Surgery Today (2021) 51:891–896
https://doi.org/10.1007/s00595-020-02178-1

ORIGINAL ARTICLE

Early re-laparotomy for patients with high-grade liver injury after damage-control surgery and perihepatic packing

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Received: 18 June 2020 / Accepted: 18 September 2020 / Published online: 10 November 2020

Abstract

Purpose The likelihood of re-bleeding after damage-control surgery (DCS) and perihepatic packing for high-grade liver injuries is a major concern. Thus, although early re-laparotomy tends to be recommended, we conducted this study to evaluate the feasibility of performing definite laparotomy within ≤ 48 h in this clinical population.

Methods The subjects of this retrospective study were 65 patients ($n = 24$, ≤ 48-h group; $n = 41$, > 48-h group) who underwent DCS and perihepatic packing. The primary outcome was the rate of repacking for bleeding during re-laparotomy and the secondary outcomes were mortality and length of stay in the intensive care unit (ICU).

Results The ≤ 48-h group had a higher rate of angioembolization and transfusion of red blood cells (RBCs), fresh frozen plasma, and platelets, but the rates of repacking and mortality were not significantly different between the groups. However, the incidence of pneumonia and ventilation support requirement were significantly lower in the ≤ 48-h group than in the > 48-h group.

Conclusion The re-laparotomy performed within ≤ 48 h after DCS and perihepatic packing is feasible for patients with high grade liver injury, using angioembolization and aggressive transfusion, as required. Early re-laparotomy reduces the need for prolonged ventilator support and the incidence of ventilator-associated pneumonia.

Keywords Liver · Trauma · Laparotomy

Introduction

Damage-control surgery (DCS) is used widely in the management of trauma patients. For patients with abdominal trauma, DCS is used in the intensive care unit (ICU), without initial surgery, to control hemorrhage and contamination, followed by intraperitoneal packing and rapid closure, which allows for resuscitation and subsequent definitive laparotomy [1]. As these patients are at high risk of abdominal compartment syndrome [2], the abdominal fascia is generally not approximated during closure [3]. The indications for DCS have been extended beyond intraperitoneal packing to include vascular and gastrointestinal injuries, mesenteric ischemia, and gross contamination [4]. It is generally recommended that re-laparotomy, and any other surgery required, be performed within 24–48 h after the index DCS [5], as delayed re-laparotomy increases the risk of infection and failure of definite fascial closure [6–8]. However, extending the timeline for re-laparotomy beyond 48 h has recently been recommended for patients with high-grade liver injury requiring perihepatic packing to prevent re-bleeding, [9, 10]. This recommendation does not consider the new management strategies for traumatic coagulopathy that have been developed, including massive transfusion protocol, diagnostic criteria, medication support, and ratio-driven resuscitation, to maintain the adequate ratio between red blood cells (RBCs), plasma, and platelets [11–13]. Strategies for the management of high-grade liver trauma have also been developed, with angioembolization used to decrease the risk of bleeding and mortality [14, 15]. Considering

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these new trauma management strategies, we hypothesized that planned re-laparotomy within ≤ 48 h after perihepatic packing could be feasible. Therefore, the aim of this study was to evaluate the feasibility of performing re-laparotomy within ≤ 48 h after perihepatic packing for patients with high-grade liver injury. The primary outcome was the rate of repacking for bleeding at the time of re-laparotomy, with secondary outcomes being mortality, length of stay (LOS) in the ICU, and complications.

Methods

Patients

Patients who underwent DCS and perihepatic packing in our trauma center between January, 2011 and December, 2019, were included in this study. The exclusion criteria were as follows: age < 18 years, death before re-laparotomy, and unplanned re-laparotomy because of bleeding. Resuscitation was performed according to the Advanced Trauma Life Support guideline, which includes indications for laparotomy [16]. During laparotomy, selective ligation of bleeding sources in the liver was performed, if possible. For persistent bleeding, liver suturing was usually performed in conjunction with a Pringle manoeuvre, applied for < 30 min. Non-anatomical liver resection was performed if suturing was not adequate to restore liver viability. Approximately 5–6 laparotomy gauzes were used for perihepatic packing, and an open abdomen was created using the vacuum pack method. Patients were transferred to the ICU for correction of the lethal triad (acidosis, hypothermia, and coagulopathy), with re-laparotomy performed after the correction of coagulopathy.

The motivation for our study was the building of our new trauma center in 2016, since when, we have performed more aggressive transfusion and angioembolization for the correction of coagulopathy [17]. However, angioembolization is not performed routinely after DCS, with the decision being made by individual surgeons. Although re-laparotomy can be performed earlier in our new trauma center with the advanced trauma procedures available, a consistent change in our protocol was not made then, with treatment strategies decided by individual surgeons. Therefore, we dichotomized patients into those who underwent re-laparotomy within ≤ 48 or > 48 h after perihepatic packing and compared injury characteristics, treatment, and clinical outcomes between the two groups.

Definitions

Liver injury was graded according to the liver injury scale of the American Association of Surgery in Trauma [18]. Liver resection included any non-anatomical resection, such as wedge resection. Angioembolization included any attempt at angiography, even in the absence of definite arterial bleeding; angioembolization after re-laparotomy was excluded. Repacking was defined as packing performed at the time of the first re-laparotomy for bleeding. Complications related to liver injury, such as biloma, were identified on abdominal computed tomography and required drainage. Pneumonia was defined as ventilator-associated pneumonia after the first period of intubation, as defined by the criteria of the National Healthcare Safety Network definition of ventilator-associated pneumonia (PNU2) [19].

Statistical analysis

After evaluating the normality of distribution of the data using the Kolmogorov–Smirnov test, continuous variables were compared between the two groups using Student's t-test (mean ± standard deviation) or the Mann–Whitney *U* test (median value and interquartile range), as appropriate, whereas categorical variables were compared using the chi-squared test. All analyses were performed using SPSS version 23.0 (IBM, Chicago, IL, USA).

Results

Patients' characteristics

Of the 133 patients who underwent perihepatic packing during the study period, 55 died before re-laparotomy (mortality rate, 41.4%) and 16 did not meet the inclusion criteria. Accordingly, 67 patients (24 in the ≤ 48-h group and 41 in the > 48-h group) were included in our analysis (Fig. 1). The initial clinical data (Table 1) and injury severity (Table 2) did not differ significantly between the two groups.

Bleeding control for liver injury

The operative times were similar in the two groups; however, the rate of angioembolization and blood transfusion during the 24 h post-surgery was greater in the ≤ 48-h group than in the > 48-h group (Table 3). Three of the eight patients in the ≤ 48-h group had no definite bleeding during angioembolization as empirical gel foam had been applied, whereas two patients in the > 48-h group had definite bleeding. The international normalized ratio (INR) and lactate level during re-laparotomy were higher in the ≤ 48-h group than in the > 48-h group, although these levels were within normal ranges.

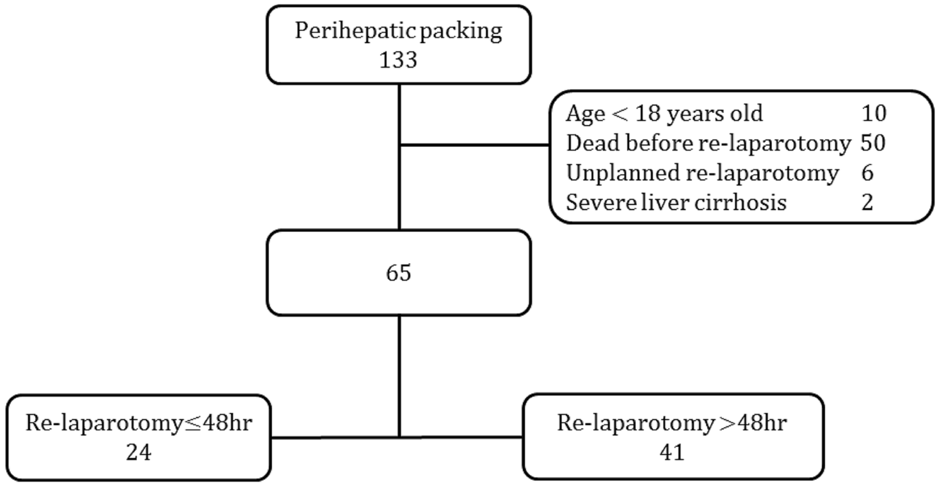

Fig. 1 Patient flowchart

Table 1 Clinical characteristics of the patients in this study

	Packing ≤ 48 h (*n* = 24)	Packing > 48 h (*n* = 41)	*p*
Sex (male:female)	18:6	33:8	0.603
Age (years)	48.0 ± 15.6	45.4 ± 13.4	0.474
Injury mechanism (blunt, %)	23 (95.8%)	37 (61.7%)	0.644
Systolic BP (mmHg)	97.3 ± 22.6	107.8 ± 32.4	0.165
Pulse (/min)	109.9 ± 26.7	98.3 ± 22.1	0.065
Glasgow coma score	10.7 ± 3.9	11.6 ± 4.1	0.398

Table 2 Distribution of injuries

	Packing ≤ 48 h (*n* = 24)	Packing > 48 h (*n* = 41)	*p*
Initial lactate (mmol/L)	4.75 [3.63–7.18]	5.23 [3.24–6.49]	0.791
Liver injury grade			0.157
III	1 (4.2%)	9 (22.0%)	
IV	17 (70.8%)	23 (56.1%)	
V	6 (25.0%)	9 (22.0%)	
Injury severity score	34 [27–37]	26 [22–41]	0.390
Abbreviated injury scale			
Head	4 [4–4]	3 [2–5]	0.435
Face and neck	2 [2–2]	2 [2–2]	1.000
Chest	3 [3–3]	3 [3–4]	0.284
Abdomen	4 [4–5]	4 [4–4]	0.128
Extremity	3 [2–3]	2 [2–3]	0.561

Clinical outcomes

There were no significant differences in the rate of repacking, mortality, and LOS in the ICU between the two groups. However, the total duration of ventilator support as well as the number of days on ventilator support after re-laparotomy were significantly lower in the ≤ 48-h group than in the > 48-h group. The incidence of ventilator-associated pneumonia was also lower in the ≤ 48-h group than in the > 48-h group, but the rate of sepsis was not different between the two groups (Table 4).

Discussion

High-grade liver injury is the leading cause of death of patients with abdominal trauma and is associated with a high mortality rate [10, 18]. In these patients, uncontrolled bleeding is associated with an increased risk of early (within 24 h)

Table 3 Procedures performed to control bleeding

	Packing ≤ 48 h (*n* = 24)	Packing > 48 h (*n* = 41)	*p*
Duration of packing (h)	28.9 ± 9.2	71.3 ± 17.5	**< 0.001**
Operation time (min)	80.5 ± 47.5	102.1 ± 51.7	0.098
Liver suture (*n*, %)	18 (75.0%)	37 (90.2%)	0.154
Liver resection (*n*, %)	3 (12.5%)	3 (7.3%)	0.662
Angio-embolization (*n*, %)	8 (33.3%)	2 (4.9%)	**0.004**
Transfusion during 24 h			
Red blood cells (units)	20 [10–26]	7 [6–18]	**0.001**
Fresh frozen plasma (units)	18 [12–29]	11 [7–14]	**0.002**
Platelets (units)	14 [8–24]	8 [0–16]	**0.033**
At second operation			
INR	1.36 [1.27–1.46]	1.21 [1.13–1.32]	**0.002**
Lactate (mmol/L)	2.55 [1.74–4.45]	1.29 [0.93–2.24]	**0.002**

Bold values indicate $p < 0.05$

Table 4 Clinical outcomes

	Packing ≤ 48 h (*n* = 24)	Packing > 48 h (*n* = 41)	*p*
Repacking (*n*, %)	3 (12.5%)	3 (7.3%)	0.662
Mortality (*n*, %)	4 (16.7%)	6 (14.6%)	0.827
ICU LOS[a] (days)	9 [5–31]	18 [11–28]	0.077
Ventilation day (days)			
Total	3 [3–7]	10 [7–19]	**< 0.001**
After re-laparotomy	2 [2–6]	9 [5–16]	**0.002**
Complications (*n*, %)			
Sepsis	4 (16.7%)	11 (26.8%)	0.348
Pneumonia	4 (16.7%)	18 (43.9%)	**0.025**
Drain for fluid collection	7 (29.2%)	6 (14.6%)	0.204
Fascia dehiscence	4 (16.7%)	5 (12.2%)	0.715
Liver abscess	2 (8.3%)	1 (2.4%)	0.549
Liver infarction	1 (4.2%)	5 (12.2%)	0.400
Biloma	2 (8.3%)	0 (0.0%)	0.133

Bold values indicate $p < 0.05$

[a]Length of stay in intensive care unit

and perioperative death [14, 20]. Our overall mortality rate was 41.4%, with 81.8% of these deaths occurring before re-laparotomy after DCS. Since Rotondo et al. introduced DCS, packing has become a widely accepted technique to control bleeding, with early re-laparotomy recommended after DCS [1, 5]. Pommerening et al. reported that delayed re-laparotomy was associated with failure of fascia closure and thus recommended that re-laparotomy be performed within 24 h, if possible, and not later than 48 h after DCS [7]. Abikhaled et al. suggested that packing be removed within 72 h of DCS, with a longer duration of packing being left increasing the risk of abscess formation and death [21]. In contrast, Nicol et al. indicated that although re-laparotomy should be performed within 48 h after packing, a prolonged duration of leaving packing in did not increase the incidence of septic complication [9]. The incidence of re-bleeding after perihepatic packing for high-grade liver injury is a principal concern and thus re-laparotomy is usually performed > 48 h after perihepatic packing [10, 22, 23]. However, the study by Nicol et al. was published more than a decade ago when angioembolization could not be performed until the first re-laparotomy [9].

The management of hepatic trauma is changing, and more non-operative strategies are being used for severe liver injury. For example, angiography with embolization can now be used to control bleeding and stabilize patients, with better outcomes [24]. In fact, Suen et al. found that hepatic angioembolization decreased the mortality rate caused by liver injury [15]. Angioembolization is now considered an important component for the control of bleeding in trauma patients, with a multidisciplinary approach after DCS improving clinical outcomes of patients with high-grade liver injury [25, 26]. We identified a higher rate of angioembolization among patients who underwent re-laparotomy within ≤ 48 h after perihepatic packing in the present study; however, a lack of precise indications for angioembolization after DCS being performed at the discretion of individual surgeons existed. Moreover, the amount of blood transfusion in patients with embolization was not significantly different. Future research is warranted to define the criteria for post-DCS angioembolization.

After DCS, the patient must be managed in the ICU to control and reverse the lethal triad of hypothermia, acidosis, and coagulopathy. To correct coagulopathy, fresh frozen plasma (FFP) and platelets are administered. Glaser et al. demonstrated that ratio-driven resuscitation in combat casualties was an independent predictor of early fascial closure after laparotomy [27], with the administration of FFP required to maintain the recommended

1:1:1 RBC:FFP:platelet ratio, based on the randomized PROPPR trial [11]. In this study, the rates of FFP and platelet administration rates were not remarkably lower than those of RBC administration in the two groups. The large volume of RBC transfusion given within 24 h may be attributed to an improved logistic process, such as active use of the blood refrigerator placed in the T bay, but the results of the study cannot be confirmed.

As leaving the packing in situ for too long may be related to sepsis, early removal of perihepatic packing has been recommended [5, 21, 28]. However, the study by Nicol et al. showed that delaying the removal of perihepatic packing did not increase the rate of infection [9]; our findings were consistent with theirs. Conversely, the duration of ventilator support required was shorter and the incidence of ventilator-associated pneumonia was lower in the ≤ 48-h group than in the > 48-h group. Furthermore, not only the duration of packing but also ICU management may be an important factor influencing clinical outcomes. Spontaneous awakening and breathing reduced the length of ventilator support and the incidence of pneumonia, with an open abdomen not being an obstacle to extubation [29, 30]. Based on the current evidence, we have now amended our ICU management protocol to include the use of light sedation and early awakening, which could decrease the LOS in the ICU and duration of ventilator support needed. However, light sedation was not utilized for patients treated with an open abdomen after DCS, being given only after the definite fascia closure. As deep sedation influences the incidence of pneumonia and ventilator support, its use before re-laparotomy might affect measured clinical outcomes. Furthermore, in our study, the duration of ventilation support in the ≤ 48-h group was reduced by 7 days, which was greater than the 3 days reported in a spontaneous awakening and breathing trial [31].

Our study has several limitations. First, its retrospective design limits assessment of causality and potentially creates selection bias. Second, although an increased use of angioembolization, transfusion, and improved ICU management was possible after the establishment of our new trauma center, the precise indications or timing of re-laparotomy did not change definitively, with some patients undergoing re-laparotomy > 48 h after DCS and perihepatic packing and angioembolization being performed inconsistently. Therefore, the performance of surgical procedures that could aid in lowering the risk of re-bleeding was limited. Third, the number of patients in our study sample was small, which limited the interpretation of results. However, it reflects the overall low incidence of high-grade liver injury and the associated high mortality rate. Fourth, the surgeons in our new trauma center have varying years of experience and include some who are young and inexperienced; therefore, surgeries performed by different surgeons to control bleeding may have influenced outcomes, owing to individual expertise level.

In conclusion, our study demonstrated that re-laparotomy performed within ≤ 48 h after DCS and perihepatic packing is feasible in patients with high-grade liver injury, using a multidisciplinary approach, which includes angioembolization and aggressive transfusion, as required. Early re-laparotomy reduced the length of ventilator support and the incidence of ventilator-associated pneumonia.

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