Nuclear factor κB inactivation in the rat liver ameliorates short term total warm ischaemia/reperfusion injury

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Background: In hepatic ischaemia/reperfusion injury, activated liver macrophages (Kupffer cells) are dominantly regulated by a transcription factor, nuclear factor κB (NFκB), with respect to expression of inflammatory cytokines, acute phase response proteins, and cell adhesion molecules.

Aims: We assessed whether inactivation of NFκB in the liver could attenuate total hepatic warm ischaemia/reperfusion injury.

Methods: We studied rats with hepatic overexpression of inhibitor κB super-repressor (IkBα SR) caused by a transgene introduced using an adenoviral vector. Hepatic ischaemia/reperfusion injury was induced under warm conditions by total occlusion of hepatoduodenal ligament structures for 20 minutes, followed by reperfusion. Controls included uninfected and control virus (AdLacZ) infected rats.

Results: IkBα SR was overexpressed in Kupffer cells as well as in hepatocytes, blocking nuclear translocation of NFκB (p65) into the nucleus after reperfusion. Gene transfection with IkBα SR, but not with LacZ, markedly attenuated ischaemia/reperfusion injury, suppressing inducible nitric oxide synthase and nitrotyrosine expression in the liver. Moreover, no remarkable hepatocyte apoptosis was detected under IkBα SR overexpression.

Conclusions: Adenoviral transfer of the IkBα SR gene in the liver ameliorates short term warm ischaemia/reperfusion injury, possibly through attenuation of hepatic macrophage activation.
of human IkB (IkBz S32A/S36A) was generated as reported elsewhere. Ad5LacZ, encoding the Escherichia coli β-galactosidase gene, was used as a control adenovirus. Adenoviral stock was amplified in HEK293 cells (CRL1573.ATCC; Manassas, Virginia, USA) and purified by double caesium gradient, as described previously, and plaque tittered. HEK293 cells were incubated in Dulbecco's modified Eagle's medium supplemented with 10% (v/v) fetal bovine serum (Dainippon Pharmaceutical, Japan) and penicillin (100 IU/ml)/streptomycin (100 μg/ml) (Meiji Seika, Japan) at 37°C. When the cells reached confluence they were infected with Ad5IkB or Ad5LacZ at a multiplicity of infection of 200 for 48–72 hours in Dulbecco's modified Eagle's medium with 5% fetal bovine serum. Adenoviruses were dialysed in 1000 ml of dialysis buffer (phosphate buffered saline 10% glycerol) overnight at 4°C before use.

Animal protocols and hepatic ischaemia/reperfusion procedure

All animals were handled according to the method approved under the institutional guidelines outlined in the Guide for Use and Care of Laboratory Animals of Kyoto University Graduate School of Medicine. Male Sprague-Dawley rats with a starting weight of 240–255 g (7–8 weeks old) were used. Recombinant adenoviruses were administered through their tail veins in a volume of 250 μl (5 × 10⁹ pfu/body) with 27 G needles. No viruses were injected in uninfected control rats. After laparotomy, whole hepatic ischaemia was induced clamping inferior vena cava at 10 and 40 minutes after reperfusion, these vessels were unclamped leading to reperfusion of the liver. This model is sublethal and exhibits resemblance to a clinical situation (Pringle's manoeuvre). After 20 minutes, these vessels were unclamped leading to reperfusion of the liver. This model is sublethal and exhibits less liver injury compared with that previously published. 

Seventy two hours after infection, rats were anaesthetised by intraperitoneal injection of 0.1 μl/g Nembutal (pentobarbital sodium 50 mg/ml; Dainippon Pharmaceutical). After laparotomy, whole hepatic ischaemia was induced clamping the hepatic artery, portal vein, and bile duct for 20 minutes without any decompression of the splanchic circulation, resembling a clinical situation (Pringle's manoeuvre). After 20 minutes, these vessels were unclamped leading to reperfusion of the liver. This model is sublethal and exhibits less liver injury compared with that previously published.

Because adenoviral infection per se possibly induces transient liver injury due to its immunogeneity, we performed the ischaemia/reperfusion procedure at 72 hours when transient liver injury induced by adenovirus should have returned to near normal. Small amounts of blood (0.4 ml) were collected from the inferior vena cava at 10 and 40 minutes after reperfusion, and liver tissues and blood samples were taken when the animals were sacrificed at 180 minutes. In some rats, liver tissues and blood samples were collected at 12 or 24 hours after reperfusion when the animals were sacrificed. At least four rats in each group were analysed at each time point. Serum separated from these samples was used for enzymatic measurement of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and lactate dehydrogenase (LDH). Serum concentration of TNF-α in each animal was also measured by means of an ELISA kit (Genzyme, Cambridge, Massachusetts, USA). Samples of the liver were snap frozen in liquid nitrogen or mounted in Tissue Tec (Sakura Finetechical Co., Tokyo, Japan) and stored at −80°C for immunohistochemistry. Some of the tissues were fixed in 10% buffered formalin for subsequent histological analysis (haematoxylin-eosin staining).

Histological assessment

Liver injury was accessed using liver specimens stained with haematoxylin-eosin. The extent of sinusoidal congestion, cytoplasmic vacuolation, and liver necrosis was semiquantitatively assessed, respectively, according to a scoring criteria previously published. Namely, congestion and vacuolation were evaluated as follows: none = 0, minimal = 1, mild = 2, moderate = 3, and severe = 4. Liver necrosis was scored as follows: none = 0, single cell necrosis = 1, up to 30% lobular necrosis = 2, up to 60% lobular necrosis = 3, and more than 60% lobular necrosis = 4. Scoring was performed in five independent high power fields on each sample, and mean values were represented. Blind analysis was performed on all samples. Infiltration of neutrophils into the liver was also estimated by means of naphthol AS-D chloroacetate esterase staining. The number of esterase positive polymorphonuclear cells was counted in 10 high power fields (×400) in each sample, and mean values were calculated.

X-gal staining analysis and immunofluorescence

Efficiency of gene transfer after adenoviral infection was assessed with X-gal staining of liver tissues from rats infected with Ad5LacZ at 72 hours. Frozen sections from the liver were evaluated for β-galactosidase activity by incubation in X-gal solution (3.3 mM K₄Fe(CN)₆·3H₂O, 3.3 mM KFe(CN)₆, 1 mM MgCl₂, 0.2% X-gal (5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside); Roche Diagnostics, Switzerland).

To access whether liver macrophages were transfected with Ad5LacZ more accurately, immunofluorescent staining against β-galactosidase and surface antigen of macrophages was performed. Frozen liver samples were cut into cryostat sections 5 μm in thickness, and fixed in acetone for 10 minutes. After washing with phosphate buffered saline, sections were incubated with mouse antiserum antigen of macrophages monoclonal antibody (ED-1, 1: 100 dilution; Chemicon International, Temecula, California, USA) and rabbit anti-β-galactosidase polyclonal antibody (1:200; ICN Pharmaceuticals, Inc., Aurora, Ohio, USA) for 60 minutes. Slides were washed with phosphate buffered saline and then incubated for 30 minutes with FITC conjugated goat antimouse IgG (1:50 dilution; Southern Biotechnology Associates, Inc., Birmingham, UK) and Texas red conjugated goat antirabbit IgG. (1: 50 dilution; Southern Biotechnology Associates, Inc.). Localization of β-galactosidase and liver tissue macrophages, and Kupffer cells was analysed using a confocal laser scanning microscope LSM510 (Carl Zeiss, Jena, Germany).

Western blot analysis for IkBα and iNOS

Rats were infected with Ad5IkB (2.5 × 10¹⁰ pfu/body) for 72 hours. Expression of dominant negative IkB protein was assessed in 20 μg of whole liver homogenates using rabbit anti-IkBα antibody (1:1000; Santa Cruz Biotechnology, Santa Cruz, California, USA). Equal amounts of lysates were electrophoresed on 15% sodium dodecyl sulphate-polyacrylamide gel electrophoresis and transferred to a polyvinylidene difluoride membrane. After blocking, the membrane was incubated with the first antibody at 4°C overnight and then with the horseradish peroxidase linked goat antirabbit secondary antibody at 1:1000 dilution (Santa Cruz Biotechnology). Chemiluminescence was detected with an ECL kit, as previously described. Equal protein loading was confirmed by staining the gels with the Coomassie stain solution (Bio-Rad Laboratories, Hercules, California, USA). For western blot of inducible nitric oxide synthase (iNOS), rabbit anti-iNOS antibody (1:1000 dilution; sc-8310, Santa Cruz Biotechnology) was used, and subsequent procedures were performed as described above.

Immunohistochemistry for NfκB, HA tagged IκBα 5R, 4-HNE, and nitrotyrosine

Paraffin embedded sections were pretreated by microwaving for 20 minutes with 1% bovine serum albumin in 0.05 M Tris buffer for 20 minutes.
HCl, pH 7.6. After blocking of endogenous peroxidase with peroxidase blocking agent, sections were incubated for 60 minutes at 37°C with goat polyclonal antibody against NFkB p65 (1:100 dilution; c-20-sc-372G; Santa Cruz Biotechnology). After being washed, sections were incubated for 60 minutes with biotin conjugated rabbit antibody against goat (1:200 dilution; AP106-b; Chemicon) labelled with peroxidase streptavidin, and visualised under UV transillumination.

Reverse transcriptase-polymerase chain reaction (RT-PCR) assay for NFkB
Messenger RNA was extracted from frozen liver tissue with a mRNA purification kit (Amersham Biosciences Corp., Piscataway, New Jersey, USA). The concentration of mRNA was ascertained by UV spectrophotometer at 260 nm and 10 μg of mRNA were used to synthesise first strand cDNA with the First Strand cDNA kit (Amersham Pharmacia). Rat TNF-α was amplified using the primer pair (each 100 μM, Bp, 5′-CAC GCT CTT CTG ACT GA-3′, forward; 5′-GGA CTC CGT GAT GTC TAA GT-3′, reverse) in a 50 μl PCR reaction containing 1.5 mM MgCl₂, 50 mM KCl, 10 mM Tris HCl, pH 8.3, and 1.4 mM deoxynucleotides (10 mM each) using 3 μl cDNA template. Dilutions of cDNA were amplified for 30 cycles at 94°C for 20 seconds, 56°C for 60 seconds, and 72°C for 60 seconds. β-Actin probe was used as the integrity control, using the primers synthesised from conserved coding sequences (265 bp, 5′-TCC TAT GTG GGT GAC GAG GC-3′, forward; 5′-TAC ATG GCT GGG GTG TTG AA-3′, reverse). PCR products were electrophoresed on 2% agarose gel, stained with ethidium bromide, and visualised under UV transillumination.

Gel mobility shift assay for NFkB
For the gel mobility shift assay for NFkB binding activity, nuclear extract protein was collected as described elsewhere.22 Double stranded NFkB specific oligodeoxynucleotide probe containing two tandemly positioned NFkB binding sites (GGG ATT TCC C) were labelled with [γ-32P]dCTP by Klenow fragment. Nuclear extract (3 μg) was incubated with a 300 fmol probe in a total of 25 μl of binding buffer (10 nM HEPES, 50 mM KCl, 1 mM EDTA, 5 mM MgCl₂, 10% glycerol, and 2 μg of poly-dIdC) for 20 minutes at room temperature. For the competition assay, a 50-fold molar excess of unlabelled oligodeoxynucleotide probe was added to nuclear extract for 15 minutes before addition of the labelled probe. The supershift assay was performed by preincubating with 1 μg of anti-p65 or anti-p50 antibodies (Santa Cruz Biotechnologies) for 60 minutes at 4°C before addition of the labelled probe. After incubation, samples were fractionated on a 4% polyacrylamide gel in 25 mM Tris Cl (pH 8.5), 190 mM glycine, and 1 mM EDTA. The gel was subsequently dried and visualised by autoradiography.

In situ detection of apoptosis
Formalin fixed paraffin embedded liver sections (5 μm) were deparaffinised in xylene and rehydrated through graded ethanol. After blocking of endogenous peroxidase with peroxidase blocking agent, sections were incubated with protease K (20 μg/ml) for 10 minutes. Then, sections were incubated with a goat anti-single strand DNA polyclonal antibody (1:400 dilution; A4506; Dako Cytomation, Kyoto, Japan), which detects apoptotic cells in situ, for 60 minutes at room temperature. After being washed, sections were incubated for 30 minutes with biotin conjugated rabbit antibody against goat (1:200 dilution; AP106-b; Chemicon) labelled with peroxidase streptavidin, and with chromogen conjugated DAB substrate for 90 seconds. Counterstaining was performed with methyl green.

Statistical analyses
Data are expressed as means (SD), and the statistical significance of differences among groups was assessed by the Student’s t test or Mann-Whitney test, as appropriate. A p value less than 0.05 was regarded as statistically significant.

Figure 1  Efficiency of adenovirus mediated gene transfer. (A) Extracts from liver homogenate (20 μg) from uninfected, Ad5LacZ infected, and Ad5IκB infected animals were examined by western blot against inhibitor κB (IkB) antibodies. Black arrow indicates inflammatory (HA) tagged IkB super-repressor (IkB SR). (B, C) Immunohistochemistry of HA tagged IkB SR (B × 200, C × 400). Black arrowheads indicate HA positive non-parenchymal cells in the liver. Immunofluorescent staining of surface antigen of macrophages (ED-1; D) and β-galactosidase (E), and their superimposed image (F) are presented (×400). Each datum is representative of four separate experiments.
RESULTS

Efficiency and targets of adenoviral gene transfer in vivo

Efficiency of adenoviral gene transfer in vivo was determined by western blotting with antibodies against IkB and immunostaining of HA tagged IkB or β-galactosidase. As reported previously, western blotting using anti-IkB antibody demonstrated high expression of HA tagged IkB S32A/S36A only in liver homogenates from Ad5IkB infected rats, not those from uninfected or Ad5LacZ infected rats (fig 1A). Immunohistochemistry using anti-HA antibody directed against HA tagged IkB SR demonstrated that more than 80% of liver cells expressed IkB SR (fig 1B, C). This efficiency was similar to that of Ad5LacZ, which was determined by X-gal staining (data not shown). More detailed morphological analysis revealed that non-parenchymal cells of the liver as well as hepatocytes were expressing IkB SR (fig 1C, arrowheads). To further determine whether liver macrophages were infected with recombinant adenoviral vectors, immunofluorescent analysis of frozen liver tissues was carried out. Immunofluorescence against β-galactosidase and macrophage specific surface antigen revealed that approximately 60% of liver macrophages as well as about 80% of hepatocytes were immunoreactive for β-galactosidase (fig 1D–F). Only a few sinusoidal endothelial cells or hepatic stellate cells were reactive for β-galactosidase according to immunofluorescence using an antirat platelet endothelial cell adhesion molecule 1 monoclonal antibody or a rabbit antirat desmin polyclonal antibody (data not shown).

Attenuation of short term warm ischaemia/reperfusion injury in the liver by IkB SR

In the present study, all rats in each group survived after reperfusion, possibly reflecting the short term nature of ischaemia. At 180 minutes after reperfusion, histological examination of uninfected and Ad5LacZ infected liver tissues demonstrated ballooning, and to some extent necrosis, of hepatocytes; these findings were most evident around the central veins (fig 2A, B). Inactivation of NFκB in the liver by overexpression of IkB SR markedly attenuated these post reperfusion histological changes (fig 2C). Semiquantitative scores for sinusoidal congestion, cytoplasmic vacuolisation, and hepatocytic necrosis at three hours were 1.4 (0.5), 1.1 (0.4), and 1.2 (0.5) (mean (SD)) in uninfected rats, and 1.7 (0.7), 1.3 (0.5), and 1.3 (0.6) in Ad5LacZ infected animals, respectively; these scores were 0.4 (0.5), 0.6 (0.6), and 0.4 (0.5) (mean (SD)) in Ad5IkB infected rats, all showing significant attenuation (p<0.05). Serum concentrations of AST, ALT, and LDH gradually increased in uninfected and Ad5LacZ infected groups and then returned to near normal values by 24 hours. No significant differences in serum concentrations of these liver enzymes were observed between these two groups (fig 2D–F). The transient increases in serum AST, ALT, and LDH were significantly attenuated in Ad5IkB infected rats at various time points. These results indicate that inactivation of NFκB in the liver by adenoviral gene transfer of IkB SR could ameliorate short term warm ischaemia/reperfusion injury.

Inhibition of nuclear translocation of NFκB and its DNA binding activity in the liver after I/R by transduction of IkB SR

Inmunohistochemistry for NFκB (p65) revealed that p65 had translocated to the nucleus in hepatocytes as well as in non-parenchymal liver cells (NPC) at three hours after reperfusion in uninfected or Ad5LacZ infected rats (fig 3A, B). Adenoviral gene transfer of IkB SR markedly suppressed this nuclear translocation of p65 in hepatocytes as well as in NPC (fig 3C). The percentage of NPC in which nuclear translocation of NFκB was detected was 85% in uninfected, 87% in Ad5LacZ infected, and 15% in Ad5IkB infected livers. Transgenes of LacZ or IkB SR had no effect on distribution of p65 in the liver before ischaemia/reperfusion (data not shown). The gel
mobility shift assay for NFκB demonstrated that gene transfer of IκBα SR dramatically suppressed DNA binding activity of NFκB after ischaemia/reperfusion while its DNA binding activity had increased markedly at three hours after reperfusion in uninjured or Ad5ILacZ infected liver (fig 3D).

We also analysed mRNA and protein expression of TNF-α and protein expression of inducible NOS (iNOS), whose genes are a target for NFκB, in the liver after reperfusion. TNF-α mRNA was barely detected in uninjured normal livers while its expression was markedly increased after reperfusion in uninjured and Ad5ILacZ infected livers (fig 3E, lanes 2–4). Overexpression of IκBα SR in the liver clearly blocked this increase even after reperfusion (fig 3E, lane 5). Serum concentrations of TNF-α at three hours after reperfusion, which were determined by ELISA, were similar to those of mRNA (fig 3F). Protein expression of iNOS markedly increased after reperfusion in uninjured and Ad5ILacZ infected livers while IκBα SR dramatically suppressed iNOS expression following reperfusion (fig 3F). These data suggest that transfer of IκBα SR effectively suppresses NFκB activation after reperfusion in non-parenchymal hepatic cells as well as in hepatocytes.

**Figure 3** Uninfected (A), Ad5LacZ infected (B), and Ad5IκBα infected (C) livers with ischaemia/reperfusion (×400) underwent immunohistochemical staining of nuclear factor κB (NFκB) p65. After reperfusion, a large number of nuclei were stained with the antibody in uninfected (A) and Ad5ILacZ infected (B) livers. In Ad5IκBα induced livers, only a small number of positive nuclei were detected (C). High power views showed that a large number of nuclei in non-parenchymal liver cells (NPCs, white arrowheads) as well as in hepatocytes were positive for p65 in uninfected (A, inset) and Ad5ILacZ infected (B, inset) livers. In contrast, in the Ad5IκBα infected liver, the nuclei of approximately 85% of hepatocytes were negative for p65 staining and only about 15% of NPCs were positive for p65 (C, inset). Black arrowheads indicate nucleus of NPCs, which were negative for p65. (D) Gel shift assay for NFκB. Nuclear extracts from fresh liver samples were assayed for NFκB DNA binding activity by electrophoretic mobility shift assay using a radiolabelled consensus NFκB site probe, as described in materials and methods. A 50-fold cold competitor was added to lane 10. Antibodies against p65 (RelA) or p50 were used for the supershift assay, respectively (for p65 lanes 2, 5, and 8; p-p50 lanes 3, 6, and 9). Data are representative of three separate experiments. (E) Messenger RNA expression of tumour necrosis factor α (TNF-α). After reperfusion, expression of TNF-α mRNA was strongly induced in uninfected and Ad5ILacZ infected animals (lanes 3 and 4). In Ad5IκBα infected animals (lane 5), expression of TNF-α mRNA was remarkably suppressed. Results are representative of three separate experiments. cDNA taken from rat liver injected with lipopolysaccharide (LPS) (10 mg/kg) for two hours was used as a positive control (lane 1). (F) Serum concentration of TNF-α in uninfected and Ad5LacZ infected animals (lanes 3 and 4). In Ad5IκBα infected animals (lane 4), the amount of iNOS was significantly smaller than in the other groups. Results are representative of three separate experiments. Normal, untreated normal rat liver.

**Attenuation of neutrophil infiltration into the liver by IκBα SR**

Infiltration of neutrophils, which play pivotal roles in inflammatory injury, was assessed in the liver by naphthol AS-D chloroacetate esterase staining. The number of infiltrating neutrophils obviously increased after reperfusion (three hours) in uninjured and Ad5ILacZ infected livers (fig 4A, B) while that in Ad5IκBα SR infected rats was not prominent, even after reperfusion (fig 4C). This effect was confirmed by counting esterase positive polymorphonuclear cells under microscopic high power fields (fig 4D).

**Lack of attenuation by IκBα SR of lipid peroxidation after reperfusion**

As a marker of lipid peroxidation resulting from oxidative stress in the liver after reperfusion, we used immunohistochemistry to detect HNE adducts in liver tissues. HNE adducts were not demonstrated in untreated normal rat livers (fig 4E) while significant amounts of HNE adducts were detected after reperfusion in untreated, Ad5ILacZ infected, and Ad5IκBα infected livers, particularly surrounding central veins (fig 4E–H). No difference in the distribution pattern of HNE adducts in the liver was observed between these three groups. These data indicate that inactivation of NFκB in the liver did not block lipid peroxidation by oxidative stress after ischaemia/reperfusion.

**Blockade of nitrotyrosine production after reperfusion by overexpressed IκBα SR**

We assessed tyrosine nitration, an index of nitrosylation of proteins by peroxynitrite and/or other free radicals, because iNOS expression was affected after reperfusion. Interestingly, nitrotyrosine adducts were detected preferentially along the sinusoidal area but not in hepatocytes, after short term ischaemia/reperfusion in uninjured and
Ad5LacZ infected livers (fig 5A, B). This increase in nitrotyrosine expression along sinusoids was dramatically suppressed in Ad5IkBa infected livers, suggesting that IkBa attenuated ischaemia/reperfusion injury through blockade of nitric oxide production by non-parenchymal hepatic cells (fig 5C).

**Suppression by IkBa SR of non-parenchymal cell apoptosis after reperfusion**

As the appearance of apoptotic cells in hepatic ischaemia/reperfusion injury remains controversial, we assessed apoptosis in the liver after reperfusion in our model. Using an antibody against single stranded DNA (ssDNA), a relatively small number of apoptotic cells were detected along the sinusoidal area at three hours after reperfusion in uninfected and Ad5LacZ infected livers, while occasionally apoptosis was also detected among hepatocytes (fig 5D, E). Gene transfer of IkBa SR suppressed the appearance of ssDNA containing cells after reperfusion (fig 5F), even though over 80% of hepatocytes were transfected with Ad5IkBa according to anti-HA immunostaining (fig 1B, C). Immunohistological analysis at 12 hours after reperfusion detected ssDNA in a few non-parenchymal cells, but not in hepatocytes, even in uninfected and Ad5LacZ infected livers (data not shown). These data suggest that proapoptotic signalling is not the main cause of reperfusion injury, at least after reperfusion following short term warm ischaemia.

**DISCUSSION**

In pathogenetic sequences underlying hepatic ischaemia/reperfusion injury, activated liver macrophages (Kupffer cells) have been assigned critical roles. During the cascade leading to activation of Kupffer cells, DNA binding activity of NFkB, a key regulator of genes encoding inflammatory cytokines, acute phase response proteins, and cell adhesion molecules, is upregulated through several mechanisms, including pathways dependent on oxidative stress or endotoxin. In the present study, we demonstrated that inactivation of NfkB in the liver using adenoviral gene transfer of IkBa SR effectively blocked a short term warm ischaemia/reperfusion injury that was transient and sublethal, showing a good resemblance to liver injury observed clinically after an intraoperative manipulation, Pringle's manoeuvre.

Immunohistochemical analysis demonstrated that the adenoviral gene transfer method used in the present study (dose 5 x 10⁹ pfu/rat) successfully delivered LacZ or IkBa SR into both parenchymal and non-parenchymal cells,
particularly Kupffer cells (fig 1B–F). Overexpressed IκBz SR effectively blocked nuclear translocation of NFκB (p65) in both cell types after reperfusion (fig 3C), abolishing increased p65 DNA binding activity that was observed in uninfected or Ad5LacZ infected rats (fig 3D). This effect resulted in marked suppression of genes whose expression is regulated by NFκB, such as TNF-α and iNOS, even after reperfusion (fig 3E–G).

Considering that a variety of inflammatory cytokines regulated by NFκB are produced predominantly by non-parenchymal cells in the liver,11 our results suggest that inactivation of Kupffer cells through blocking NFκB from DNA binding is possibly the major mechanism underlying the protective effect of IκBz SR observed in the present study.

Among potential mechanisms contributing to hepatic ischaemia/reperfusion injury,4 formation of ROS and reactive nitrogen species after reperfusion has been recognised as a critical factor.1–3 36–38 Generally, SOD scavenges superoxide to form oxygen and hydrogen peroxide, which is further detoxified via catalase to produce water and oxygen. An excessive amount of hydrogen peroxide, however, can undergo a one electron reduction with Fe (II) to form Fe (III) and the highly toxic hydroxyl radical, a very reactive species that rapidly induces lipid peroxidation.19 In the present study, inactivation of NFκB in parenchymal and non-parenchymal hepatic cells did not affect lipid peroxidation after reperfusion (fig 4E–H). This lipid peroxidation after reperfusion possibly accounts for the incomplete nature of suppression of transient increases in serum AST, ALT, and LDH in Ad5IκBz infected livers (fig 2D to F), even though they appeared nearly intact by haematoxylin–eosin staining (fig 2C).

Nitric oxide is another bioregulatory molecule produced in the liver after reperfusion; production involves upregulated expression of iNOS which has been implicated in the pathogenesis of ischaemia/reperfusion injury.2–4 35 While nitric oxide can directly affect cell signalling, it also forms peroxynitrite, a highly reactive nitrogen species produced by reaction with ROS that carries out nitration of tyrosine residues in proteins. In the present study, iNOS expression was blocked dramatically via NFκB inactivation (fig 3G), which should suppress nitric oxide synthesis even after reperfusion of Ad5IκBz infected livers. If nitric oxide synthesis is blocked, formation of peroxynitrite should be attenuated. This hypothesis was supported by suppressed expression of nitrotyrosine after reperfusion in these livers (fig 3C). Thus we conclude that suppression of iNOS induction by IκBz SR in non-parenchymal cells, possibly Kupffer cells, can account for part of the beneficial effect from IκBz SR gene transfer in the present study.

While the generally accepted mechanism of hepatic reperfusion injury is cell damage involving oncotic necrosis,11 several recent reports have proposed that apoptotic cell death during hepatic ischaemia/reperfusion also may participate in the mechanism of the injury.21–23 NFκB is known as an antiapoptotic transcription factor in the liver12 42 and its blockade results in frequent occurrence of apoptosis of hepatocytes under proapoptotic stimuli.16–18 In the present study, we blocked NFκB activation after reperfusion in both parenchymal and non-parenchymal cells by transfer of IκBz SR. However, we observed no remarkable appearance of apoptotic cells in Ad5IκBz infected livers even at 12 hours after reperfusion, while a few apoptotic cells, mainly non-parenchymal cells, were detected in uninfected and Ad5LacZ infected livers. Because the ssDNA staining might not be a definitive tool for detecting apoptotic cells, we cannot conclude that apoptotic cell death does not participate in the mechanism underlying reperfusion injury in short term warm total hepatic ischaemia. From our data, however, we speculate that apoptotic cell death does not play a major role in our model. Inactivation of NFκB in donor livers was found to increase histologically evident tissue injury and apoptosis after experimental liver transplantation representing cold hepatic ischaemia/reperfusion.40 Differences in animal models and duration of ischaemia may account for the disagreement between that report and our study.

In summary, we successfully attenuated hepatic reperfusion injury after short term warm total ischaemia by delivering the IκBz SR gene to the rat liver. Because NFκB may be required for proliferation of intact hepatocytes,27 non-parenchymal cell selective as opposed to non-selective inactivation of NFκB should be more beneficial if the strategy of the present study were applied to clinical situations. Moreover, relatively short term inactivation of NFκB limited to non-parenchymal cells would be safer than adenoviral gene expression of IκBz SR for 1–2 weeks. For example, Kupffer cell selective transfer of NFκB decoy, which binds NFκB and blocks its translocation to the nucleus,11 may come to represent a clinically important way of preventing ischaemia/reperfusion injury during hepatic surgery.

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Conflict of interest: None declared.

REFERENCES

EDITOR’S QUIZ: GI SNAPSHOT

Answer

From question on page 813

Helical computed tomography scan revealed a low density, well circumscribed cystic mass, 21 × 12 × 22 cm in size, in the left hepatic lobe with multiple daughter cysts floating inside, compatible with a hydatid cyst. The biliary system and spleen were normal (fig 1). Results of serum IgG antibody titre to Echinococcus granulosus was higher than 1:2560. Likewise, a pretreatment magnetic resonance cholangiogram was performed ruling out bile leaks.

In this case, perioperative treatment with albendazole, simple endocystectomy, aspiration of the residual contents of the cyst cavity, and omentoplasty were performed. After two months the patient was asymptomatic.

Cystic hydatid disease due to infection with the metacestode of Echinococcus granulosus has a worldwide distribution, and the liver is the most common site (70%). Surgery is the recommended treatment for hepatic hydatid cysts. However, encouraging reports suggest that under carefully controlled conditions, percutaneous aspiration with the use of concomitant antihelminthic therapy may be a safe alternative treatment.

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EDITOR'S QUIZ: GI SNAPSHOT

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