Primary Definitive Hemostasis for Traumatic Massive Hemoperitoneum With Hemodynamic Instability Improves Outcomes: A Single-Center, Propensity Score-Matched Analysis

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Abstract

Background

Currently, damage control laparotomy (DCL) is a standard operative approach for traumatic massive hemoperitoneum with hemodynamic instability. However, we have often observed unsatisfactory hemostatic effects of DCL for severe abdominal traumas, requiring definitive hemostasis (DH). We hypothesized that primary DH could improve the outcomes of hemodynamically unstable patients with traumatic massive hemoperitoneum compared with DCL.

Methods

This retrospective, single-center, observational study evaluated hemodynamically unstable patients with traumatic massive hemoperitoneum requiring surgical intervention between 2005 and 2020. The patient population was divided into two groups: a DH group and a DCL group. Propensity score matching was used to adjust for differences in baseline characteristics in the two groups, a one-to-one matched analysis using nearest-neighbor matching was performed based on the estimated propensity score of each group. The primary outcome was in-hospital mortality, and secondary outcomes were 48-hour mortality and 28-day mortality.

Results

A total of 170 patients met the inclusion criteria; 141 patients underwent primary DH, and 29 underwent DCL. In the propensity-matched analysis with 27 pairs, the DH group had significantly lower in-hospital mortality (odds ratio [OR] 0.154; 95% confidence interval (CI) 0.035 to 0.682) and 28-day mortality (OR 0.200; 95% CI 0.044 to 0.913) than the DCL group, but the 48-hour mortality did not differ significantly between the two groups (25.9% vs. 44.4%; OR 0.375; 95% CI 0.099-1.414).

Conclusions

Primary DH is an effective surgical procedure for traumatic massive hemoperitoneum with hemodynamic instability. Primary DH can be the standard surgical intervention for severe abdominal trauma.

Introduction

Currently, damage control laparotomy (DCL) is a standard operative approach for traumatic massive hemoperitoneum with hemodynamic instability. Rotondo et al. reported the usefulness of DCL (1), followed by a series of similar reports (2-6). They emphasized that expeditious hemostasis was paramount to prevent trauma-induced coagulopathy (7, 8). We also frequently performed DCL to rescue moribund victims, but we often observed unsatisfactory hemostatic effects of DCL for severe abdominal trauma, requiring definitive hemostasis (DH).

On the other hand, with the establishment of damage control resuscitation (DCR) for severe trauma, we can avoid trauma-induced coagulopathy by preemptive massive transfusion, limiting crystalloid, and adequate supplementation of some coagulation factor concentrates (9). Thus, intensive care focused on trauma-induced coagulopathy has made it possible to perform relatively long-time surgery, and the need for DCL has been decreased. As a result, we gradually shifted the surgical strategy for severe abdominal trauma from DCL to mandatory primary DH.

We hypothesized that primary DH could potentially improve the outcomes of traumatic massive hemoperitoneum with hemodynamic instability compared with DCL.

Materials And Methods

Study design

The Institutional Review Board of Saitama Medical University approved this study protocol. A retrospective, observational study of patients who underwent urgent laparotomy for massive hemoperitoneum with hemodynamic instability at a level I trauma center in Japan between January 2005 and December 2020 was conducted. From a prospective trauma database maintained by the Department of Emergency and Critical Care Medicine, the data were reviewed to obtain age, sex, mechanism of injury, Glasgow coma scale (GCS) score, systolic blood pressure (SBP), heart rate (HR), Injury Severity Score (ISS), head/neck, chest, abdomen, and extremity Abbreviated Injury Scale (AIS) score, dominant sources of hemorrhage, and surgical procedures.

Inclusion and exclusion criteria

Trauma patients who underwent surgical intervention for massive hemoperitoneum with hemodynamic instability were included. Hemodynamic instability was defined as an SBP of 90 mmHg or lower before surgical intervention. Patients with prehospital cardiac arrest who could not be resuscitated despite surgical intervention were excluded.

Operative procedure

The selection of surgical procedure was based on the physicians' clinical judgment. DCL was defined as any surgical procedure that resulted in temporary abdominal closure or abdominal packing, and DH was defined as completed definitive hemostasis. Based on the surgical procedure, patients were classified as either undergoing primary DH (DH group) or DCL (DCL group).

Outcomes

The primary outcome was in-hospital mortality, and the secondary outcomes were 48-hour mortality and 28-day mortality.

Statistical analysis

Patients in the DH and DCL groups were then matched 1:1 based on their propensity scores, using the nearest neighbor method and a caliper width of 0.2 standard deviations for the propensity score. Age, GCS, SBP, ISS, and dominant sources of hemorrhage (hepatic injury without inferior vena cava [IVC] injury, hepatic injury with IVC injury, great vessel injury, splenic injury, pancreas injury, and mesenteric injury) were selected as potential confounders and entered in the model. In the descriptive statistics, numeric or ordered variables are presented as medians and interquartile ranges, and categorical variables are shown as counts and percentages. Significance was defined as a p value of less than 0.05 or was assessed with 95% confidence intervals in all statistical analyses. Medians and ranges of continuous data were compared using the Mann-Whitney U test. Categorical data were compared using Pearson's chi-squared test or Fisher's exact test as appropriate. In the propensity score-matched analysis, we compared the outcomes between the two groups, using conditional logistic regression analyses. Data were analyzed using SPSS software, version 24 (IBM Corp., Armonk, NY).

Results

After the exclusion of ineligible patients, 170 eligible patients were divided into the DH group (n=141) and the DCL group (n=29) (Fig. 1). By one-to-one propensity score matching, 27 pairs from the DH and DCL groups were selected. The C-statistic for goodness of fit was 0.810 in the propensity score model.

Table 1 shows the demographics and Table 2 shows the dominant sources of hemorrhage of all patients (n=170) and of the propensity score-matched patients (n=54). Table 3 shows the surgical procedures in the DH group. In all patients, the median GCS score, ISS, the proportion of patients with a high AIS (>3) of the chest and extremities, hepatic injury with IVC injury, splenic injury, great vessel injury, and mesenteric injury were significantly different between the two groups. After propensity score matching, patient distributions were closely balanced between the DH and DCL groups.

The in-hospital mortality rate of the entire cohort was 27.6% (47/170), the 48-hour mortality rate was 14.7% (25/170), and the 28-day mortality rate was 21.2% (36/170). Table 2 shows in-hospital mortality (primary outcome), 48-hour mortality, and 28-day mortality (secondary outcomes), cause of death in the DH and DCL groups. In the analysis of all patients, in-hospital, 48-day mortality, and 28-day mortality were significantly lower in the DH group than in the DCL group. The propensity score-matched analysis showed significant differences between the DH and DCL groups in in-hospital mortality (33.3% vs. 74.1%; odds ratio [OR] 0.154; 95% confidence interval [CI] 0.035-0.682) and 28-day mortality (29.6% vs. 59.3%; HR 0.200; 95% CI 0.044-0.913). But the 48-hour mortality did not differ significantly between the two groups (25.9% vs. 44.4%; OR 0.375; 95% CI 0.099-1.414). The one-year survival curves showed higher survival in the DH group (log-rank p=0.002) (Fig. 2).

Discussion

The results of this study showed that primary DH for traumatic massive hemoperitoneum with hemodynamic instability improved a long-term mortality compared with DCL. Supporting this concept are

the data from Harvin et al. showing that DCL was associated with increased mortality (10). Although Harvin et al. focused on the patients requiring emergent laparotomy for all severe abdominal trauma, the present study may be the first to focus on traumatic massive hemoperitoneum with hemodynamic instability, which most likely leads to DCL.

There were many possible explanations as to why primary DH improved a long-term outcome. First, primary DH needs only one-time surgery. Patients with severe abdominal injury often have severe concomitant injuries. In particular, a severe brain injury and orthopedic injuries including spinal, pelvic and femoral fractures require both early surgical intervention and multidisciplinary management. A severe head injury requires the head-up position. Early definitive fixations for spinal, pelvic, and femoral fractures are always necessary for early mobilization to prevent pneumonia and venous thromboembolism. Although DCL with an open abdomen and re-operations interfere with the management of these concomitant injuries, primary DH requiring only one-time surgery can allow us to dedicate subsequent management to concomitant injuries. The present data of all patients showed that the mortality rate of brain injury, sepsis, or multiple organ injury was low. Second, hepato-biliary-pancreatic (HBP) surgery has evolved over the decades. Traumatic massive hemoperitoneum is often caused by HBP injuries; therefore, an HBP surgical procedure is often necessary. Currently, establishment of surgical procedures and development of energy devices, surgical staplers, and electrocautery have made hepatectomy and pancreatectomy technically easier and faster. Finally, DCR has evolved and become well known. DCR aims at preventing or reversing coagulopathy through permissive hypotension, limiting crystalloids, and delivering higher ratios of plasma and platelets. Thus, the implementation of DCR allowed us to perform DH requiring a prolonged surgical procedure. In absolute terms, DH potentially has a greater hemostatic effect than DCL.

The present in-hospital, 48-hour mortality, and 28-day mortality rates of all patients (including cardiac arrest on admission) were 27.6%, 14.7%, and 21.2%, respectively. In 2002, Clarke et al. published data from 1986 to 1999 reporting a mortality rate of 40% for hypotensive trauma patients undergoing laparotomy within 90 minutes of arrival (7). In 2017, Harvin et al. reported that the mortality rate of hypotensive trauma patients undergoing emergent laparotomy was 46% (11). In 2020, Traynor et al. reported that the in-hospital mortality rate of patients who underwent DCL in high-income countries was 29% (12). Even though these studies excluded patients with cardiac arrest on admission or intra-operative death, the present outcomes including patients with cardiac arrest or intra-operative death were superior to these reports. The present data were satisfactory compared with these other reports, affirming our surgical strategy based on mandatory DH.

The aim of DCL is to avoid the lethal triad that is described as the metabolic derangement of hypothermia, coagulopathy, and metabolic acidosis (6). The tenet that the lethal triad leads to a “vicious, bloody cycle” and subsequent irreversible physiological exhaustion is emphasized far too much in abdominal trauma surgery. When the concept of “Damage Control” was first described in 1983 (13), HBP surgery was still a high-risk procedure, and DCR had not yet been established. At that time, expeditious hemostasis with abdominal packing was the only optimal procedure to avoid the lethal triad. However,

with current development of HBP surgery and established DCR, DCL is no longer required. Higa et al. reported improved mortality and no abdominal compartment syndrome in severe abdominal trauma requiring laparotomy, despite a decrease in the rate of DCL at three years, and they pointed out the overuse of DCL (14).

This study has several limitations. First, the small sample size and single-center design limit the power and generalizability of the present findings. Second, although propensity scores were used to balance the groups' characteristics, there could be some other unmeasurable confounders and potential bias. Finally, the short-term outcome might be largely affected by the attending surgeons. Since there was no clear-cut indication for DCL, attending surgeons had to select the optimal procedures based on each patient's clinical status, severity of the injured organ, and concomitant injuries. Therefore, multi-institutional, prospective, observational studies will be useful in resolving these limitations and remaining questions.

Conclusion

Primary DH is an effective surgical procedure for traumatic massive hemoperitoneum with hemodynamic instability. Primary DH can be the standard surgical intervention for severe abdominal trauma.

Abbreviations

AIS Abbreviated injury score

CI Confidence interval

DCL Damage control laparotomy

DCR Damage control resuscitation

DH Definitive hemostasis

GCS Glasgow Coma Scale

HBP Hepato-biliary-pancreas

ISS Injury severity score

IVC Inferior vena cava

OR Odds ratio

SBP Systolic blood pressure

Declarations

Authors' contributions

MM conceived and designed the study. MM participated in writing, MS was responsible for statistical analysis. All authors read and approved the final manuscript.

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Availability of data and materials

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Ethics approval and consent to participate

The Institutional Review Board of Saitama Medical University approved this study protocol.

Consent for publication

Not applicable

Competing interests

All authors declare that they have no competing interests.

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Tables

Table 1. Demographic Characteristics of the DH and DCL groups

	Before matching			After matching		
	DH group	DCL group	P value	DH group	DCL group	P value
Patients, n	141	29		27	27	
Age, y, median (IQR)	44 (22-61)	51 (30-68)	0.224	49 (25.5-63)	49 (27.5-65.5)	0.797
Male, n (%)	109 (77.3)	18 (62.1)	0.130	20 (74.1)	16 (59.3)	0.248
Penetrating injury, n (%)	12 (8.5)	2 (6.9)	0.773	4 (14.8)	2 (7.41)	0.386
Glasgow Coma Scale score, median (IQR)	14 (12-15)	9 (3-13)	0.000	12 (3-14)	9 (3-12.5)	0.445
Systolic blood pressure (mmHg), median (IQR)	84 (70-100)	80 (53-90)	0.051	79 (60-97.5)	77 (46.5-88)	0.228
Injury severity score, median (IQR)	29 (21-42)	38 (33-45)	0.004	35 (25.5-45)	38 (31.5-45)	0.739
AIS, n (%)						
AIS head/neck>3	17 (12.1)	2 (6.9)	0.422	4 (14.8)	2 (7.41)	0.386
AIS chest>3	31 (22.0)	13 (44.8)	0.001	8 (29.6)	11 (40.7)	0.393
AIS abdomen>3	116 (82.2)	26 (89.7)	0.329	23 (85.2)	25 (92.6)	0.386
AIS extremity>3	6 (4.3)	4 (13.8)	0.047	2 (7.4)	4 (14.8)	0.386

AIS Abbreviated Injury Scale, DCL Damage Control Surgery, DH Definitive Hemostasis, IQR Interquartile range

Table 2. Dominant sources of hemorrhage of the DH and DCL group

	Before matching			After matching		
	DH group n=141	DCL group n=29	P value	DH group n=27	DCL group n=27	P value
Hepatic injury, n (%)	54 (38.3)	19 (65.5)	0.007	18 (66.6)	19 (70.4)	0.770
without juxta-hepatic venous injury	46 (32.6)	13 (44.8)	0.209	14 (51.9)	13 (48.1)	0.785
with juxta-hepatic venous injury	8 (5.7)	6 (20.7)	0.007	4 (14.8)	6 (22.2)	0.484
Splenic injury, n (%)	46 (32.6)	3 (10.3)	0.016	3 (11.1)	3 (11.1)	1.000
Great vessel injury, n (%)	3 (2.1)	3 (10.3)	0.029	3 (11.1)	1 (3.7)	0.299
Pancreas injury, n (%)	7 (5.0)	2 (6.9)	0.672	2 (7.4)	2 (7.4)	1.000
mesenteric injury, n (%)	29 (20.6)	2 (6.9)	0.083	1 (3.7)	2 (7.4)	0.552

DCL Damage Control Surgery, DH Definitive Hemostasis

Table 3. Surgical procedures of the DH group

	Before matching n=141	After matching n=27
Hepatectomy, n (%)	28 (19.8)	7 (25.9)
IVC repair, n (%)	10 (7.1)	6 (22.2)
Hepatorrhaphy, n (%)	16 (11.3)	5 (18.5)
Splenectomy, n (%)	32 (22.7)	3 (11.1)
Distal pancreatectomy, n (%)	10 (7.1)	2 (7.4)
Aortic repair, n (%)	1 (0.71)	1 (3.7)
bowel and mesenteric repair, n (%)	30 (21.3)	1 (3.7)
Splenorrhaphy, n (%)	4 (2.8)	0
Partial splenectomy, n (%)	3 (2.1)	0
Pancreatico-duodenectomy, n (%)	2 (1.4)	0
Others, n (%)	5 (3.5)	2 (7.4)

Table 4. Outcomes of DH and DCL groups

	Before matching				After matching			
	DH group	DCL group	OR	95% CI	DH group	DCL group	OR*	95% CI*
	n=141	n=29			n=27	n=27		
In-hospital mortality, n (%)	26 (18.1)	21 (72.4)	0.086	0.034-0.216	9 (33.3)	20 (74.1)	0.154	0.035-0.682
48-hour mortality, n (%)	12 (8.5)	13 (44.8)	0.114	0.045-0.293	7 (25.9)	12 (44.4)	0.375	0.099-1.414
28-day mortality, n (%)	19 (13.5)	17 (58.6)	0.110	0.045-0.266	8 (29.6)	16 (59.3)	0.200	0.044-0.913
Cause of death, n (%)								
Uncontrollable hemorrhage	11 (7.8)	17 (58.6)	0.060	0.023-0.156	6 (22.2)	16 (59.3)	0.167	0.037-0.745
Multiple organ failure	4 (2.8)	2 (6.9)	0.394	0.069-2.261	3 (11.1)	2 (7.4)	1.500	0.251-8.977
Traumatic brain injury	5 (3.5)	2 (6.9)	0.496	0.091-2.693	0	2 (7.4)	0.015	0.000-1327
Sepsis	2 (1.4)	0			0	0		

CI Confidence Interval, DCL Damage Control Surgery, DH Definitive Hemostasis, OR Odds Ratio

*OR and 95% CI were calculated using by conditional logistic regression analyses

Figures

Figure 1

Flow chart of hemodynamically unstable patients with traumatic hemoperitoneum requiring surgical intervention and propensity score matching of patients who underwent DH and DCL

Figure 2

Kaplan-Meier estimation of in-hospital survival in propensity score-matched DH and DCL groups. The P value was generated with the use of a log-rank test.