Use of a Refined Operative Strategy in Combination with the Multidisciplinary Approach to Manage Blunt Juxtahepatic Venous Injuries

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Background: Despite continuous advances in traumatology, juxtahepatic venous injuries are still the most difficult and deadly form of liver trauma. Most deaths result from exsanguination, and reported mortality ranges from 50% to 80%. This is an evaluation on our experience with the management of this high mortality injury following a refined operative strategy.

Methods: This is a retrospective study of consecutive patients sustaining blunt juxtahepatic venous injuries. The management for these patients was mainly a refined operative strategy combined with a multidisciplinary approach. Preoperative conditions and the patient demographics were gathered. In addition, the number and type of interventional procedures, overall complications, and operative procedures were collected and analyzed.

Results: From January, 1996 to March, 2004, 19 patients (M:F = 13:6) with juxtahepatic venous injuries were included and all were managed operatively. The operative procedures included hepatectomy by finger fracture technique for direct repair (8), perihepatic packing (1), packing and hepatic artery embolization (1), packing and hepatic artery ligation (1), hepatorrhaphy and packing (5), packing followed by hepatectomy (2) and atriocaval shunt for direct repair (1). The survival rate for the packing group was higher than that of the direct repair group (75% versus 45%), but was not statistically significant (*p* = 0.352). Injury to the retrohepatic vena cava influenced the patient's survival significantly (*p* = 0.041). The overall survival was 58% (11/19).

Conclusion: A well-defined operative strategy helps surgeons deal with the problem of blunt juxtahepatic venous injury, and its combination with multidisciplinary management will improve patient outcomes.

Key Words: Juxtahepatic Venous Injuries, Surgical Strategy, Multidisciplinary Management, Angioembolization

J uxtahepatic venous injuries (Grade V hepatic injuries) including those to the retrohepatic vena cava (RVC) or major hepatic veins, represent the most difficult and lethal form of liver trauma.[1–3] The mortality of such injuries ranges between 50 and 80%.[1–4] Death is especially common for such injuries when it was caused by blunt trauma.[3–6] Juxtahepatic venous injuries are a formidable challenge to trauma surgeons due to the difficulty in achieving hemorrhage control in this surgically inaccessible area.[6,7]

The high mortality rate associated with juxtahepatic venous injuries has led to various therapeutic options.[3,5,7] These techniques include intraparenchymal or perihepatic packing, hepatectomy including even lobar resection, deep hepatic suture, finger fracture technique for direct vessel repair, and vascular isolation procedures.[2,5,7] No consensus on the best approach for these devastating injuries has ever been reached. Hepatic packing was initially abandoned due to its high associated complications in the early 20th century, but it was reported to successfully treat extremely severe hepatic injuries and has increased in popularity recently.[3–5,7–13] Packing offers a logical and simpler method of stopping intraoperative exsanguination by restoration and reinforcement of the disrupted containment structure of liver.[11–13] Direct venous repair remains an effective method for dealing with juxtahepatic venous injuries that cannot be controlled by packing. With the advances in traumatology the concept of a multidisciplinary management for complex hepatic injuries has developed. It emphasizes early surgical intervention to control bleeding, packing and damage control, early angioembolization, staged operation, and computed tomographic (CT) scan-guided drainage of hepatic abscess.[2,3,11,13]

Few articles have focused specifically on the treatment of Grade V injuries, specifically after blunt trauma.[2,7] A multicenter study by Cogbill et al. analyzed the combined experiences of the management of complex hepatic injuries. The reported liver-related mortality for Grade V injuries was 66%.[4] Recently, Asensio et al. reported a single center experience on the outcome of Grade IV and V liver injuries with

mortality rates of 37% and 67%, respectively.[2] They concluded that a multidisciplinary approach lowered the mortality for such injuries. In this study we aim to gain a better understanding of the complex management of juxtahepatic venous injuries and to establish an optimal operative strategy for such injuries, with attention to a multimodality approach.

MATERIALS AND METHODS

From January 1996 to March 2004, the charts of 372 patients diagnosed with liver injury by abdominal CT scan or operative findings were reviewed in detail. The severity of liver injury was graded according to the American Association for the Surgery of Trauma (AAST) Organ Injury Scale.[14] All patients with blunt abdominal trauma were initially assessed and resuscitated in the emergency department according to the Advanced Trauma Life Support guidelines.[15] Patients with stable hemodynamics or who stabilized rapidly after resuscitation underwent an abdominal CT scan as indicated. We defined juxtahepatic venous injuries as injuries to the RVC, major hepatic veins, or both. We considered injuries to the more peripheral locations of the hepatic veins (outside 7 cm of the confluence zone) as Grade IV injuries because they were much easier to approach and manage with various surgical techniques.

In this study, we have followed the principles outlined in the literature for the management of patients with blunt hepatic injuries.[16,17] A nonsurgical approach was undertaken for patients who remained hemodynamically stable after initial resuscitation and had no other abdominal trauma requiring surgery. Surgical management was undertaken if the nonoperative criteria were not met. During the period of our study, the concept of multidisciplinary management evolved. We also used a multidisciplinary approach to manage this potentially fatal condition, including early, aggressive operation to control hemorrhage, packing and damage control, staged operation, early angiography and angioembolization, and CT-guided drainage of hepatic collections and/or abscesses.

The operative strategy for complex hepatic injuries had not been established during the early period of this study until our experience and reports in the related literature were sufficient to create the protocol (Fig. 1). The protocol was modified from Pachter et al., who had set the guideline for the treatment of complex hepatic injuries treatment.[18] In this series, all patients with grade V hepatic injury underwent operative management due to rapid deterioration despite resuscitation. Qualified general surgeons and familiar with hepatic resection managed all patients intraoperatively. A generous long midline incision was used in the early period, but we have now shifted to the Mercedes-Benz incision for complex hepatic injury if an abdominal CT scan before surgery confirmed the diagnosis. Operative approaches were determined by the sites of hepatic injuries including the intraparenchymal major vein(s), extraparenchymal vein(s), and RVC alone or combined. In general perihepatic packing would be

Table 1 Comparison of clinical data between survivors and non-survivors

	Survivors (n=11)	Non-survivors (n=8)
Age	30.6 ± 8.36	29.1 ± 16.3
Blood loss in OR	8081.0 ± 6806.9	7700.0 ± 4344.8
ISS	32.8 ± 5.4	36.0 ± 8.9
APACHE II	17.1 ± 7.0	20.2 ± 11.5
RTS	6.2 ± 2.1	4.6 ± 3.2
Mean BP at ER	52.7 ± 35.9	45.0 ± 40.9
Initial AST	1045.4 ± 790.9	579.2 ± 689.8
ICU stay	11.6 ± 10.4	4.8 ± 9.2

ISS, Injury Severity Score; AST, asparate transaminase; APACHE II, Acute Physiology and Chronic Health Evaluation classification system II; RTS, Revised Trauma Score.
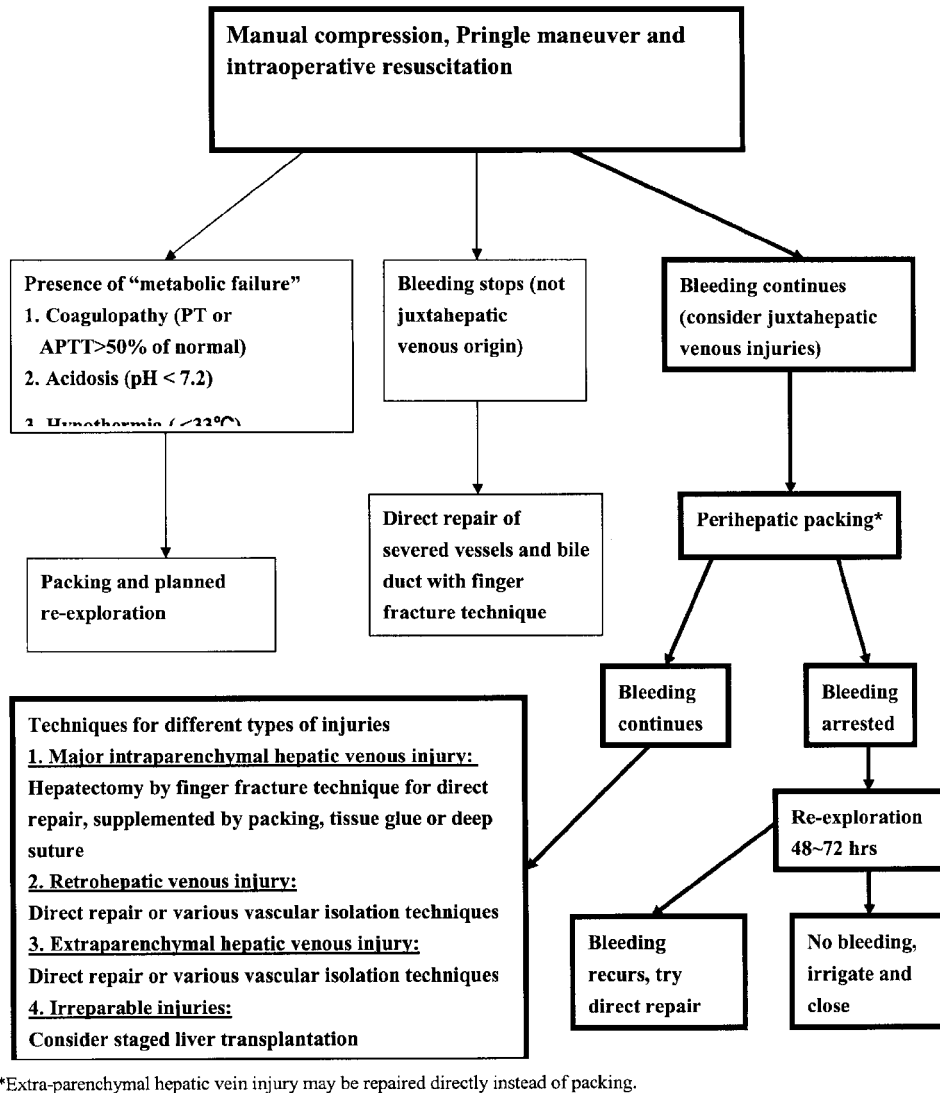
used first and planned re-exploration was chosen if hemorrhage stopped or the criteria for 'damage control' were met. For patients whose hemorrhage continued after packing, more aggressive operative techniques such as nonanatomical resection, or lobectomy were performed to directly repair the injured vessels (Fig. 1). We considered angioembolization for the following conditions:[1] evidence of contrast media pooling on CT scan;[2] postoperative hemorrhage (amount of blood transfusion >1500 mL over 24 hours);[3] postoperative hemobilia.

Demographic Data Including Age, Gender, Injury Severity Score

(ISS), Acute Physiology and Chronic Health Evaluation classification system (APACHE II score), Revised Trauma Score (RTS), length of intensive care unit (ICU) stay, admission vital signs, initial liver function, and intraoperative blood loss were collected. The number and type of interventional procedures, along with overall complications and operative procedures were recorded. Outcome was measured by the overall survival. To analyze the difference between survivor group and the non-survivor group, the Fisher's exact test was applied to the categorical factors and the Student's *t* test was applied for the continuous factors. A *p* value of ≤ 0.05 was considered significant.

RESULTS

Nineteen patients (M:F = 13:6) who sustained blunt hepatic trauma were included in this study. Comparing the clinical data between the survivors and non-survivors did not determine any significant difference in age, intraoperative blood loss, mean blood pressure in the emergency room, ISS, APACHE II score, RTS, initial aspartate transaminase value (AST), and the length of ICU stay (Table 1). The operative procedures included hepatectomy by finger fracture technique for direct repair,[8] perihepatic packing,[1] packing and hepatic artery embolization,[1] packing and hepatic artery ligation,[1] deep hepatic suture and packing,[5] packing followed by hepatectomy[2] and atriocaval shunt for direct repair.[1]

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┌─────────────────────────────────────────────┐
│ Manual compression, Pringle maneuver and     │
│ intraoperative resuscitation                  │
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Presence of "metabolic failure"
1. Coagulopathy (PT or APTT>50% of normal)
2. Acidosis (pH < 7.2)
3. Hypothermia (<33°C)

Bleeding stops (not juxtahepatic venous origin)

Bleeding continues (consider juxtahepatic venous injuries)

Packing and planned re-exploration

Direct repair of severed vessels and bile duct with finger fracture technique

Perihepatic packing*

Techniques for different types of injuries
1. Major intraparenchymal hepatic venous injury:
Hepatectomy by finger fracture technique for direct repair, supplemented by packing, tissue glue or deep suture
2. Retrohepatic venous injury:
Direct repair or various vascular isolation techniques
3. Extraparenchymal hepatic venous injury:
Direct repair or various vascular isolation techniques
4. Irreparable injuries:
Consider staged liver transplantation

Bleeding continues

Bleeding arrested

Re-exploration 48~72 hrs

Bleeding recurs, try direct repair

No bleeding, irrigate and close

*Extra-parenchymal hepatic vein injury may be repaired directly instead of packing.

Fig. 1.

In this series, 19 patients had 26 vessel injuries, which meant some patients had multiple vessel injuries. From analysis of the relationship between survival and anatomic location of the injuries, we found that the injury to the RVC influenced the patient's survival significantly ($p = 0.041$) (Table 2). Of the patients with RVC injuries (n = 6), one patient survived after direct repair. The remaining five cases died despite aggressive operative intervention. The majority of our patients had right hepatic veins injuries (15/19), and three had combined middle hepatic vein injuries (3/15). The intra-parenchymal portion of the right hepatic and middle veins are located in the thickest and least mobile portion of the liver, making them less accessible than the left hepatic vein. In this study we had to perform ten hepatectomies including eight nonanatomical lobectomies to directly repair the injured veins.

To elucidate the factors influencing outcome, we first analyzed the relationship between surgical procedures and survival. Patients were divided into two groups according to operative procedures:[1] the packing group, which means perihepatic packing was the main method for control of bleeding; and,[2] the repair group, which means direct repair of the

Table 2 Outcome and anatomic location of injury in blunt hepatic injury

Location of injury	Outcome		
	Survivors (n=11)	Nonsurvivors (n=8)	p Value
RHV	9	6	NS
MHV	2	2	NS
LHV	1	1	NS
RVC	1	5	0.041*

RVH, right hepatic vein; MHV, middle hepatic vein; LHV, left hepatic vein; RVC, retrohepatic vena cava; NS, not significant; *$p < 0.05$ by Fisher's exact test

Table 3 Outcome compared by surgical procedures

	Outcome		
Procedures	Survivals	Mortality	*p* Value
Packing group*	6	2	0.352
Direct repair group†	5	6	

*Packing group including: packing,[1] packing + hepatic artery ligation,[1] packing + angioembolization,[1] packing + hepatorrhaphy[5]
†Direct repair including: hepatectomy for repair,[8] packing followed by hepatectomy,[2] atriocaval shunt for direct repair.[1]

injured vessels was used to stop bleeding. Six patients received packing as the main surgical intervention and survived; while two patients underwent packing in desperation but died. In our series, eight patients underwent hepatectomy for direct repair and another two patients who initially were managed by packing underwent hepatectomy later due to persistent hemorrhage. The use of hepatectomy as the operative procedure was due to failure of packing and deep hepatic suture and it was the only way to stop hemorrhage. Two patients in this series with extra-parenchymal hepatic vein injuries were managed by direct repair and survived. We performed atriocaval shunt for one patient with left hepatic vein injury who survived without sequelae. Although the survival rate for the packing group was higher than that of the direct repair group (75% versus 45%), there was no significant difference between two groups (*p* = 0.352) (Table 3). The overall survival was 58% (11/19).

The postoperative complications for all patients except those who died in the first 24 hours were hepatic failure,[2] renal failure,[4] respiratory failure,[8] intra-abdominal abscess,[3] biloma,[3] chest empyema[2] and abdominal compartment syndrome.[2] Interventional radiologic procedures were used to control postoperative hemorrhage control or for postoperative complications. One patient with right hepatic vein injury was treated successfully with packing and selective angioembolization. Two cases of bilomas were treated by CT-guided drainage and one was managed conservatively. Three patients of intra-abdominal abscesses were managed by either CT-guided drainage[2] or surgical drainage.[1] Two patients with chest empyema were treated by thoracoscopic drainage. The causes of death in the eight non-survivors were coagulopathy, and persistent postoperative hemorrhage;[3] severe sepsis;[3] prolonged shock and multiorgan failure.[2]

DISCUSSION

Severe hepatic injury with concomitant juxtahepatic venous injuries represents a formidable challenge to trauma surgeons.[2,6,7,19] These patients mostly present in shock and have sustained multiple injuries and are physiologically compromised. Their management requires aggressive resuscitation and early operative approach to control hemorrhage.[1,2,7,20] The surgical inaccessibility of the juxtahepatic veins causes difficulty in achieving adequate exposure for hemorrhage control. The majority of deaths are caused by rapid intraoperative exsanguination during attempts at vessel repair. This type of hepatic injury has been associated with high mortality rate between 50 and 80% in recent series.[2,7,13,19,20] The mortality is especially higher for blunt hepatic injury because of the great force generating during impact and deceleration. A direct blow to the anterior surface of the liver will result in deep lacerations in the central segments IV, V, and VIII. The deceleration injury will cause lacerations along the insertion of the triangular and falciform ligaments.[7,21,22]

Cogbill et al.,[4] in their multi-center experience, stated that liver-related mortality for Grade V hepatic injury was 66%, and perihepatic packing was an effective and safe adjunct for patients with coagulopathy. In another remarkable study of a large series for hepatic injuries, Richardson et al.[20] described a 71.8% mortality rate for Grade V hepatic injuries. They recommended a multimodality approach to improve the outcome. Recently, Asensio et al.[2] in their single-center series reported that the mortality for Grade V hepatic injuries was 77%. Similarly, they stressed a multidisciplinary approach to improve outcome. It appears that a new trend has evolved, which proposes packing as the main surgical technique and a multidisciplinary approach to deal with complex hepatic injuries. This management incorporates interventional techniques such as angiography and selective angioembolization, endoscopic retrograde cholangiopancreatography and biliary stent, and CT scan-guided drainage as effective adjuncts.[2,3,5,13,20,22,23]

As evident from the literature, we now manage our patients sustaining juxtahepatic venous injuries following a revised protocol. In our protocol, the most important step was early, aggressive operative intervention to control hemorrhage. Following the operative strategy, we generally used Pringle maneuver and bimanual compression for temporary hemorrhage control while the anesthesiologists continued intraoperative resuscitation. If profuse hemorrhage continued from the posterior aspect of the right hepatic lobe, the lesser sac, suprahepatic area, or the deep parenchymal fractures despite the Pringle maneuver, this strongly suggested juxtahepatic venous injuries. Thus, expeditious perihepatic packing was applied. For patients with continuous bleeding after well-applied packing, more advanced techniques including hepatectomy by finger fracture technique (for intra-parenchymal hepatic veins), vascular isolation methods, or both were used to manage these potentially fatal conditions (Fig. 1). In addition our limited experience showed that the extra-parenchymal hepatic vein injury could be managed by direct repair instead of packing. "Damage control" operation and staged operation were chosen for patients who were extremely physiologically compromised and in metabolic failure. We used the following criteria indicating damage control: 1) coagulopathy (PT or APTT>50% of normal); 2) acidosis (pH < 7.2); 3) hypothermia (<33°C).[2,20,24–26] Planned re-laparotomy was usually performed 12 to 24 hours later. Multidisci-

plinary management was applied as indicated to manage these complex hepatic injuries.

In the early 20th century hepatic packing was the "mainstay of therapy" for uncontrollable hemorrhage.[10,11–27] Later packing was abandoned due to its associated high infection and mortality rates. Although some surgeons disapprove use of perihepatic packing others advocate its usefulness in severe liver injuries especially in the presence of coagulopathy, hypothermia, and acidosis.[8–11,19,20] Buckman et al.[19] stated that restoration or reinforcement of disrupted containment structures of liver would help for control of juxtahepatic venous bleeding. In this series, the authors' experience showed that well-applied perihepatic packing could control severe juxtahepatic bleeding alone or in combination with other adjunctive techniques. It has been well known that the mortality rate of severe hepatic trauma usually increases substantially based on the size of the injured liver parenchyma and the magnitude of surgical procedures.[7] Packing reduces the need for wide exposure and direct venous repair, as well as the risk of intraoperative exsanguination; particularly when a severe bursting rupture over the right lobe was present. The dramatic healing ability of the liver will cure the injury itself, while some manageable sequelae might need further treatment.

Direct venous repair by finger fracture technique and/or various vascular isolation techniques have been applied successfully for juxtahepatic venous injuries.[4–6, 16, 28–32] Pachter et al.[30] suggested that direct suture ligation of the severed vessels and bile duct was the most effective treatment for complex hepatic injury. In their study, the finger fracture technique was successfully performed to stop bleeding in 87% of patients with severe hepatic injuries. In our series, while packing could not effectively stop bleeding, we performed hepatectomies by finger fracture technique with the mortality rate of 50% for patients with intra-parenchyma hepatic vein injuries (5/10). In our study the survival for the packing group was higher than that of direct repair group although it was not statistically significant, which may be due to the limited number of cases in this study. We strongly believe that patients who can be managed by packing have favorable outcomes. Our statistical analysis for the anatomic location showed that RVC injury carried poorest results compared with other hepatic vein injuries. This might be due to the deepest location of the RCV and the greater force inducing RVC injury. The duration of shock has been a crucial factor influencing the survival greatly. In our study the statistic analysis did not include this factor due to inability to record the duration of shock accurately. Our observations however supported that the duration of shock had a significant effect on patients' survival.

From clinical evidence it seems that direct venous repair incurs more blood loss during exposure leading to more blood transfusions and related complications, and a longer period of shock. All these contribute poorer prognosis for the direct repair group. Direct venous repair remains the most effective

management for juxtahepatic venous injuries, and it acts as the rescue therapy when perihepatic packing fails. For patients with irreparable hepatic injuries, liver transplantation has been used as a last resort recently.[5,7,18] In our series, no patient sustaining a liver injury severe enough to warrant liver transplantation. At present liver transplantation should be used as a limited option due to the availability of donor.[5,7,21]

To gain excellent exposure of the juxtahepatic veins for repair, we suggest a Mercedes-Benz incision, a bilateral subcostal incision with an upper midline vertical incision and excision of the xiphoid process, for patients with severe hepatic injuries. This incision is widely used by liver transplant surgeons and still can offer a generous exploration of the abdominal cavity.[28] This procedure combined with vascular cross-clamp technique decreases the use of shunt.[28,29] In the early period of our series, one patient was treated by shunt, but thereafter we seldom used this technique.

In this study, we established a refined operative strategy for juxtahepatic venous injuries based on our experience and the accumulating evidence in the literature. We consider that direct venous repair and perihepatic packing do not contradict each other, but are complementary to each other. Judicious use of packing will reduce the need for direct venous repair, which might result in a fatal air embolization or profuse hemorrhage during attempts to rotate the liver for exposure. Direct venous repair will be the necessary strategy if packing and other adjunctive methods do not effectively stop bleeding from the juxtahepatic veins. Hepatectomy gives excellent exposure for direct repair of the injured intra-parenchymal vessels, but usually adjunctive techniques such as packing, tissue glue[33,34] or deep suture are required to stop the diffuse oozing from the large raw surface of liver after major resection. We found that fibrin glue as a spray could stop bleeding from small veins and diffuse oozing on the raw surface, thereby lessening the use of packing after hepatectomy. The trauma surgeon should be familiar with hepatic resection to carry out this procedure effectively. Multidisciplinary management with early angioembolization and CT-guided drainage of hepatic fluid collection will help to manage the most difficult form of hepatic injuries and improve the patient outcomes. Liver transplantation should only be considered as a life-saving procedure for patients with intractable hepatic injuries. The overall survival of this study (58%) was comparable with the results of other centers.[2,4,7,20] Although our preliminary result was satisfactory, we suggest that more cases be required to determine its efficacy.

In summary, the authors' experience suggests that an optimal operative strategy combined with a multidisciplinary approach will help the surgeon cope with the most difficult form of hepatic injury and greatly improve the outcomes of patients.

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