ORIGINAL ARTICLE

Tolerance of the Liver to Intermittent Pringle Maneuver in Hepatectomy for Liver Tumors

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Background: Hepatectomy can be performed with a low mortality rate, but massive hemorrhage during the operation remains a potentially lethal problem. The Pringle maneuver is traditionally used during hepatectomy to reduce blood loss, but the effect on the metabolic function of hepatocytes is potentially harmful. Although our randomized study showed that an intermittent Pringle maneuver is safe and effective during hepatectomy, the upper limit of the duration of the Pringle maneuver is not known.

Hypothesis: The liver can tolerate intermittent Pringle maneuver if the duration is not excessive.

Design: From July 20, 1995, to November 25, 1997, 112 patients underwent hepatectomy for liver tumors. The data of 50 patients who had hepatectomy without the Pringle maneuver were compared with those of 62 patients who had a liver transection using a Pringle maneuver for 20 minutes and a 5-minute clamp-free interval. The data were collected prospectively.

Main Outcome Measures: The surface area of liver transection was measured, and blood loss during liver transection per centimeter square of transection area was calculated. Routine liver biochemical tests, arterial ketone body ratio (AKBR), and plasma cytokine—interleukin (IL) 1α, 1β, 2, and 6, and tumor necrosis factor α—levels were measured before and after the operation. The morbidity and hospital mortality rates were also compared among the patients with different ischemic durations and those without an intermittent Pringle maneuver.

Setting: Tertiary referral center.

Results: The cutoff point of accumulated ischemic time that induced substantial liver damage, as shown by the postoperative recovery rate of the AKBR, was found to be 120 minutes. Compared with the control group, the patients whose accumulated ischemic time was shorter than 120 minutes had less blood loss related to transection area (10 mL/cm^2 vs 22 mL/cm^2; $P<.001$), less blood transfused (0 L vs 0.6 L; $P=.004$), a shorter transection time related to transection area (2.0 min/cm^2 vs 2.8 min/cm^2; $P=.002$), a significantly higher AKBR in the first 2 hours after liver transection, an equal recovery rate of the AKBR, and a comparable increase of the plasma level of IL-6 postoperatively. For the patients whose accumulated ischemic time was longer than 120 minutes, blood loss from the transection area was less than for the control group (14 mL/cm^2 vs 22 mL/cm^2; $P<.05$), but the transection time related to the transection area and the blood transfusion volume did not differ from those of the control group. Furthermore, they had a significantly lower recovery rate of the AKBR and higher plasma levels of IL-6 postoperatively than the control group.

Conclusion: The upper limit of tolerance of the liver to intermittent Pringle maneuver is 120 minutes.

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HEPATIC VASCULAR control is used by many surgeons to prevent massive hemorrhage during hepatectomy. The hepatic vascular inflow occlusion provides a relatively bloodless operative field and allows an unhurried, meticulous, and accurate intrahepatic dissection and hemostasis. There is always a risk of ischemic damage to the hepatocytes, however, especially in patients with chronic liver disease, the degree of which is likely to be accentuated with a prolonged period of vascular inflow occlusion. Within the period of ischemia that the liver can tolerate, the liver can recover from the operative and ischemic injury. Otherwise, a deterioration of liver function will ensue. The duration of the

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PATIENTS AND METHODS

From July 20, 1995, to November 25, 1997, 112 patients (aged >18 years) undergoing hepatectomy were included in the study. The first 100 consecutive patients had been included in a randomized trial[1] for the evaluation of the Pringle maneuver (50 patients had hepatectomy under the Pringle maneuver, and 50 patients did not). The rest of the patients, seen from March 29 to November 25, 1997, received major hepatectomy with the use of an intermittent Pringle maneuver. The procedure of the intermittent Pringle maneuver was applied at the time of liver transection and consisted of cross-clamping the hepatoduodenal ligament (and the aberrant left hepatic artery, if that was present) for 20 minutes and releasing the clamp for 5 minutes until the liver transection was completed. Liver transection was performed in all patients by an ultrasonic dissector. Major hepatectomy was defined according to Goldsmith and Woodburne nomenclature[2] as the resection of 2 or more liver segments. For patients with a major hepatectomy, hilar dissection was done to ligate and divide the ipsilateral branch of the hepatic artery and portal vein. Minor hepatectomy was defined as the resection of only 1 or less than 1 segment. The study protocol was approved by the Ethics Committee of The University of Hong Kong, Hong Kong, China. Informed consent was obtained from every patient before the operation.

PREOPERATIVE ASSESSMENT

All patients had an indocyanine green clearance test[3]; measurement of the arterial ketone body ratio (acetoacetate to β-hydroxybutyrate [AKBR]) and serum transferrin, prealbumin, and retinol-binding protein levels; and routine liver and renal biochemical tests. The AKBR was performed by the method described by Ozawa,[4] using commercial kits (Ketorex; Sanwa Kagaku Kenkyusho Co, Nagoya, Japan) and a spectrophotometer[5] (Keto-340 II; Sanwa Kagaku Kenkyusho Co). Transferrin, prealbumin, and retinol-binding protein levels were measured by rate nephelometry using an array analyzer (Beckman Array Analyzer; Beckman Instruments Inc, Fullerton, Calif). Plasma levels of cytokines (interleukin [IL] 1α, IL-1β, IL-2, IL-6, and tumor necrosis factor α) were measured in 40 patients (24 patients in the group having the Pringle maneuver and 16 patients in the control group) in the latter part of the study. The levels of cytokines were measured by enzyme-linked immunosorbent assay (Quantikine kit; R&D Systems, Minneapolis, Minn), and the data were analyzed by commercial software (Softmax for Windows 95; Molecular Devices, Sunnyvale, Calif).

INTRAOPERATIVE ASSESSMENT

The AKBR and cytokine levels were measured before, during, and after liver transection and then hourly for 4 hours. The volume of blood loss was accurately measured before, during, and after liver transection from the weight of the soaked gauze, blood collected from the containers of suction apparatus, and an ultrasonic dissector. The volume of irrigation fluid was deducted accordingly. The blood loss was assessed in 3 phases of hepatectomy because the efficacy of the Pringle maneuver was measured mainly by the amount of blood loss during the transection phase. The duration of the liver transection was noted. After the liver transection was completed, the transection surface was marked on a piece of transparent plastic sheet. It was immediately transcribed to a piece of paper containing marks of square millimeter for the measurement of the area of liver transection surface. The blood loss during transection was expressed as milliliters per square centimeter of liver transection surface. Similarly, the liver transection time was expressed as minutes per square centimeter of liver transection surface. The liver transection time was measured from the beginning to the end of the liver transection. The ischemic time was the accumulated total duration of the application of the Pringle maneuver.

POSTOPERATIVE ASSESSMENT

The AKBR and cytokine levels were measured after the operation each day for the first 2 days. Serum transferrin, prealbumin, and retinol-binding protein levels were measured on postoperative days 1, 4, and 8. Routine hematologic tests and liver and renal biochemical tests were performed daily for 7 days. The indocyanine green clearance test was repeated on postoperative day 8. The recovery rate of the AKBR postoperatively was defined as follows: the AKBR minus the AKBR immediately after transection was divided by the AKBR immediately after transection.

STATISTICAL ANALYSIS

Results are expressed as medians and ranges. The Mann-Whitney *U* test was used to compare continuous variables. The χ^2 test was used to compare discrete variables. Significance was defined as $P<.05$. All the statistical analyses were made using a commercial statistical software package (SPSS for Windows; SPSS Inc, Chicago, Ill).

liver's tolerance to the Pringle maneuver remains the major concern of liver surgeons. We did this study to define the duration of Pringle maneuver that the liver can tolerate without substantial posthepatectomy injury.

RESULTS

The postoperative recovery rate of the AKBR was compared between the control group and the group having the Pringle maneuver with different accumulated ischemic times (**Figure 1**). The recovery rate for the group having the Pringle maneuver was significantly lower than that of the control group when the accumulated ischemic time exceeded 120 minutes in the third and fourth hours after liver transection and on the second day postoperatively. The upper limit of the Pringle maneuver was then set at 120 minutes. According to this upper limit of ischemic duration, the patients were categorized into Pringle group 1 (n = 50), whose accumulated ischemic time did not exceed 120 minutes; Pringle group 2 (n = 12), whose accumulated ischemic time exceeded 120 minutes; and a control group (n = 50) in whom hepatectomy was performed without a Pringle maneuver. The 3 groups of patients were comparable in terms of the hematologic status and liver biochemical test results, except the serum alanine aminotransferase (ALT) levels (**Table 1**). The tumor size, the proportion of patients with major hepatectomy, and the prevalence of chronic liver diseases were similar among the 3 groups (**Table 2**).

Compared with the control group, the benefit of Pringle maneuver was mainly seen in the patients in Pringle group 1 (Table 2). There was a reduction in blood loss per transection area, transection time per transection area, and blood transfusion requirement in the patients in Pringle group 1. In the patients in Pringle group 2, compared with those in the control group, there was a reduction only in blood loss per transection area, but their blood transfusion requirement and transection time per transection area were not reduced.

In the postoperative period, the AKBR recovery rate of the patients in Pringle group 1 was comparable with those in the control group. On the contrary, the patients in Pringle group 2 manifested a value of AKBR recovery rate less than 0 in the first 4 hours, indicating that their recovery was delayed (**Figure 2**, top).

Because of the higher preoperative serum ALT levels in the patients whose accumulated ischemic time exceeded 120 minutes, the difference between preoperative and postoperative levels of serum alanine aminotransferase was compared among the 3 groups to assess the degree of parenchymal injury. The increase of serum ALT levels of the patients in Pringle group 2 was significantly higher ($P<.05$) than that of the patients in the control group and Pringle group 1 throughout the first 6 postoperative days (**Figure 3**). The serum bilirubin levels of the patients in the 2 Pringle groups were lower than those of the control group, but compared with the control group, a significantly lower ($P<.05$) serum bilirubin level was found only in the patients in Pringle group 1 (**Figure 4**). A significantly higher ($P<.05$) level of increase of IL-6 postoperatively was seen in patients in Pringle 2 group than in those in the control group and Pringle group 1 (**Figure 5**, top).

Further analysis was made in the patients with chronic liver diseases (liver cirrhosis and chronic hepatitis). The analysis indicated similar findings as in the whole group of patients (**Table 3** and Figures 2 [bottom] and 5 [bottom]).

The levels of the plasma IL-1α and -1β, IL-2, and tumor necrosis factor α were very low before and after liver transection in patients in all 3 groups. The levels of 3 short-half-life carrier proteins and albumin and the degree of deterioration of indocyanine green clearance did not differ significantly between the 2 Pringle groups and the control group, whatever the liver status ($P>.05$).

Although morbidity among the 3 groups did not differ significantly (Table 2), whatever the liver status, there was a tendency of a higher postoperative complication rate in the patients whose accumulated ischemic duration exceeded 120 minutes, especially those with a cirrhotic liver (Tables 2 and 3). The details of the postoperative complications are listed in **Table 4**.

A subphrenic abscess developed in 1 patient with a normal liver in Pringle group 1 (accumulated ischemic

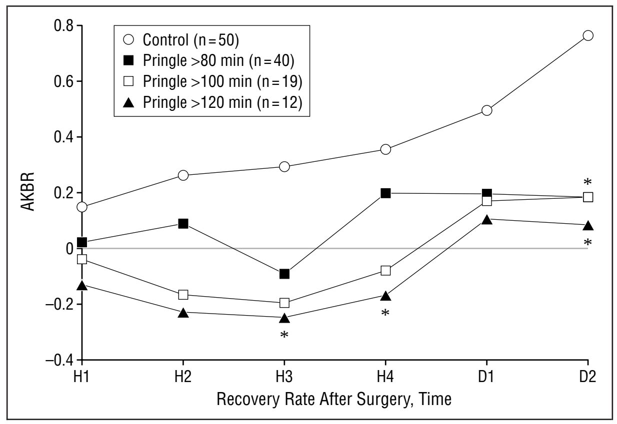

Figure 1. *The recovery rate of the arterial ketone body ratio (AKBR) in the patients undergoing a Pringle maneuver with different ischemic durations compared with the control group, as measured hourly (H) during the first 4 hours after surgery and days (D) 1 and 2. The recovery rate of the AKBR = (AKBR − AKBR immediately after transection)/AKBR immediately after transection. Pringle >80 minutes, Pringle >100 minutes, and Pringle >120 minutes indicate patients having the Pringle maneuver with accumulated ischemic durations longer than 80, 100, and 120 minutes, respectively; asterisk,* P<.05*, patients having the Pringle maneuver (various durations) vs control group.*

Table 1. Preoperative Data of Patients With Hepatectomy With the Pringle Maneuver and Control Patients*

Variable	Control Group (n = 50)	Pringle Group 1 (n = 50)	Pringle Group 2 (n = 12)
Age, y	52.5 (25-80)	52 (19-79)	50 (37-70)
Sex, M/F	41:9	39:11	10:2
Hemoglobin level, g/L	13.8 (8.6-16.5)	14.2 (8.7-16.6)	14.5 (11.0-17.0)
Platelet count, $\times 10^9$/L	198.5 (65-421)	183.5 (52-479)	211.0 (82-317)
Prothrombin time, s	10.9 (9.4-13.9)	11.3 (9.5-15.3)	10.7 (9.8-11.7)
Serum levels			
Total bilirubin, µmol/L†	11.0 (5.0-27.0)	11.0 (3.0-29.0)	11.0 (4.0-34.0)
Aspartate aminotransferase, U/L	36 (16-227)	35 (10-148)	59 (10-283)
Alanine aminotransferase, U/L	34.0 (8-344)	38.0 (8-207)	67.5 (10-174)‡
Albumin, g/L	41 (23-50)	41 (30-50)	41 (35-48)
Arterial ketone body ratio	0.86 (0.15-3.20)	0.85 (0.18-3.10)	0.91 (0.35-1.82)
Indocyanine green retention at 15 min, %	8.4 (1.6-26.5)	8.7 (1.4-52.7)	9.2 (4.3-21.2)

**Pringle group 1 indicates patients with accumulated ischemic time <120 minutes; Pringle group 2, patients with accumulated ischemic time >120 minutes. Values are given as median (range).*

†*To convert bilirubin from micromoles per liter to milligrams per deciliter, divide micromoles per liter by 17.1.*

‡P<*.05, Pringle group 2 vs control group and Pringle group 1.*

Table 2. Intraoperative and Postoperative Data on All Patients Undergoing Hepatectomy With or Without Pringle Maneuver*

Variable	Control Group (n = 50)	Pringle Group 1 (n = 50)	Pringle Group 2 (n = 12)	*P*† Control Group vs Pringle Group 1	*P*† Control Group vs Pringle Group 2	*P*† Pringle Group 1 vs Pringle Group 2
Ischemia duration, min	0	83 (24-114)	134.5 (123-201)	. . .	. . .	<**.001**
Major hepatectomy, No. (%)	35 (70)	33 (66)	10 (83.3)	. . .	. . .	. . .
Cirrhosis, No. (%)	16 (32)	18 (36)	1 (8.3)	. . .	. . .	. . .
Chronic hepatitis, No. (%)	12 (24)	15 (30)	7 (58.3)	. . .	. . .	. . .
Normal liver, No. (%)	22 (44)	17 (34)	4 (33.3)	. . .	. . .	. . .
Tumor size, cm	6.4 (2-23)	5.0 (1-15)	8.0 (0.3-17.0)	.51	.59	.41
Transection area, cm^2	60.0 (16-155)	67.0 (22-130)	89.5 (58-115)	.42	**.004**	**.004**
Total blood loss, L	1.99 (0.26-13.90)	1.01 (0.23-9.02)	2.03 (0.56-9.42)	<**.001**	.74	.06
Blood loss during liver transection, L	1.41 (0.17-11.4)	0.56 (0.09-5.93)	1.36 (0.30-8.50)	<**.001**	.67	**.03**
Blood loss per transection area, mL/cm^2	22 (5-150)	10 (3-46)	14 (4-74)	<**.001**	**.05**	.23
Transection time, min	169.0 (40-463)	125.5 (33-245)	219.0 (174-300)	**.01**	**.01**	<**.001**
Transection time, min/cm^2	2.8 (0.2-6.0)	2.0 (0.9-4.2)	2.6 (1.8-3.6)	**.002**	.69	**.01**
Blood transfusion, L	0.6 (0-12.9)	0 (0-4.3)	0 (0-8.6)	**.002**	.44	.28
Blood transfusion, L‡	0.6 (0-9.9)	0 (0-4.3)	0 (0-8.6)	**.004**	.51	. . .
Postoperative complication, No. (%)	15 (30)	13 (26)	6 (50)	.66	.16	.10

**Values are given as median (range) except as otherwise noted. Ellipses indicate not applicable.*
†Boldface values indicate statistical significance.
‡The comparison of blood transfusion among the 3 groups after excluding the patient in the control group whose blood transfusion was 12.9 L.

duration, 85 minutes), and the patient died of septicemia. Two patients in the control group with a normal liver died of liver failure (1 patient) and renal failure (1 patient).

COMMENT

The history of hepatic surgery is always a struggle against bleeding. Uncontrollable massive hemorrhage will lead to a deterioration of liver function and increased postoperative morbidity and mortality. Among all procedures of vascular control in hepatectomy, the Pringle maneuver is the simplest one to apply and was shown to be effective in reducing bleeding.[1] The limit of ischemic period that the liver can tolerate, however, remains the major concern of many surgeons. Elias et al[6] reported that an intermittent Pringle maneuver might be used for longer than 120 minutes without major complications, even in abnormal livers. Huguet et al[7] showed that patients with chronic liver diseases had increased postoperative morbidity and mortality rates after 60 minutes of continuous vascular exclusion. Kim et al[8] demonstrated that prolonged hepatic inflow occlusion could be used during hepatectomy for up to 60 minutes without serious complication in selected patients with active chronic liver disease. Wu et al[9] suggested that a cirrhotic liver could tolerate intermittent ischemia for up to 200 minutes without increased postoperative morbidity and mortality and serious long-term sequelae. All of these studies, however, were retrospective and focused on the clinical results and the levels of liver enzymes. A consistent result was not obtained from all these studies.

To find out the cutoff point of the ischemic duration during which the liver function is well preserved, we compared the postoperative recovery rate of the AKBR between the patients with a Pringle maneuver under different accumulated ischemic durations and the patients without a Pringle maneuver (Figure 1). The AKBR was chosen because it reflects the liver mitochondrial function, which is essential in maintaining liver cell viability under stress,[4,10] and is a useful marker for hepatic tolerance to portal triad cross-clamping in cirrhotic liver resection[11] and the energy status of the hepatic remnant.[12] The accuracy of the AKBR in reflecting liver function status was questioned by 2 recent studies[13,14] because the AKBR in these 2 studies varied greatly among individual patients for different periods. The difference may be explained by different extents of the use of the 2 types of ketone body, which probably depend on the blood glucose level and the adequacy of the perfusion of extrahepatic tissues. To reduce the effects of the differences among individual patients, we used the AKBR recovery rate, which was assessed only within a short time after hepatectomy, so that the variation in the condition that can affect the use of ketone bodies can be reduced. Unlike in other studies, the serum ALT level was not chosen because it happened that the patients in Pringle group 2 had a higher preoperative serum ALT level than did other patients.

The patients benefited from a Pringle maneuver and had a better preservation of liver function than the control group if the Pringle maneuver was used for less than 120 minutes. Within the 120 minutes' duration of ischemia, the recovery rate of the AKBR was well maintained even in the patients with cirrhosis. The delay of AKBR recovery in the patients whose accumulated ischemic time exceeded 120 minutes suggested that the liver was seriously injured and needed more time to recover from the acute stress (**Figure 6**). Furthermore, the increase of serum ALT levels was much higher in the patients whose ischemic time exceeded 120 minutes. Similarly, the lower level of bilirubin in the group having the Pringle maneuver was only contributed by the patients

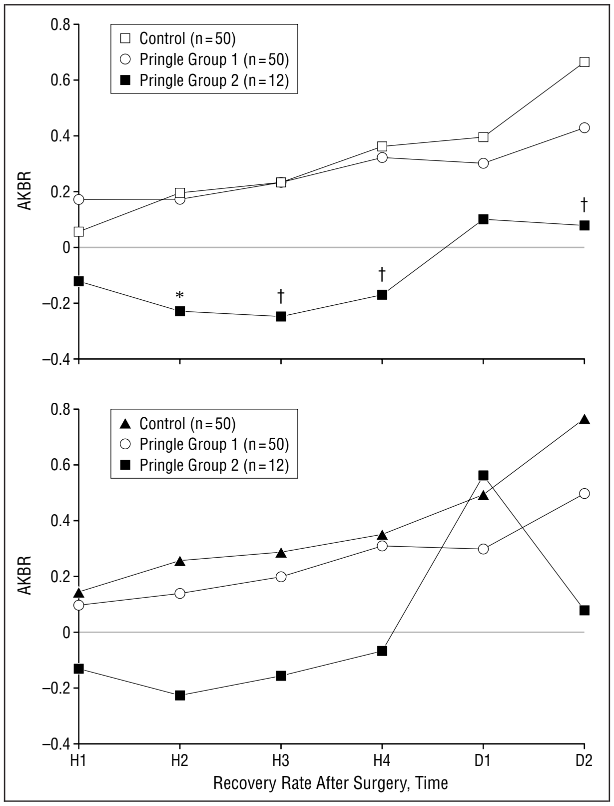

Figure 2. *The recovery rate of the arterial ketone body ratio (AKBR) of all patients (top) and patients with chronic liver diseases (bottom), as measured hourly (H) in the first 4 hours after liver transection and days (D) 1 and 2. Pringle group 1 indicates patients having an accumulated ischemic duration shorter than 120 minutes; Pringle group 2, patients with an accumulated ischemic duration longer than 120 minutes; asterisk, the difference between Pringle group 2 vs control group is significant; and dagger, the difference between Pringle group 2 vs Pringle group 1 is significant (*P<*.05 for both).*

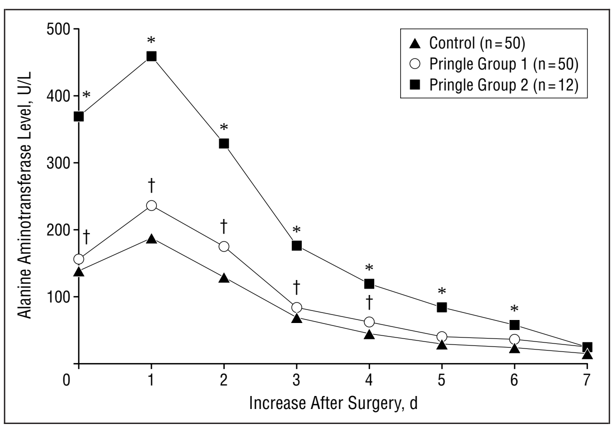

Figure 3. *Time of increase of serum alanine aminotransferase levels (compared with preoperative levels) of all patients postoperatively, by days measured. Asterisk indicates the difference between Pringle group 2 vs control group is significant; dagger, the difference between Pringle group 1 vs Pringle group 2 is significant (*P<*.05 for both).*

in Pringle group 1. The findings were further supported by the levels of IL-6, which is a response to ischemia-reperfusion injury[15] and correlates with complications and the mortality.[16] The levels of IL-6 were significantly higher in the patients whose ischemic time exceeded 120 minutes.

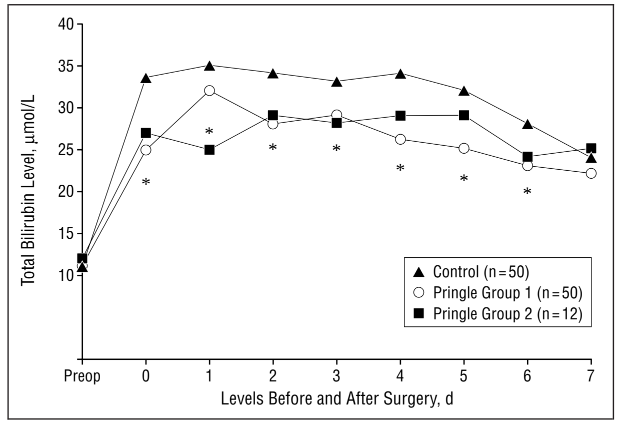

Figure 4. *Time of serum total bilirubin levels of all patients immediately before and after surgery, by days measured. Asterisk indicates the difference between Pringle group 1 vs control group is significant (*P<*.05).*

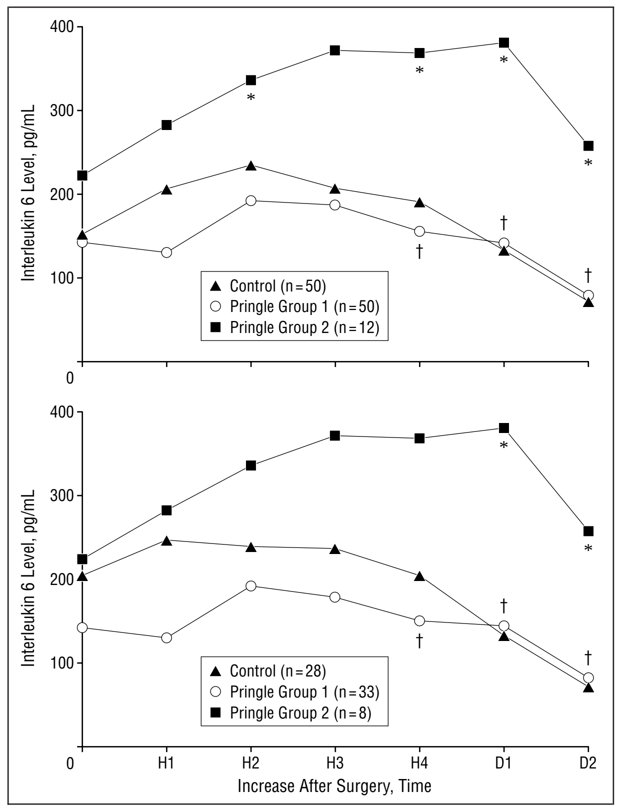

Figure 5. *The increase of plasma interleukin 6 (IL-6) levels (compared with preoperative IL-6 levels) in all patients (top) and patients with chronic liver disease (bottom), as measured immediately, hourly (H) the first 4 hours, and days (D) 1 and 2 after liver transection. Asterisk indicates the difference between Pringle group 2 vs control group is significant; dagger, the difference between Pringle group 2 vs Pringle group 1 is significant (*P<*.05 for both).*

Consistent with the experience of Japanese investigators,[17] tumor necrosis factor α, which is considered to be the main and the first wave of cytokine synthesis under stress[18] and is related to ischemia-reperfusion injury,[19] could not be found in the control and Pringle groups of our series. Contrary to previous experience,[20] IL-1α and IL-1β, the production of which should respond to stress promptly,[18,21] was found in low levels in all patients in the present study. The difference may be

Table 3. Intraoperative and Postoperative Data on Patients With Chronic Liver Diseases With Hepatectomy With a Pringle Maneuver and Control Patients*

				P†		
				Control Group vs		
Variable	Control Group (n = 28)	Pringle Group 1 (n = 33)	Pringle Group 2 (n = 8)	Pringle Group 1	Pringle Group 2	Pringle Group 1 vs Pringle Group 2
Ischemia duration, min	0	81.0 (24-112)	134.5 (126-175)	. . .	. . .	**<.001**
Major hepatectomy, No. (%)	19 (68)	21 (64)	7 (88)	. . .	. . .	. . .
Tumor size, cm	5.2 (2-13)	5.0 (1-15)	11.0 (3.1-17)	.90	**.02**	**.03**
Transection area, cm²	59 (35-155)	60 (22-107)	84.5 (58-115)	.68	**.004**	**.02**
Total blood loss, L	1.99 (0.79-9.36)	0.93 (0.23-3.26)	2.08 (0.56-9.42)	**.003**	.79	.13
Blood loss during liver transection, L	1.24 (0.31-6.0)	0.52 (0.09-2.55)	1.38 (0.3-8.5)	**<.001**	.73	.07
Blood loss per transection area, mL/cm²	23 (5-98)	10 (3-33)	13 (4-74)	**<.001**	.17	.34
Transection time, min	140 (89-260)	127 (33-244)	219 (175-264)	**.04**	**.006**	**.003**
Transection time, min/cm²	2.9 (1.1-5.3)	2.0 (0.9-4.2)	2.6 (2.1-3.5)	**.007**	.59	.70
Blood transfusion, L	0.3 (0-12.9)	0 (0-1.0)	0 (0-3.6)	**.003**	.45	.17
Blood transfusion, L‡	0 (0-9.0)	0 (0-1.0)	0 (0-3.6)	**.005**	.54	. . .
Postoperative complication, No. (%)	8 (29)	11 (33)	5 (62)	.69	.09	.13

*Values are given as median (range) except as otherwise noted. Ellipses indicate not applicable.
†Boldface values indicate statistical significance.
‡The comparison of blood transfusion among the 3 groups after excluding the patient in the control group whose blood transfusion was 12.9 L.

Table 4. Overall Postoperative Morbidity and Hospital Mortality by Number of Patients*

Morbidity and Mortality	Control Group (n = 50)	Pringle Group 1 (n = 50)	Pringle Group 2 (n = 12)
Complication			
Pulmonary	8	4	1
Wound infection	4	2	1
Subphrenic abscess	0	1 (1)	0
Biliary fistula	1	1	0
Pseudomembranous colitis	0	1	0
Limb cellulitis	0	0	1
Pleural effusion	6	3	1
Wound dehiscence	1	0	0
Intra-abdominal bleeding	1	1	0
Bleeding peptic ulcer	1	1	1
Superior mesenteric vein thrombosis	1 (1)	0	0
Uremia	1 (1)	0	0
Pulmonary edema	1	1	1
Incision hernia	0	0	1
Infected ascites	0	0	1
Hospital death	**2**	**1**	**0**

*The numbers in parentheses indicate patients who died of the complication.

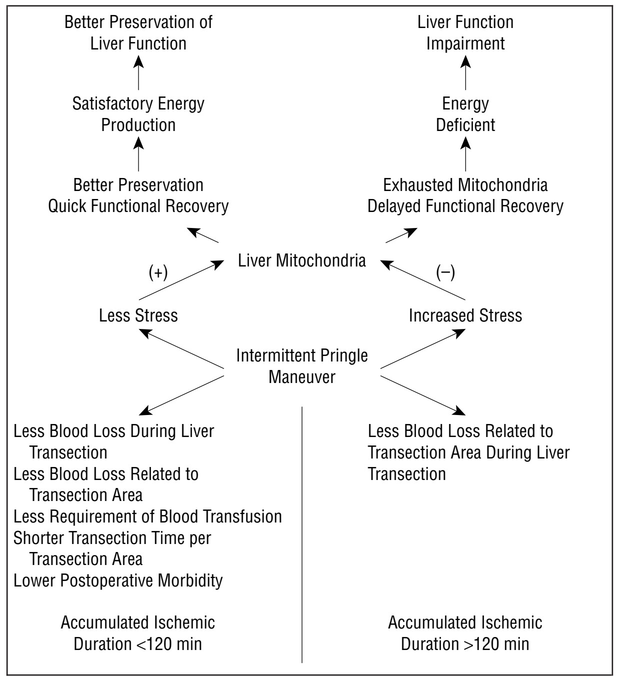

Figure 6. *Tolerance of the liver to an intermittent Pringle maneuver. Plus sign indicates protects; minus sign, compromises.*

because the Pringle maneuver was used in a continuous manner in the aforementioned studies, but in the present studies, it was used in an intermittent manner. Conceivably, an intermittent Pringle maneuver induces less stress and better preservation of liver sinusoidal cells, which are the major source of cytokine production.

The patients whose accumulated ischemic time exceeded 120 minutes had a larger transection area (Table 2). This is likely to be the case in patients who require the resection of middle segments of the liver, such as the right anterior segment or left medial segment. To avoid the prolongation of ischemia in such patients, the ipsilateral inflow pedicle may be clamped while transecting one side of liver segment.[22] When the ischemic duration exceeds 120 minutes and the liver transection is not yet completed, it may be advisable to continue the liver transection without the Pringle maneuver because the risk of liver failure negates the benefit of reducing blood loss. Fortunately, when the liver transection is nearly completed, the major source of bleeding is from the hepatic vein, and the need for the Pringle maneuver is diminished.

The liver is able to tolerate an intermittent Pringle maneuver within 120 minutes because it is not rendered totally ischemic.[23] The presence of hepatovenous back-perfusion plays a critical role during the Pringle maneuver. Tatsuma et al[24] showed that backflow from the hepatic veins could maintain liver adenosine triphosphate synthesis and, hence, liver viability during the Pringle maneuver. The perfusion of liver by hepatovenous backflow, however, is never perfect. In an animal experiment, continuous hepatic inflow interruption for 90 or 120 minutes resulted in severe injury to hepatic cells and liver sinusoids and in multiorgan failure.[25] In the present study, a tendency toward a higher incidence of postoperative complications was found in the patients whose accumulated ischemic duration exceeded 120 minutes. Therefore, liver transection using the Pringle maneuver has to be performed as expeditiously as possible.

CONCLUSION

Intermittent Pringle maneuver during liver transection is well tolerated within 120 minutes, whatever the liver status.

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