Liver Packing for Complex Trauma

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Submitted

ABSTRACT

Background: Increased awareness of the need to institute damage control surgery has led to a higher incidence of liver packing. The safety and efficacy of perihepatic packing to control liver hemorrhage were studied.

Methods: A prospective, protocol driven study, including all patients with a liver injury conducted over a period 2008-2013. All patients who underwent surgery for abdominal trauma with a major liver bleeding were further analyzed. Visible bleeding vessels were ligated and the liver packed for control of ongoing venous bleeding. Removal of packs was planned after 48-72 hours. The outcome was survival and vascular complications.

Results: Two-hundred-eighteen patients with a liver injury underwent operative management for abdominal trauma. Eighty-two (38%) patients had a major liver bleeding. In 19 patients bleeding was controlled after simple ligation of visible bleeding vessels. Fifty-nine patients required perihepatic packing to control bleeding. Inflow occlusion was performed in 19 patients, visible bleeding vessels were ligated in 11 patients and 8 patients had juxtahepatic venous injury. Four patients exsanguinated, and 11 patients died later during hospital stay. Repair of juxtahepatic venous injuries was delayed. Early relook and removal of packs was related to a higher rate of rebleeding ($p< 0,0001$). Nine patients developed delayed intrahepatic vascular complications, regardless the complexity of liverinjury and surgical intervention ($p=0,327$).

Conclusion: Ligation of visible bleeding vessels and liver packing are safe surgical techniques to control major liver bleeding, and definitive repair of juxtahepatic venous injuries may be delayed.

INTRODUCTION

A major reason for the reduced in mortality from hepatic injuries during the last three decades has been a shift from performing liver resections to therapeutic packing.[1,2,3] Packing is effective in controlling major venous bleeding with suture ligation of visible arterial bleeding from the liver.[4] Control of deep arterial intrahepatic bleeding may be difficult to achieve.[5] Some authors report successful management of penetrating liver injuries with a Sengstaken-Blakemore intrahepatic balloon[6,7] and routine hepatic angiography has been reported as a useful adjunct to perihepatic packing[8]. An increased awareness of the need to institute damage control surgery in the unstable patient has most likely led to a higher incidence of patients who undergo liver packing. There also appears to be little consensus on the optimum timing for re-look and removal of liver packs.[2,9] Despite the succes of packing complex liver injuries, recently some authors advocate performing resections [10], and concern has been expressed about management of highly lethal juxtahepatic venous injuries[11]. Optimal surgical management of patients with a bleeding liver injuries remains a topic of contention.

Liver bleeding at our institution is initially managed surgically by manual compression and temporary packing or inflow occlusion. This is followed by definitive control by the ligation of visible bleeding vessels and liver packing to control ongoing venous bleeding. The removal of packs was planned after 48-hours and postoperative angiography was only indicated for failure of removal of packs due to ongoing bleeding.

The aim of this protocol driven study was to assess the safety and efficacy of perihepatic packing and ligation of visible bleeding vessels to control liver bleeding in patients undergoing operative management of liver trauma.

PATIENTS AND METHODS

A prospective evaluation of 412 patients with liver trauma admitted to Groote Schuur Hospital Trauma Centre in Cape Town, South Africa, was performed from 2008 to 2013. Ethics approval was granted from the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town. The study was conducted in a level-1 Trauma Centre and tertiary hepatobiliary referral hospital serving a population of 2.5 million people. All patients were resuscitated and managed according to the Advanced Trauma Life Support (ATLS®) principles.[12] The indications for surgery for liver injuries were hemodynamic instability or generalized peritonitis. Liver injuries were graded according the Organ Injury Scale of the American Association of Surgery for Trauma.[13] Patient demographics, mechanism of injury, operative intervention, intra-abdominal associated injuries, morbidity, and mortality were documented.

Inclusion criteria: Due to diagnosic challenges initially all patients with active bleeding in the right upper quadrant were identified. Patients with intrahepatic or juxtahepatic bleeding as the main source of bloodloss were then included in this study and further analysed. A major hepatic bleed was defined as a bleeding not controlled after temporary packing of the liver.

Exclusion criteria: patients with liver injuries that were managed non-operatively, patients with a liver injury requiring simple surgical repair or stopped bleeding spontaneously, and patients with a liver injury in which associated perihepatic injuries caused the main source of bloodloss were excluded from further analyses.

Outcome parameters.

The primary outcome of this study was liver related mortality. Liver related mortality was defined as death due to ongoing liver bleeding, liver failure, or death related to complications of massive fluid resuscitation, initiated as a result of major bleeding.

The secondary outcome include all liver injury related morbidity.

Morbidity was classified as the occurrence of liver related complications or surgical complications. Liver related complications were divided in vascular (delayed hemorrhage, pseudoaneurysm and liver necrosis) and biliary complications.

Biliary complications and surgical complications were graded according the Clavien Dindo classification of surgical complications.[15] Severe general surgical complications were defined as complications graded as 3 or higher.

Operative Management: Bleeding from the liver was initially controlled by manual and temporary compression with packs in all patients that needed operative interventions. Intrahepatic visible bleeding from vessels was ligated. Superficial suture closing of liver lacerations was avoided. If there was ongoing bleeding through the liver packs, intermittent inflow occlusion was performed as described by Pringle[14] with a vascular clamp placed across the hepatoduodenal ligament. The clamp was then removed and any visible vessels and bile leaks were suture ligated. In the case of an injury near the free edge of the liver, a finger fracture technique was used to open the tract of the injury followed by ligation of the involved vessel. A formal liver resection was not considered as part of the initial surgical management. Persistent posterior dark venous bleeding after inflow conclusion was indicative of a juxtahepatic vena caval injury. For persistent bleeding, abdominal swabs were placed anterior and posterior to the liver to staunch blood loss and provide hemostasis by tamponade. These packs were not forced into the liver injury but were used to restore the normal anatomical continuity of the liver. Typically 6 packs or more were used to provide a firm tamponade of the injury. Arterial bleeders were controlled prior to therapeutic perihepatic packing and this involved removing the vascular inflow occlusion. Patients with liver packing were managed as patients with an open abdomen. Patients who underwent liverpacking were transferred to the intensive care unit (ICU) for further resuscitation as part of the damage control strategy. Patients

were returned to the operating room after 48-72 hours for removal of the packs. Indications for postoperative angiography were: clinical suspicion for ongoing intrahepatic bleeding with intrahepatic contrast extravasation seen on computed tomography and rebleeding requiring repacking at the first relook laparatomy.

Treatment of liver related complications was multidisciplinary when appropriate and included angiography and angioembolization, ERCP and stenting of biliary leaks, CT-guided drainage of hepatic and perihepatic abscesses or biliary collections. Surgical interventions included either laparotomy or laparoscopy.

Statistical analysis. Results were presented as number (%) or as median (P_{25}-P_{75}). Patient groups were compared using the Pearson's chi-squared test or Fisher's exact test for categorical variables, and the Mann-Whitney or Kruskal-Wallis test for non-normally distributed data. Statistical analyses were performed using SPSS statistical software, version 20. P values< 0.05 were considered statistically significant. Multivariable forward stepwise logistic regression analysis including factors with univariable p<0.10.

RESULTS

Four hundred and twelve patients presented with a liver injury, the type of management, and the indications for 218 patients who were selected for surgery are presented in table 1. A management flow chart presenting the methods of hemorrhage control is presented in figure 1.

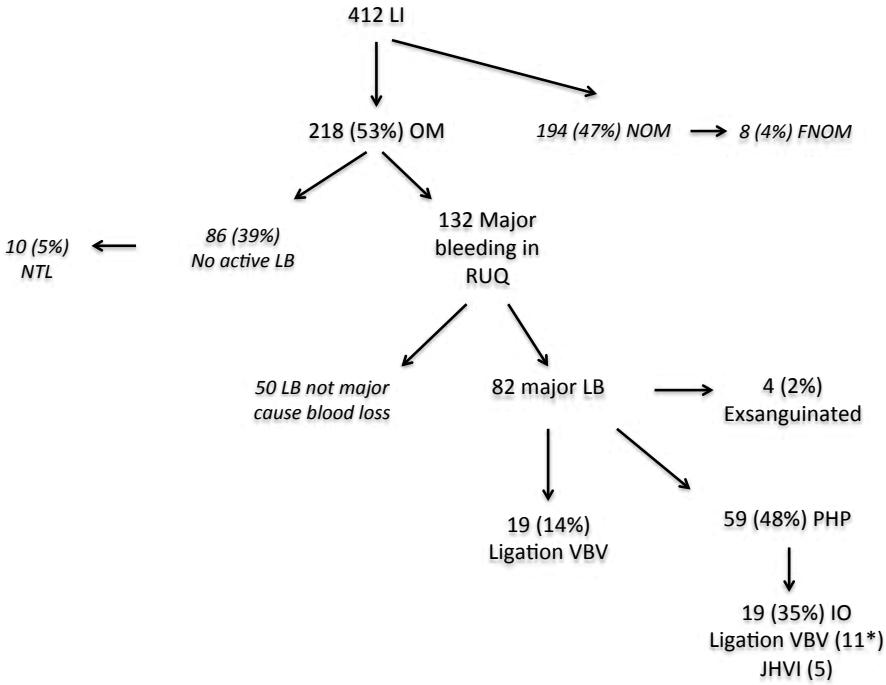
One hundred thirty and two of the 218 (61%) patients were identified with a major bleeding in right upper quadrant of the abdomen. Eighty six (39%) patients had no obvious major liverbleeding, and hemosstasis was controlled after simple surgical interventions or spontaneously.

Eighty two of the 132 operated liver injured patients (62%) patients (75 men, 7 women; mean age 28, range; 13-74, years) had a major hepatic bleeding causing the main source of blood loss. Fifteen patients (18%) sustained blunt trauma, and 67 (82%) sustained penetrating trauma, 11 (13%) due to stab wounds and 56 (68%) due to gunshot wounds. Seventy four patients had intrahepatic bleeding and eight patients had juxtahepatic bleeding. The median ISS was 22 (interquartile range 16-29).

Packing and selective ligation of visible intrahepatic bleeding vessels.

In all patients an attempt was made to pack the liver and control bleeding. In 19 patients bleeding was controlled after temporary packing and ligation of a visible bleeding vessel. Sixty three patients had a major liver injury in which the bleeding could not be controlled by temporary packing or simple suture and required more complicated procedures. Twenty patients required intermittent inflow occlusion to identify the bleeding

Figure 1: Management of Patients with a liver injury following abdominal trauma.



LI: Liver Injuries
RUQ: Right Upper Quadrant
IO: Inflow Occlusion
NTL: Non-Therapeutic-Laparotomy
OM: Operative Mangement
VBV: Visible Bleeding Vessel
JHV: Juxtahepatic Venous Injury
LB: Liver Bleeding
PHP: Peri Hepatic Packing

Table 1. Grading of liver injuries in 412 patients according the Organ Injury Scaling of the American Association of Surgery in Trauma.[13]

OIS	Total	NOM	**OM**	**Indications for surgery**			**Surgical Intervention**	
				Unstable	P	CT	Sutures	PHP
I	65	35	**30**	5	21	4	0	-
II	140	69	**71**	9	56	6	10	7
III	133	56	**77**	13	57	7	5	28
IV	59	27	**32**	2	26	4	4	12
V	15	7	**8**	-	8	-	-	5
	412	*194*	***218***					

OIS=Organ Injury Scale, NOM=nonoperative management, OM=operative management, P=peritonitis, CT=computed tomography, PHP=peri-hepatic packing.

Table 2. Timing of the first re-look laparotomy in 59 therapeutically packed patients.

Re-look (h)	No. of patients (n=59)	ACS	PBL	Transfered	Planned removal of packs	Rebleeding
< 48	13	4	6	3		6(67%)
48	33				33	3(9%)
72	13				13	0(0%)
P-value						**P<0.001**

Data were analyzed with a Pearson Chi-squared analysis or Fisher Exact Test. Boldface fonts indicate statistically significant differences.
Removal of packs was planned after 48-72 hours. Indications for early removal of packs (<48 hours) were abdominal compartment syndrome (ACS), proximal small bowel ligation (PBL), and transfer from a secondary hospital.

site. Of these patients eight had a juxtahepatic venous injury and in 11 patients a visible bleeding vessel was suture ligated. Finger fracture technique was applied for adequate exposure in only a single case. In one other patient balloon tamponade of the bullet tract was used to control bleeding, a subsequent CTA did not reveal intrahepatic blush. Four patients died during operations due to exsanguination. The liver was therapeutically packed the remaining 59 patients with major liver bleeding. Thirteen of these 59 patients returned to the operating theatre within 48 hours; the indications for an early relook are presented in table 2. Early removal of packs was associated with a higher rate of re-bleeding than removal of packs after 48 h : 6 of 13 versus 3 of the 46 after 48 hours re-operated patients.

Table 3. Predictive factors for hospital mortality in patients with liver trauma, results of a multivariable forward stepwise logistic regression analysis including factors with univariable p<0.10.

	Odds Ratio	95% CI	P-Value
Shock	4.6	1,3-17	0.019
Packing	37	4.6-300	0.001

CI = confidence interval

Resections.

In 6 of the 59 patients devitalized tissue was debrided during the relook laparotomy and removal of packs, formal hepatic resections were not performed.

Juxtahepatic venous injuries.

Eight patients of the 63 patients with major hepatic bleeding had complex juxtahepatic venous injuries. Primary repair was not attempted and all liver injuries were packed. All definitive repairs of juxtahepatic venous injuries were delayed 48 hours after secondary

resuscitation. Three patients died within 24 hours during operation due to exsanguination. Five patients who underwent initial abdominal packing returned to the operating theatre 48 hours later for removal of packs and direct hepatic venous repair. Control of liver inflow with hepatoduodenal vascular clamping was used in all of these patients, with total hepatic isolation in 1 patient.

In the remaining 50 of 132 (38%) patients with a major bleeding in the right upper quadrant of the abdomen not the liverbleeding but associated perihepatic injuries caused the main source of bloodloss. *Perihepatic injuries included:* the common hepatic artery (2) and right hepatic artery (2), aortic injuries (2), juxtarenal (2) and infrarenal (4) vena caval injuries, and 38 patients had right kidney injuries. The surgical interventions to control bleeding were: ligation of the common hepatic artery (2) and right hepatic artery (2) and subsequent cholecystectomy. Primary aortic repair and aortic repair with interposition graft in a single patient. Two IVC injuries were primarily repaired, 2 infrarenal IVC injuries ligated, 2 IVC injuries were packed and definitive repair was delayed. Sixteen nephrectomies were performed.

*Primary Outcome of patients with a liver injury selected for operative management***.**

Fifteen of the 218 (7%) operatively treated liver injury patients died. Predictive factors for mortality were shock on admission (p=0.02) and liver injuries requiring packing to control hemorrhage (p=0.001) (table 3). Four patients with high grade (IV(1) & (V(3)) liverinjuries due to gunshot wounds exsanguinated in the operating theatre and mortality was directly attributable to the liver injury. Eleven patients (5 GLI and 6 blunt) died in the intensive care unit. Three patients died due to severe traumatic brain injuries. Eight patients developed multi organ failure. Three of these patients had liver related complications (biliary fistula (2), liver necrosis (1)). Liver related operative mortality was 3% (7/218).

*Secondary Outcome***.**

The incidences of the vascular and general complications are presented in table 4. Nine of the 218 (4%) liver injured and operated patients had vascular complications (pseudoaneurysm (6), livernecrosis (3). Three patients had sustained blunt trauma and 6 patients penetrating trauma (SLI (2) and GLI (4)). No different complication rates were found for patient who had surgical repair of the liver and those who had no intervention on the liver or had only packing. Specifically, there was no significance difference in patients who required ligation of a visible intrahepatic bleeding vessel and patients who did not, with respect to vascular complications.

Table 4. Complications and hospital stay in 218 operatively treated patients with a liver Injury.

	No intervention, simple surgical technique, or hemostasis achieved after temporary packing (n=136)	**Sutures only(n=19)**	**Sutures + Packing (n=11)**	**Packing only(n=52)**	**P-Value**
Vascular complications	4 (2.9%)	1 (5.3%)	1 (9.1%)	3 (5.8%)	0.327 [2]
General complications	47 (34.6%)	10 (52.6%)	11 (100%)	52 (100%)	<0.0001 [2]
I	11	1	2	8	
II	17	4	2	8	
III	8	3	4	20	
IV	3	1	2	11	
V	8	1	1	5	
Hospital stay [1]	12 [7-19]	10 [7-15]	27 [14-41]	23 [13-30]	<0.0001 [3]

Vascular complications were classified as delayed bleeding, pseudoaneurysm or liver necrosis.
General Surgical complications were graded according the Clavien Dindo Classification.
Hospital Stay was presented in days, median [25th-75th percentile][1].
Data were analyzed with a Pearson Chi-squared analysis or Kruskal-Wallis Test. Boldface fonts indicate statistically significant differences.

Vascular complications.

Six pseudoaneurysms were diagnosed between 15-51 days post injury. All six patients initially underwent early initial surgery. In one of the six patients a suture was used to ligate an intraparenchymal vessel. Indications for postoperative angiography were: radiological findings in combination with a fall in hemoglobin serum level (n=1), drainage of fresh blood via the percutaneous drain (n=2) and hemobilia (n=3). All pseudoaneurysms were successfully angioembolized. One patient had a concomitant major bile leak, which was managed with endoscopic sphincterotomy and temporary biliary stenting.

Three patients were diagnosed with liver necrosis on CT. In all patients the hepatic artery was ligated during initial surgery, after injuries of the common hepatic artery (2) and right hepatic artery (1). Two of these patients were successful managed with percutaneous drainage, and one patient required a relaparotomy. One patient with a grade III liver injury had a complete transection of the common hepatic artery underwent a laparotomy for abdominal sepsis. This patient died because of multiple organ failure on day 5 post injury.

General surgical complications.

The incidence of general surgical complications is presented in table 4. Sixty three (31%) patients who underwent initial operative management had postoperative intraabdominal septic complications (table 5). There was a difference in septic complications related to the mechanism of injury. Seventeen (8,3%) patients required one or more relooks for intraabdominal septic complications (pancreatic fistula (5), duodenal fistula (3), enteric fistula (3), mechanical obstruction (3), missed bowel perforation (1), acalculous cholecystitis (1), necrotizing fasciitis (1)). General complications, hospital stay and mortality were higher in patients with major hepatic bleeding requiring packing to control bleeding.

Table 5: Septic complications in 218 patients who were managed operatively.

	Overall (N=218)	**Blunt (N=35)**	**GSW (N=137)**	**SW (N=46)**	**P-value**
Septic complications [1]	63 (29%)	18 (51%)	38 (28%)	7 (15%)	**0.002**

DISCUSSION

Uncontrolled bleeding is the main cause of early death in patients with a liver injury. Despite improvement in resuscitation and critical care facilities the mortality of complex hepatic injuries remains high. The overall operative mortality rate in consecutive adult liver injuries in our study was 7%. Overall mortality in liver injuries ranges from 10 to 42%, and depends on the mechanism of injury.[16] Seven of the deaths were directly attributable to the liver injury, liver related operative mortality was 3%, and the remainder were due to associated injuries.

The results of this study showed that suture ligation and liver packing are effective surgical tools to achieve hemostasis. Due to direct suture repair of visible intrahepatic bleeding vessels, the use of angiography as adjunct to perihepatic packing in this study was limited, and only indicated in selective cases. The repair of juxtahepatic venous injuries can wel be delayed when initial abdominal and perihepatic packing is performed. A first relook laparotomy and removal of packs only after 48-hours was associated with the lowest risk on rebleed.

Perihepatic packing has become the most widely used and successful method for management of severe liver injury.[1,2,3] There is concern about the timing of the planned re-look laparotomy and when the liver packs should be removed. Similar to the results of an earlier retrospective study from our institution, removal of liver packs should be performed after 48 hours, as this is associated with the lowest risk of rebleeding.[3] Although the evidence that supports the efficacy of damage control surgery compared to traditional laparatomy is limited, and there has been an increase in incidence of patients

who undergo damage control.[17,18] Surgeons should be aware of the increase of morbidity in patients who unnecesarily undergo a damage control laparotomy.

In damage control surgery for the liver, severe parenchymal damage has initally been left untreated. We feel that all vissible bleeding vessels should be ligated prior to packing, in order to limit the need for adjuvant postoperative angiography and subsequent embolization. Direct suturing of the liver edges with large, blunt tipped o chromic suture is controversial and not recommended, because complications due to direct suture repair may lead to intrahepatic hematomas or haemobilia. Alternative techniques include hepatotomy which potentially can lead to extensive additional parenchymal bleeding while searching for the intrahepatic bleeding vessel.[19] Hepatotomy or the finger fracture technique was applied in only 1 patient in this series. Hirschberg and Mattox advocate this technique only in patients who are well resuscitated and can tolerate additional blood loss.[5]

Recently some authors suggested that resection of the injured portion of the liver can definitively control bleeding, eliminate devitalized tissue, and avoid bile leak and should be considered as a surgical option in patients with complex injuries, and can be accomplished with low mortality and liver related morbidity. In this series we did not perform anatomical or non-anatomical resection to control bleeding. During a relook laparotomy 6 non-anatomical liver resections or debridement of devitalized liver parenchyma were performed.

Penetrating tracts through the hepatic tissue can be challenging. Recently a series of patients with penetrating liver injuries have been managed successfully with a Sengstaken- Blakemore balloon.[6,7] Although this alternative surgical technique is viable in the present series in 1 of the 183 patients with penetrating liver injuries balloon tamponade of the tract was used.

Currently angiography is recommended as an adjuvant to perihepatic packing.[8] Mortality following embolization is reported to be low, but concern has been expressed about a significant morbidity.[20,21] Furthermore angiography and subsequent embolization is not readily available in all operating theatres and performing a routine angiography in a postoperative critical ill patient is not a benign procedure. Although angioembolization is available in our hospital, in this series of patients the role of postoperative angiography is very limited and was used for treatment of delayed bleeding, and hepatic artery pseudoaneurysms. Post traumatic hepatic artery pseudoaneurysm is an uncommon delayed complication. Pseudoaneurysm detected by CT should be treated as early as possible, since occasionally hepatic artery pseudoaneurysm may become symptomatic.[22,23] A follow up CT scan in a 'young' trauma population for a rarely seen, but potential lethal complication is controversial. The high number needed to treat and negative effects of radiation exposure are matters of concern, and clinical examination and follow up might be the preferred method.

Juxtahepatic venous injuries are the most devastating liver injuries with a high mortality. Buckman *at al* outlined three main surgical strategies (direct venous repair, anatomic resection and tamponade with containment) and recently reports of using fenestrated grafts have been reported. These advanced radiological intervention techniques are not widely available. While a few authors report successful results on shunting, direct repair of venous injuries without the necessity performing a sternotomy has been reported as being more successful.[24] But direct repair of venous injuries requires full mobilization of the liver and places the patient at risk when not performed in a well-resuscitated patient.

The approach of juxtahepatic venous injuries in this series is a damage control strategy, containment by tamponade using packs followed by a direct repair, when feasible after initial resuscitation and an experienced team has been mobilized.

While this prospective series of patients is large the number of vascular complications is low. The comparison of small groups in this paper by means of significance testing needs to be interpreted in the light of the very low power to detect statistically significant differences.

In conclusion; early recognition of the magnitude of complex liver injuries and a clear treatment strategy for peri- and intra-hepatic injuries is essential. Suture ligation and liver packing are effective surgical tools to achieve hemostasis. Direct suture repair of visible intrahepatic bleeding seems successfull with subsequent limited need for postoperative angiography. Repair of juxtahepatic venous injuries can be delayed, while patients are being resuscitated and an experienced surgical team is mobilized The first relook laparotomy and removal of packs should be performed after 48-hours.

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