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ORIGINAL SCIENTIFIC REPORT

Early Surgery in Prone Position for Associated Injuries in Patients Undergoing Non-operative Management for Splenic and Liver Injuries

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Abstract

Background In patients undergoing non-operative management (NOM) of blunt splenic and/or liver injuries, no data exist on the safety of same-admission surgery in prone position for concomitant injuries.

Methods Retrospective study including adult trauma patients with blunt splenic/liver injuries and attempted NOM from 01/2009 to 06/2015 was conducted. Patient and injury characteristics as well as outcomes [failed (f)NOM, mortality] of patients with/without surgery in prone position were compared ('prone' vs. 'non-prone' group).

Results A total of 244 patients with blunt splenic/liver injury and attempted NOM were included. Forty patients (16.4%) underwent surgery in prone position on median post-injury day 2.0 [interquartile range (IQR) 3.0]. Surgery in prone position was mostly performed for associated spinal or pelvic injuries. The ISS was significantly higher, and the proportion of patients with high-grade injuries (OIS $\geq$ 3) was significantly less frequent in the 'prone' group (30.0 $\pm$ 14.5 vs. 23.9 $\pm$ 13.2, $p = 0.009$ and 27.5 vs. 53.9%, $p = 0.002$). In-hospital mortality as well as NOM failure rates were not significantly different between the 'prone' and 'non-prone' group (2.5 vs. 2.9%, $p = 1.000$; 0.0 vs. 4.4%, $p = 0.362$). Eleven patients with high-grade injuries were operated in prone position at median day 3 (IQR 3.0). None of these patients failed NOM. However, one patient with a grade IV splenic injury required immediate splenectomy after being operated in right-sided position on the day of admission.

Conclusion In this single-center analysis, surgery in prone position was performed in a substantial number of patients with splenic/liver injuries without increasing the fNOM rate. However, caution should be used in patients with grade IV/V splenic injuries.

Introduction

Non-operative management (NOM) of hemodynamic stable patients with blunt splenic and liver injuries has become the standard of treatment over the past decades [1–5]. The failure rate of NOM has been reported to be 10–20% for splenic injuries and 5–10% for liver lesions and depends on different factors such as the grade of organ injury, hemodynamic condition, amount of hemoperitoneum and blush on contrast-enhanced computed tomography (CT) scan [6, 7].

Concomitant injuries, e.g., fractures to limb, spine or pelvis, occur in two-thirds of patients with blunt SOI [8].

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These injuries may require early surgery in prone position to achieve good functional outcomes, early mobilization or to avoid neurologic worsening. Although clinically relevant, currently, no literature on the safety and timing of same-admission surgery in prone position in this group of patients exists.

The aim of the current study was to investigate the safety of early, same-admission surgery in prone position for concomitant injuries on the failure rate of patients with blunt liver and/or splenic injuries undergoing NOM. We hypothesize that early surgery in prone position for associated injuries does not increase the failure rate of NOM in patients with blunt solid organ injuries (SOI).

Methods

Ethical approval for the current study was obtained from the Institutional Revision Board of the Bern University Hospital (KEK BE 005/2016).

Patient selection

Adult trauma patients with blunt SOI (liver and/or spleen) undergoing non-operative management (NOM) admitted to Bern University Hospital, Switzerland, from 01/2009 until 06/2015 were retrospectively reviewed. The Bern University Hospital is a tertiary facility that includes a level I trauma center with a yearly admission rate of approximately 500 major trauma patients [Injury Severity Index (ISS) > 15].

All patients were managed and resuscitated according to Advanced Trauma Life Support (ATLS®; American College of Surgeons Committee on Trauma, Chicago, Illinois, USA) principles [9]. Inclusion criteria were age of >16 years and blunt SOI with attempted NOM. Hemodynamic instability was defined as a systolic blood pressure <90 mmHg and no or only transient response to volume resuscitation.

Attempted NOM was defined as no surgery for the SOI within the first 6 h from admission and was only performed in hemodynamically stable patients and at the discretion of the attending trauma team. Patients that required surgery for their SOI after 6 h from admission were defined as failed NOM (fNOM). Patients that underwent surgery for their SOI within 6 h from admission were defined as primary operative management (OM) and were excluded from further analysis.

After the primary survey, patients who were hemodynamically stable routinely underwent CT scan. The grade of SOI and the amount of hemoperitoneum were not considered exclusive or stringent criteria for surgery. In patients with a contrast blush on CT and hemodynamic stability, angioembolization was performed.

The standard of care for NOM included continuous monitoring of vital signs in the intermediate care or intensive care unit and serial hemoglobin levels every 6–8 h. Furthermore, an ultrasound within the first 12 h after trauma is performed to re-evaluate the amount of abdominal blood. Patients with high-grade injuries are immobilized with bed rest for 24 h. Subsequently, they are allowed to walk within the hospital. Moreover, patients with grade IV and V SOI receive a follow-up CT scan on post-injury day 7 and 60.

A surgical intervention (splenorrhaphy, splenectomy, liver packing, etc.) for the SOI $\geq$ 6 h after hospital admission was defined as failed NOM (fNOM). Radiological interventions [e.g., transcatheter arterial embolization (TAE)] were not defined as fNOM. Patients who died within the first 24 h after hospital admission were excluded from the current study.

Data collection

Data were retrospectively collected using the prospective institutional trauma registry [Trauma Audit and Research Network (TARN)] database and electronic patient records.

Data collection included patient characteristics (sex, age, gender and patients with and without surgery in prone position) and injury characteristics [Abbreviated Injury Scale (AIS; head, chest, abdomen, extremities and external) and ISS], the injured solid organ (liver and spleen) as well as the Organ Injury Scale (OIS) and outcome (in-hospital mortality and fNOM). A severe injury was defined as an AIS $\geq$ 3 of any body region.

Abdominal CT scans were obtained on admission in all patients. Based on abdominal CT scan, SOI were classified according to the American Association for the Surgery of Trauma (AAST) Organ Injury Scale (OIS) into low-grade (OIS < 3) and high-grade (OIS $\geq$ 3) injuries [10, 11].

'Prone' group versus 'non-prone' group

'Early surgery in prone position' was defined as 'same-admission surgery.' The indication and time of operation in prone position were at the discretion of the treating trauma team. No standardized protocol was in place when to operate patients in prone position; however, this was only performed in hemodynamic stable conditions. The time from hospital admission to surgery was drawn from the electronic charts.

The 'prone' group was compared to the 'non-prone' group regarding patients' demographics, injury characteristics and outcomes (mortality and fNOM).

Statistical analysis

Results were reported as numbers and percentages, means and standard deviations (SD) or medians and interquartile ranges (IQR), as appropriate. Categorical variables were compared using the Fisher's exact test. The Mann–Whitney *U* test was used for analysis of continuous variables. p values ≤ 0.05 were considered statistically significant.

The effect of surgery in prone position on the in-hospital mortality rate was tested in univariable analysis and adjusted for clinically important predictors in multivariable analysis. Clinically important predictor variables for mortality were included into the multivariable analysis if p values were <0.1 in univariable analysis. Collinearity was assessed using the variance inflation factor (VIF). A VIF < 5 was assumed to rule out collinearity. As none of the patients in the 'prone group' failed NOM, no multivariable analysis could be performed.

All statistical analyses were performed using SSPS statistics (Version 22, IBM Corporation, Armonk, NY).

Results

Within the 78-month study period, a total of 281 adult patients with blunt splenic and/or liver injuries were identified. Figure 1 shows the study outline. Overall, 30 patients (10.7%) required immediate laparotomy (primary operative management [OM]) because of hemodynamic instability or continued need for blood transfusion and therefore were excluded. Another seven patients were excluded because of fatal outcome less than 24 h after the initial trauma (Fig. 1).

In total, 244 patients with attempted NOM of blunt SOI were further analyzed. The mean age was 40.7 ± 18.5 years old, and the mean ISS was 24.9 ± 13.6. Overall, 111 patients (45.5%) underwent surgical procedures for associated injuries. Of those, forty patients (16.4%; 40 out of 244 patients) underwent surgery in prone position on median post-injury day 2.0 (IQR 0.0–3.0). In 39 patients, surgery in prone position was performed for associated spinal or pelvic injuries, and one patient was operated in prone position for an upper arm fracture. Median duration of these operations in prone position was 132.5 min (IQR 82.5–210.0). The remaining 71 patients underwent surgical procedures in supine or right-sided positioning.

Eleven out of the 40 patients (27.5%) in the 'prone' group suffered from high-grade (OIS $\geq$ 3) SOI injuries (Table 1). A significantly longer time to surgery in prone position was found for the 11 patients with high-grade SOI compared to the 29 patients suffering from low-grade SOI [median day 3 (IQR 2.0–8.0) vs. median day 1 (IQR 0.0–2.5), $p = 0.023$]. None of these patients failed NOM.

The ISS was significantly higher, and the proportion of patients with a high-grade SOI was significantly less frequent in the 'prone' than in the 'non-prone' group (30.0 ± 14.5 vs. 23.9 ± 13.2, $p = 0.009$ and 27.5 vs. 53.9%, $p = 0.002$) (Table 2). Severe chest trauma was significantly more common in the prone group compared to the non-prone group (80 vs. 60.3%, $p = 0.019$). Moreover, severe spinal injuries as well as severe pelvic injuries occurred significantly more often in the 'prone' group than in the 'non-prone' group (12.5 vs. 2.0%, $p = 0.007$; 25.0 vs. 5.4%, $p = 0.007$) [Table 2].

Overall, the fNOM rate was 3.7% ($n = 9$). When comparing the fNOM rates between the 'prone' and the 'non-prone' groups in univariable analysis, no significant differences was found (0.0 vs. 4.4%, $p = 0.362$). None of the nine patients that experienced fNOM required surgery for associated injuries in prone position. However, there were four patients with fNOM that required surgery for associated injuries in supine or right-sided positioning. One patient with a grade IV splenic injury required immediate splenectomy after being operated for a left femoral fracture in right-sided position on the same day of admission. Directly postoperatively, after being repositioned from the right-sided position to supine position, this patient rapidly developed a hemorrhagic shock. Abdominal sonography revealed blood in all quadrants, and the patient underwent immediate splenectomy. One patient with initial interventional embolization of a grade IV splenic injury and hemicraniectomy and evacuation of an intracerebral hematoma required splenectomy 8 h later due to delayed bleeding. Two patients underwent orthopedic stabilization of femoral fractures *after* splenectomy due to a fNOM.

Overall in-hospital mortality was 2.9% ($n = 7$). When comparing the mortality rates between the 'prone' and the 'non-prone' groups in univariable analysis, no significant differences were found (2.9 vs. 2.5%, $p = 1.000$). Increasing age [adjusted OR 1.050 (95% CI 1.009–1.093), $p = 0.016$] and ISS [adjusted OR 1.060 (95% CI 1.004–1.121), $p = 0.037$] were independently associated with in-hospital mortality. No significant effect of surgery in prone position on in-hospital mortality was found [adjusted OR 1.109 (95% CI 0.116–10.631), $p = 0.929$]. Following variables were included into this regression model: age, gender, AIS head $\geq$3, surgery in prone position and ISS. No collinearity was detected, and the VIF was <5 in all included variables.

One SOI-related mortality occurred in the group of seven patients that died. This was a patient from the 'non-prone' group that succumbed to hemorrhage shock after coiling of the splenic artery (splenic injury grade V) and the necessity of laparotomy and splenectomy in the further

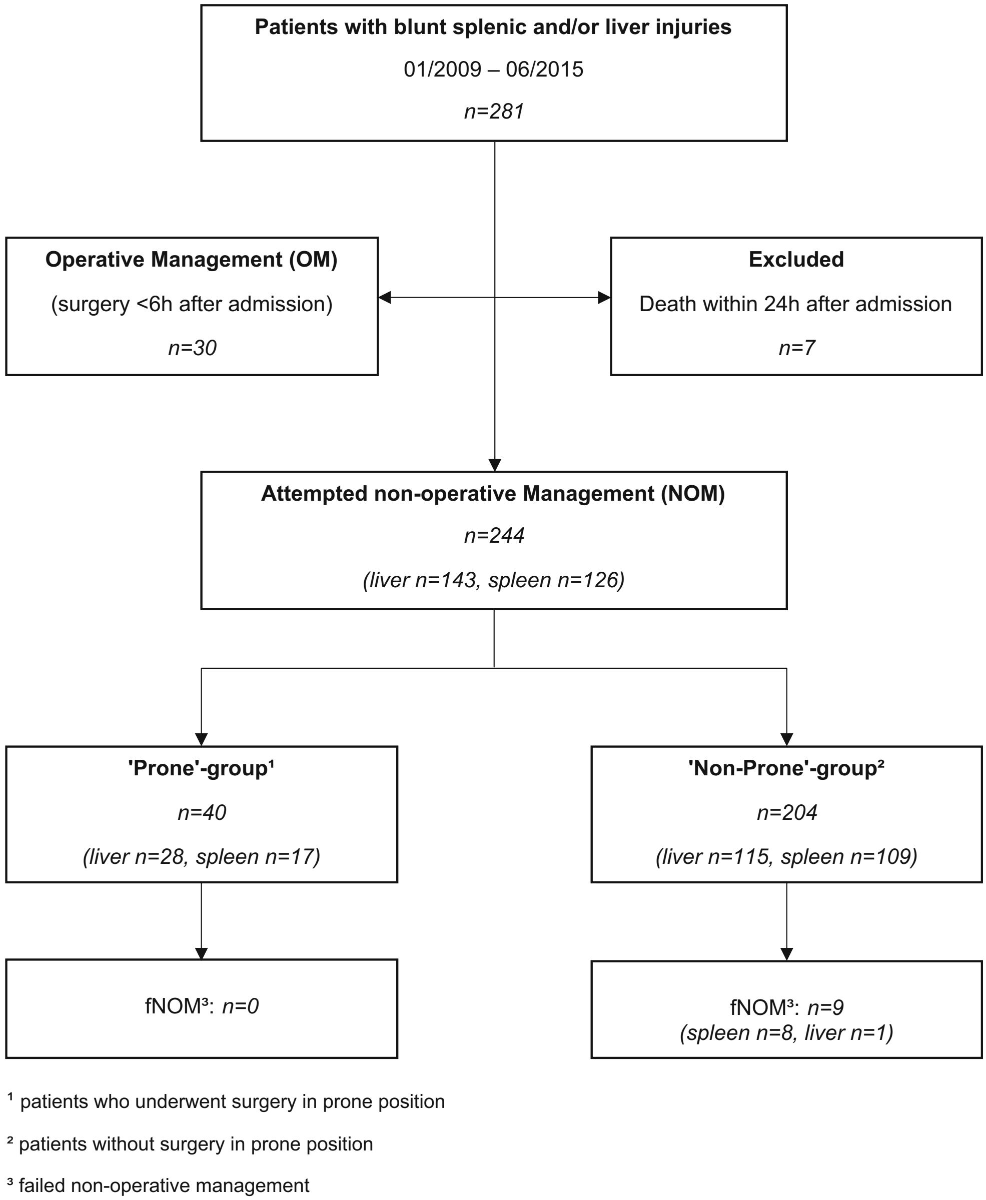

Fig. 1 Included patients and treatment

course with postoperative lack of stabilization of the circulatory system. The remaining six patients died from concomitant injuries. One of the 'prone' patients died due to a coagulation disorder during a spinal stabilization procedure, receiving mass transfusion for spinal bleeding and experiencing unsuccessful cardiopulmonary resuscitation. In this patient, SOI-related bleeding was ruled out by intraoperative abdominal ultrasound. The remaining five patients died from severe traumatic head injury with subsequent hypoxic brain damage.

Discussion

In this study, 244 patients with blunt liver and/or splenic injuries and attempted NOM were included. These patients were divided into the 'prone' versus the 'non-prone' group and compared in terms of fNOM and in-hospital mortality as well as patients' characteristics. Currently, there is no literature investigating the safety of early prone position for patients suffering blunt SOI.

A zero failure rate was seen for NOM in conjunction with surgery for associated injuries in prone position. NOM was successful in 100% of the 'prone' and in 95.6% of the 'non-prone' group suggesting the feasibility of early prone

Table 1 Demographics and injury characteristics of patients in the 'prone' group with high-grade splenic and/or liver injuries[a]

Patient	Age (years)	Sex	ISS	Injuries	Reason for prone	OIS liver/ spleen	PID[b]
1	62	Female	18	Spinal rotation injury, severe chest trauma	Spinal reposition	Spleen III	0
2	51	Female	59	Pelvic fracture, spinal and chest trauma, forearm fracture	ORIF sacrum	Spleen III	3
3	49	Female	22	Spinal burst fracture, extremity fractures	Spinal stabilization	Liver III	2
4	64	Male	22	Unstable vertebral fracture, severe chest and extremity trauma	Spinal spondylodesis	Liver III	3
5	44	Male	43	Spinal burst fracture, pelvis and extremity fractures, chest trauma	Spinal decompression	Liver III	5
6	53	Male	41	Spinal and pelvic fractures, chest trauma	ORIF and spinal stabilization	Liver III	5
7	27	Male	66	Pelvic and spinal fractures, severe TBI, chest trauma, multiple extremity fractures	Spinal stabilization	Liver III	13
8	63	Male	41	Spinal rotation injury with incomplete paraplegia, chest trauma	Reposition	Liver IV	0
9	27	Male	17	Burst-split fracture, flail chest, TBI	Spinal stabilization	Liver IV	12
10	43	Female	29	Spinal luxation fracture, TBI[c], chest trauma, bowel perforation	Spinal stabilization	Spleen II Liver III	2
11	29	Female	57	Pelvic fracture, chest and extremity trauma, TBI	Intramedullary nail	Spleen IV Liver III	8

[a]Organ Injury Scale (OIS) > 3

[b]Post-injury day

[c]Traumatic brain injury

Table 2 Baseline characteristics of the study population

	All patients (n = 244)	Prone group (n = 40)	Non-prone group (n = 204)	p value*
Age (years; mean ± SD[a])	40.7 ± 18.5	40.8 ± 15.8	40.9 ± 19.6	0.968
Male gender	160 (66.7%)	19 (47.5%)	141 (69.1%)	0.011
ISS[b] (mean ± SD[a])	24.9 ± 13.6	30.0 ± 14.5	23.9 ± 13.2	0.016
AIS[c] head ≥ 3 (n, %)	56 (23.0%)	12 (30.0%)	44 (21.6%)	0.303
AIS chest ≥ 3 (n, %)	155 (63.5%)	32 (80.0%)	123 (60.3%)	0.019
AIS abdomen ≥ 3 (n, %)	131 (53.7%)	14 (35.0%)	117 (57.4%)	0.014
AIS pelvis ≥ 3 (n, %)	21 (8.6%)	10 (25.0%)	11 (5.4%)	0.000
AIS spine ≥ 3 (n, %)	9 (3.7%)	5 (12.5%)	4 (2.0%)	0.007
OIS[d] liver/spleen ≥ 3 (n, %)	121 (49.6%)	11 (27.5%)	110 (53.9%)	0.003
Hospital length of stay, days (median, IQR[e])	10.0 (5.0–15.0)	14.0 (9.0–17.0)	9.0 (5.0–14.0)	0.002
ICU length of stay, days (median, IQR[e])	2.0 (1.0–5.0)	3.7 (2.3–8.5)	1.7 (1.0–4.5)	0.001
Failure NOM[f] of SOI[g]	9 (3.7%)	0 (0.0%)	9 (4.4%)	0.362
Mortality (n, %)	7 (2.9%)	1 (2.5%)	6 (2.9%)	1.000

*Fisher's exact test, Mann–Whitney U test

[a]Standard deviation

[b]Injury Severity Score

[c]Abbreviated Injury Scale

[d]Organ Injury Scale

[e]Interquartile range

[f]Non-operative treatment

[g]Solid organ injury

position in patients suffering from SOI. Comparable rates of successful NOM were also gained in other studies with sNOM rates between 80–85% for splenic and 82–100% for hepatic injuries [8, 12–16]; however, same-admission surgery in prone position was not investigated in these studies.

The grade of SOI is considered to be one of the strongest predictors for fNOM [2, 16–20], which correlates with our results. Nevertheless, 11 patients with high-grade SOI were operated on in prone position on median day 3. None of these patients failed NOM. However, caution should be used in patients with grade IV or V splenic injuries since one male patient with a grade IV splenic injury suffered from severe splenic hemorrhage when operated in right-lateral positioning for a left-sided femoral fracture on post-injury day 0. Of note, in this patient, in the initial CT scan no signs of arterial contrast blush were apparent.

Comparing the ‘prone’ and the ‘non-prone’ group, there was a significant difference between the OIS with more high-grade injuries in the ‘non-prone’ group. This might be due to a more cautious approach in patients with high-grade SOI regarding the indication for surgery in prone position. On the other hand, the ISS was significantly higher in the ‘prone’ group which is explained by the additional pelvic or spinal fractures these patients were suffering from.

Overall, failure of NOM occurred in nine patients (3.7%), all of them in the ‘non-prone’ group and with high-grade splenic injuries. All of these patients suffered from delayed bleeding, and laparotomy with splenectomy or surgical hemostasis between PID 0 and PID 21 was performed.

In the present study, TAE was used in 32 patients mostly with splenic injuries. Of those, three patients (7.5%) of the ‘prone’ group underwent TAE before surgery in prone position. TAE was performed either immediately after admission or as a salvage procedure in patients with ongoing bleeding or with delayed splenic rupture, however, only in patients that were hemodynamically stable. TAE has been reported to be a valuable adjunct in the NOM of blunt splenic and hepatic injuries, increasing especially the splenic salvage rate [21–29]. The current patients were all treated at a level I trauma center with the possibility of immediate abdominal surgical intervention or TAE at any time. The described approach to operate patients with blunt SOI early in prone position may not be generalized to smaller hospitals without 24/7 surgical, interventional radiological and ICU coverage.

This study has several limitations due its retrospective design and low number of included patients. Moreover, the decision to treat the patients non-operatively for their SOI or the indication and timing of operation in prone position for concomitant injuries were at the discretion of the treating trauma team, potentially resulting in a selection bias. Therefore, the conclusions were drawn with caution.

Conclusion

In patients undergoing NOM of blunt liver or splenic injuries, early surgery in prone position for concomitant injuries appears to be safe. However, this approach necessitates the possibility and hospital resources for immediate abdominal surgical intervention or TAE at any time. Moreover, caution should be used in patients with grade IV and V splenic injuries. In this group of patients, waiting for at least 3 days from accident to surgery in prone position is recommended. Further prospective investigation on whether early prone position is safe in patients treated with NOM for SOI is warranted.

Compliance with ethical standards

Conflict of interest Kathrin Markert, Tobias Haltmeier, Tatsiana Khatsilouskaya, Marius Keel, Daniel Candinas and Beat Schnüriger have no conflicts of interest or financial ties to disclose.

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