in rats (HE staining). A: sham-operated group; B: I-R group; C: baicalin 120 mg·kg^{-1} group. See Tab 1 for rat treatments. ×400.

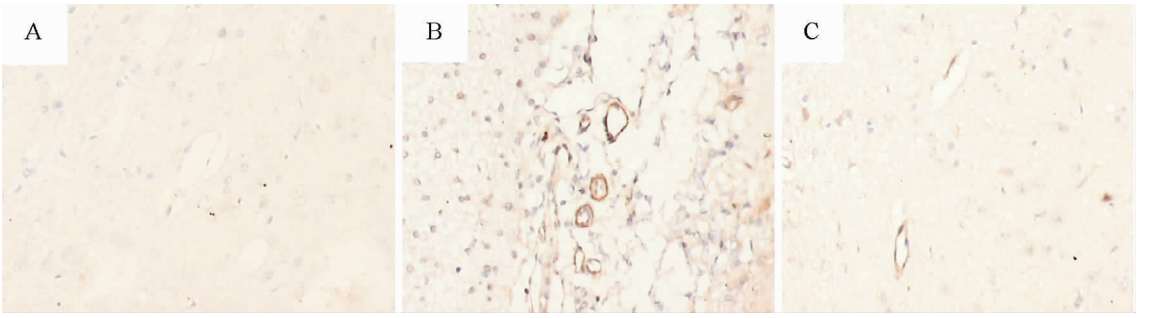

Fig 3. Representative photographs of intracellular adhesion molecule-1 (ICAM-1) expression in cerebral cortex after I-R in rats. A: sham-operated group; B: I-R group; C: baicalin 120 mg·kg^{-1} group. See Tab 1 for rat treatments. ×200.

regulated (Fig 3, Tab 2). Although the expression of iNOS mRNA was not detected in the sham-operated rat brain, it has been induced significantly in cerebral cortex after I-R injury. After administration with baicalin, the expression of iNOS mRNA was markedly decreased, compared with the I-R rats (Fig 4 A and B).

Tab 2. Effect of baicalin on ICAM-1 expression after I-R in rats

Group	Dose/mg·kg^{-1}	Absorbance
Sham	–	0.06 ± 0.02
I-R	–	0.24 ± 0.05**
Baicalin	60	0.14 ± 0.04$^{*\#}$
	120	0.12 ± 0.05$^{\#\#}$

See Tab 1 for rat treatment. The absorbance of ICAM-1 was summed in 5 fields of each slide. $\bar{x} \pm s$, $n = 4$. $^{*}P < 0.05$, $^{**}P < 0.01$, compared with sham-operated rats; $^{\#}P < 0.05$, $^{\#\#}P < 0.01$, compared with I-R rats.

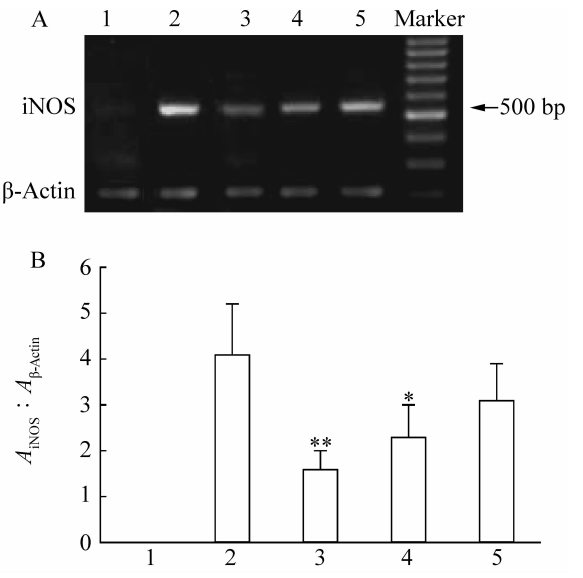

Fig 4. Effect of baicalin on expression of inducible nitric oxide synthase (iNOS) mRNA in cerebral cortex after I-R in rats. See Tab 1 for treatments. Lane 1: sham; lane 2: I-R; lane 3: baicalin 120 mg·kg^{-1}; lane 4: baicalin 60 mg·kg^{-1}; lane 5: nimodipine. $\bar{x} \pm s$, $n = 4$. $^{*}P < 0.05$, $^{**}P < 0.01$, compared with I-R rats.

2.5 Effect of baicalin on IL-1 level

After I-R injury, IL-1 level was increased from (0.86 ± 0.26) to (1.79 ± 0.31) $\mu g \cdot L^{-1}$ ($n = 6$, $P < 0.01$). Baicalin 60 and 120 $mg \cdot kg^{-1}$ treatment markedly decreased IL-1 level to (1.25 ± 0.33) and (1.06 ± 0.24) $\mu g \cdot L^{-1}$, respectively ($n = 6$, $P < 0.01$, $P < 0.05$, compared with I-R group). However, nimodipine had no significant effect on the IL-1 production, which was (1.37 ± 0.24) $\mu g \cdot L^{-1}$.

3 DISCUSSION

Focal cerebral ischemia is known to result in a dense ischemic core and a less severe ischemic penumbra. Some studies have found a time-dependent enlargement of brain infarction volume after reperfusion, implying that some of the ischemic penumbra has developed into infarction. Many factors have been implicated in the mechanisms of the secondary injury, including inflammatory reaction induced by release of proinflammatory cytokines and adhesion molecules, such as IL-1 and ICAM-1, etc., which is thought to exacerbate tissue injury by facilitating leukocyte adhesion to endothelium and migration, obstructing capillaries and releasing cytotoxic products, etc. So the anti-inflammatory drugs may play a protective effect on the second injury by decreasing the expression of ICAM-1, neutrophils infiltration or proinflammatory cytokines after transient ischemic insult.

In the present study, the expression of ICAM-1 protein and iNOS mRNA was increased by several folds after transient cerebral ischemia, which is consistent with former reports[12], and the level of NF-κB protein was parallelly increased. Our present study also revealed that cerebral ischemia resulted in the accumulation of neutrophils in the surrounding ischemic cortex region. Baicalin adminstration significantly improved neurological deficit, decreased the volume of cortex infarction. Meanwhile, our findings of decreased ICAM-1 expression, coincident with reduced tissue accumulation of neutrophils, suggesting that baicalin treatment attenuate ischemic neuronal injury by inhibiting infiltration of peripherial inflammatory cells.

NF-κB, an inducible transcription factor, plays a pivotal role on the regulation of inflammatory cascade response to cerebral ischemia. On activation by a wide range of extracellular signals after ischemic attack, including oxidant stress and proinflammatory cytokines, NF-κB triggers the expression of inflammation genes, such as ICAM-1, iNOS, as well as IL-1, and exhibits neurotoxic effects[13]. Therefore, some agents that inhibit or block the extracellular signals of NF-κB may decrease the NF-κB expression, further reduce the expression of inflammatory genes. In our study, NF-κB expression was increased in ischemic cortex, which was likely due to high concentrations of reactive oxygen system, a known activator of NF-κB. Accordingly, NF-κB activation was accompanied with iNOS and ICAM-1 over-expression. Baicalin is a polyphenolic flavonoid compound and possesses potent antioxidant action, which provides a chemical base for inhibiting the NF-κB activation. Our study found that baicalin decreased the expression of NF-κB protein, which may be related to its elimination on oxygen free radicals, and prevent amplification of inflammation by inhibiting IL-1 production. The observation was consistent with previous findings *in vitro* models[3, 5, 14]. The expression of ICAM-1, IL-1 and iNOS was also decreased simultaneously. To sum up, these results support the previous information that inhibition of NF-κB activation is neuroprotective and can effectively limit neuronal loss from I-R injuries *via* modulating proinflammatory cytokine and adhesive molecule expression[13].

In conclusion, baicalin possesses protective effect on cerebral injury induced by transient MCA occlusion. The improved outcome is associated with its inhibitory effect on NF-κB activation, adhesive molecule expression, as well as pro-inflammatory mediators release. The study provides a theoretical base for clinical use of ba-

icalin.

4 REFERENCES:

[1] Danton GH, Dietrich WD. Inflammatory mechanisms after ischemia and stroke[J]. *J Neuropathol Exp Neurol*, 2003, **62**(2):127 - 136.

[2] Minami M, Satoh M. Chemokines and their receptors in the brain: pathophysiological roles in ischemic brain injury[J]. *Life Sci*, 2003, **74**(2 - 3):321 - 327.

[3] Chen CC, Chow MP, Huang WC, Lin YC, Chang YJ. Flavonoids inhibit tumor necrosis factor-alpha-induced up-regulation of intercellular adhesion molecule-1 (ICAM-1) in respiratory epithelial cells through activator protein-1 and nuclear factor-kappaB: structure-activity relationships[J]. *Mol Pharmacol*, 2004, **66**(3): 683 - 693.

[4] Gao Z, Huang K, Yang X, Xu H. Free radical scavenging and antioxidant activities of flavonoids extracted from the radix of *Scutellaria baicalensis* Georgi[J]. *Biochim Biophys Acta*, 1999, **1472**(3):643 - 650.

[5] Nakamura N, Hayasaka S, Zhang XY, Nagaki Y, Matsumoto M, Hayasaka Y, *et al*. Effects of baicalin, baicalein, and wogonin on interleukin-6 and interleukin-8 expression, and nuclear factor-kappaB binding activities induced by interleukin-1beta in human retinal pigment epithelial cell line[J]. *Exp Eye Res*, 2003, **77**(2): 195 - 202.

[6] Shen YC, Chiou WF, Chou YC, Chen CF. Mechanisms in mediating the anti-inflammatory effects of baicalin and baicalein in human leukocytes[J]. *Eur J Pharmacol*, 2003, **465**(1 - 2):171 - 181.

[7] Ouyang CH, Wu JL, Li LZ. Protective effect of baicalin on lipid peroxidation induced by myocardial post ischemic reperfusion in rats[J]. *J Xianning Med Coll* (咸宁医学院学报), 2001, **15**(1):32 - 34.

[8] Heo HJ, Kim DO, Choi SJ, Shin DH, Lee CY. Potent inhibitory effect of flavonoids in *Scutellaria baicalensis* on amyloid beta protein-induced neurotoxicity[J]. *J Agric Food Chem*, 2004, **52**(13):4128 - 4132.

[9] Lee HH, Yang LL, Wang CC, Hu SY, Chang SF, Lee YH. Differential effects of natural polyphenols on neuronal survival in primary cultured central neurons against glutamate- and glucose deprivation-induced neuronal death[J]. *Brain Res*, 2003, **986**(1 - 2):103 - 113.

[10] Longa EZ, Weinstein PR, Carlson S, Cummins R. Reversible middle cerebral artery occlusion without craniectomy in rats[J]. *Stroke*, 1989, **20**(1):84 - 91.

[11] Bradford MM. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding[J]. *Anal Biochem*, 1976, **72**:248 - 254.

[12] Sundararajan S, Gamboa JL, Victor NA, Wanderi EW, Lust WD, Landreth GE. Peroxisome proliferator-activated receptor-gamma ligands reduce inflammation and infarction size in transient focal ischemia[J]. *Neuroscience*, 2005, **130**(3):685 - 696.

[13] Mattson MP, Culmsee C, Yu Z, Camandola S. Roles of nuclear factor kappaB in neuronal survival and plasticity[J]. *J Neurochem*, 2000, **74**(2):443 - 456.

[14] Song YZ, Yang YJ, Jia YJ. Effect of baicalin on the expression of nuclear factor-κB/IκBα induced by hydrogen peroxide in astrocytes[J]. *Chin J Contemp Pediatr* (中国当代儿科杂志), 2002, **4**(6):436 - 438.

黄芩苷对大鼠局灶性短暂性脑缺血再灌继发炎性损伤的保护作用

欧阳昌汉, 吴基良
(咸宁学院药理学教研室, 湖北 咸宁　437100)

摘要: 目的　研究黄芩苷对大鼠短暂性脑缺血再灌损伤的保护作用是否与其调节炎症因子和粘附分子的表达有关。**方法**　线栓法制备大脑中动脉阻断短暂局灶性脑缺血模型,缺血 2 h, 再灌注 24 h。评价神经功能状态和脑梗死体积;用免疫组化、分光光度法测定组织细胞间粘附分子(ICAM)1 表达和髓过氧化物酶活性;HE 染色观察组织炎性细胞浸润;RT-PCR、免疫印迹和放免法分别测定大脑缺血皮质诱导型一氧化氮合酶(iNOS)、核因子 κB(NF-κB)和白细胞介素 1(IL-1)的表达。**结果**　黄芩苷能显著降低大鼠短暂性脑缺血后皮质梗死体积,改善神经功能状态,抑制 ICAM-1, iNOS 和 NF-κB 表达,降低缺血皮质 IL-1 含量,与模型组相比具有显著性差异。**结论**　黄芩苷通过抑制炎性介质的表达和释放对大鼠短暂性脑缺血损伤具有保护作用。

关键词: 黄芩苷; 脑缺血; 细胞间粘附分子; 一氧化氮合酶; NF-κB; 白细胞介素 1

(本文编辑　董立春)