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Safety and Efficacy of Non-Operative Management with Selective Angioembolization for Adult Patients with Isolated Liver Trauma: A Retrospective Cohort Study

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ABSTRACT

Background: Non-operative management (NOM) has become the standard of care for hemodynamically stable patients with liver trauma, yet data from the Gulf region remain limited. We evaluated the success, safety, and outcomes of NOM compared with surgical management in patients with isolated liver trauma. Patients and Methods: This retrospective cohort study included consecutive adult patients with isolated liver trauma (American Association for the Surgery of Trauma [AAST] grade I–V) treated between 1 June 2022 and 30 June 2023. Patients who were hemodynamically stable or responded to initial resuscitation underwent whole-body CT and, when appropriate, NOM with angioembolization and percutaneous drainage; non-responders underwent emergency laparotomy. The primary outcome was NOM success (surgery-free hospital course, i.e., completion of the hospital stay without abdominal surgery, among patients initially assigned to NOM, analyzed by intention-to-treat; in-hospital death without surgery was recorded separately). Secondary outcomes were in-hospital mortality, complications within 30 days, intensive care unit (ICU) admission, blood transfusion, and hospital stay. Results: A total of 236 patients were screened, and 157 with isolated liver trauma were included: 141 (89.8%) were initially managed non-operatively and 16 (10.2%) underwent upfront emergency laparotomy for hemodynamic instability (all grade IV–V). Among the 141 patients initially assigned to NOM, 3 (2.1%) failed NOM and required salvage laparotomy; thus, 19 patients (12.1%) underwent surgery overall (16 upfront operations and 3 NOM failures). NOM succeeded in 138 of 141 patients (97.9%; 95% CI 93.9–99.3%), including all 117 patients with grade I–III injuries, 18 of 20 (90.0%) with grade IV, and 3 of 4 (75.0%) with grade V. When the one in-hospital death without surgery was also counted as failure (sensitivity analysis), the rate was 137 of 141 (97.2%; 95% CI 92.9–98.9%). Angiography was performed in 56 NOM patients (39.7%) and embolization in 42 (29.8%). In an as-treated comparison of all operated patients (n = 19) with patients successfully treated with NOM (n = 138), mortality was 36.8% versus 0.7%, complications 52.6% versus 10.1%, and ICU admission 94.7% versus 15.9% (all $P < 0.001$). These differences largely reflect baseline differences in physiological status and injury severity. Complications increased with injury grade, and biloma was the most frequent complication after successful NOM. Conclusion: In a setting with round-the-clock CT, interventional radiology, and trauma

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surgery coverage, NOM supported by early CT imaging and selective angioembolization was successful in 97.9% of patients initially selected for it, including selected high-grade injuries. Because 3 patients failed NOM and required salvage surgery, and because patients selected for surgery differed markedly in physiology and injury severity, outcome comparisons with upfront surgery should be interpreted as association rather than causation. Careful patient selection, close monitoring, and immediate access to angioembolization and the operating room remain essential. Prospective multicenter studies in the United Arab Emirates are warranted.

Keywords: Liver Trauma, Non-Operative Management (Nom), Angioembolization, Surgical Management, Complications.

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1. INTRODUCTION

Trauma remains a major cause of death and disability, and mortality among severely injured patients admitted to intensive care remains substantial [1]. Uncontrolled hemorrhage is one of the principal causes of preventable death after injury, and abdominal injuries contribute substantially to this burden [2]. The liver is one of the most frequently injured organs in blunt abdominal trauma and is commonly injured in penetrating trauma. With the widespread use of contrast-enhanced CT, more liver injuries are now detected, and most of them are low-grade injuries that heal without intervention [3,4]. Over the past three decades, the management of liver injuries has shifted from mandatory laparotomy to a selective non-operative approach, supported by a better understanding of hepatic anatomy and of the organ's hemostatic and regenerative capacity [5]. Current guidelines recommend NOM for hemodynamically stable patients irrespective of injury grade, provided that serial clinical assessment, repeat imaging, angiography, and an immediately available operating room are accessible. [3,4]. Non-operative care has been associated with fewer intra-abdominal complications, fewer non-therapeutic laparotomies, lower transfusion requirements, shorter hospital stay, and lower costs [4,5]. Conversely, NOM requires institutional resources and expertise, and its failure or inappropriate use in a patient with ongoing hemorrhage can be harmful. High-grade injuries in particular carry a risk of failure and of biliary and infectious complications, which makes patient selection the cornerstone of safe practice [4,5]. Regional data on this topic are limited. A retrospective study from 2014 to 2016 included 75 patients with liver injuries and reported an overall NOM success of approximately 81%, with lower success in high-grade injuries [6]. Since 2022, Our Centre have managed liver trauma according to a standardized protocol that combines whole-body CT, structured monitoring, and on-site angioembolization. To our knowledge, the outcomes of this approach in the United Arab Emirates have not been reported.

The aim of this study was to evaluate the effectiveness, safety, and outcomes of NOM in patients with isolated liver trauma treated at our hospitals between June 2022 and June 2023. The primary objective was to determine the NOM success rate. The secondary objectives were to describe mortality, morbidity, ICU admission, transfusion requirements, and hospital stay in patients managed non-operatively and surgically, to explore the relationship between injury grade and outcome, and to identify the factors that guide patient selection.

2. PARTICIPANTS AND METHODOLOGY

This was a retrospective cohort study including all consecutive adult patients with isolated liver trauma who met the inclusion criteria during the study period. It was conducted in the Emergency departments and trauma services of our hospitals, a group of tertiary-care hospitals that provide 24-hour emergency, CT, interventional radiology, trauma surgery, and intensive care services. The study covered the period from 1 June 2022 to 30 June 2023. The study was conducted in accordance with the Declaration of Helsinki and applicable institutional requirements. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies. All consecutive patients aged 18 years or older with isolated liver trauma were eligible. Isolated liver trauma was defined as a liver injury without any other significant injury, i.e., no injury with an Abbreviated Injury Scale (AIS) score ≥ 3 in any other body region; minor associated injuries (AIS ≤ 2, such as superficial contusions or abrasions) were allowed. Both blunt and penetrating mechanisms were eligible. Patients were excluded if they had associated significant injuries (AIS ≥ 3 in another body region), were younger than 18 years, were transferred to or from another facility within 24 hours of arrival, or had incomplete medical records. The injury grade was assigned according to the AAST organ injury scale (2018 revision) based on CT or, in patients who went directly to the operating room, of intraoperative findings [7]. All patients were assessed according to the Advanced Trauma Life Support (ATLS) principles, with Focused Assessment with Sonography for Trauma (FAST) and chest and pelvic radiographs. Hemodynamically stable patients and patients who responded to the initial rapid infusion of 1000 ml of crystalloid underwent whole-body contrast-enhanced CT with arterial

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and portal venous phases. NOM was offered to these patients regardless of injury grade and consisted of admission to a monitored bed (ward, high-dependency unit, or ICU according to severity), serial clinical examination, serial hemoglobin measurement, and early follow-up imaging with contrast-enhanced ultrasound (CEUS) or CT. Angiography with embolization was performed for contrast extravasation, pseudoaneurysm, or ongoing bleeding on CT, and percutaneous drainage was used for symptomatic bilomas or infected collections. Patients who remained hypotensive despite resuscitation, or who had peritonitis, underwent emergency laparotomy without CT.

Definitions and outcomes. The management first performed was classified as NOM or upfront surgery. Patients initially stabilized and assigned to NOM who subsequently developed secondary hemodynamic instability or ongoing bleeding were classified as NOM failures and underwent emergency surgical exploration. NOM success was defined as completion of the hospital course without abdominal surgery (a surgery-free hospital course); in-hospital death without surgery was recorded and reported separately as mortality. In a sensitivity analysis, in-hospital death without surgery was also counted as NOM failure. Angiography, embolization, and percutaneous drainage were not considered surgery. The primary outcome, NOM success, was analyzed by intention-to-treat among all patients initially assigned to NOM, with NOM failures counted as failures. In this cohort, 3 patients failed NOM; together with the 16 patients who underwent upfront surgery, a total of 19 patients underwent operative management. The comparison of secondary outcomes is an as-treated analysis, not an intention-to-treat analysis: patients were classified according to the management finally performed (all operated patients, n = 19, versus patients successfully treated with NOM, n = 138); the outcomes of upfront surgery and NOM failure are also shown separately in Table 5. Secondary outcomes were in-hospital mortality, complications within 30 days of injury (biloma, biliary fistula, hepatic abscess, pseudoaneurysm, postoperative or secondary hemorrhage, persistent bleeding after embolization, and abdominal compartment syndrome; complications are reported both as the number of patients with at least one complication and as individual events, because a patient could have more than one), ICU admission, transfusion of packed red blood cells, and length of hospital stay.

Data collection. Two investigators extracted data from the electronic medical records using a standardized form; discrepancies were resolved by discussion, with a third senior investigator adjudicating when consensus was not reached. The variables included demographics, mechanism of injury, vital signs, and laboratory values on arrival, CT findings (injury grade and estimated hemoperitoneum volume), interventions, complications, and outcomes.

Sample size. All consecutive eligible patients were included, and no sampling procedure was applied. Using OpenEpi, for an expected NOM success rate of 95% with an absolute precision of ±5% at the 95% confidence level, a minimum of 73 patients managed non-operatively was required; 157 eligible patients were included, of whom 141 were initially managed non-operatively; the resulting 95% CI for the primary outcome (93.9–99.3%) was narrower than the planned precision.
Statistical analysis. Continuous variables are expressed as mean ± standard deviation (SD) or median and interquartile range (IQR) according to their distribution (Shapiro–Wilk test) and were compared with Welch's t-test or the Mann–Whitney U test. Categorical variables are expressed as numbers and percentages and were compared with Fisher's exact test (Fisher–Freeman–Halton test for variables with more than two categories). Confidence intervals (CI) for proportions were calculated with the Wilson method. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Given the small size of the upfront surgery (n = 16) and NOM failure (n = 3) cohorts, multivariable adjustment was not feasible; comparisons between management groups are therefore descriptive and subject to confounding by indication. No correction for multiple comparisons was applied because the analysis was exploratory. Analyses were performed with SPSS Statistics, version 28 (IBM Corp., Armonk, NY, USA).

3. RESULTS

A total of 236 patients with liver trauma were treated at Burjeel Hospitals between 1 June 2022 and 30 June 2023. Seventy-nine patients were excluded (58 with associated injuries, 12 younger than 18 years, and 9 with incomplete records or transfer within 24 hours), leaving 157 patients with isolated liver trauma for analysis. Of these, 141 patients (89.8%) were initially managed non-operatively (NOM), and 16 patients (10.2%), all with grade IV–V injuries, underwent upfront emergency laparotomy because of hypovolemic shock. Among the 141 patients initially assigned to NOM, 3 (2.1%; 1 with grade V and 2 with grade IV injuries) failed NOM and required emergency surgical exploration. Thus, a total of 19 patients (12.1%) underwent surgery: 16 upfront operations and 3 NOM failures. NOM was successful in 138 patients (97.9% of those initially assigned to NOM). The flow of patients is shown in Figure 1.

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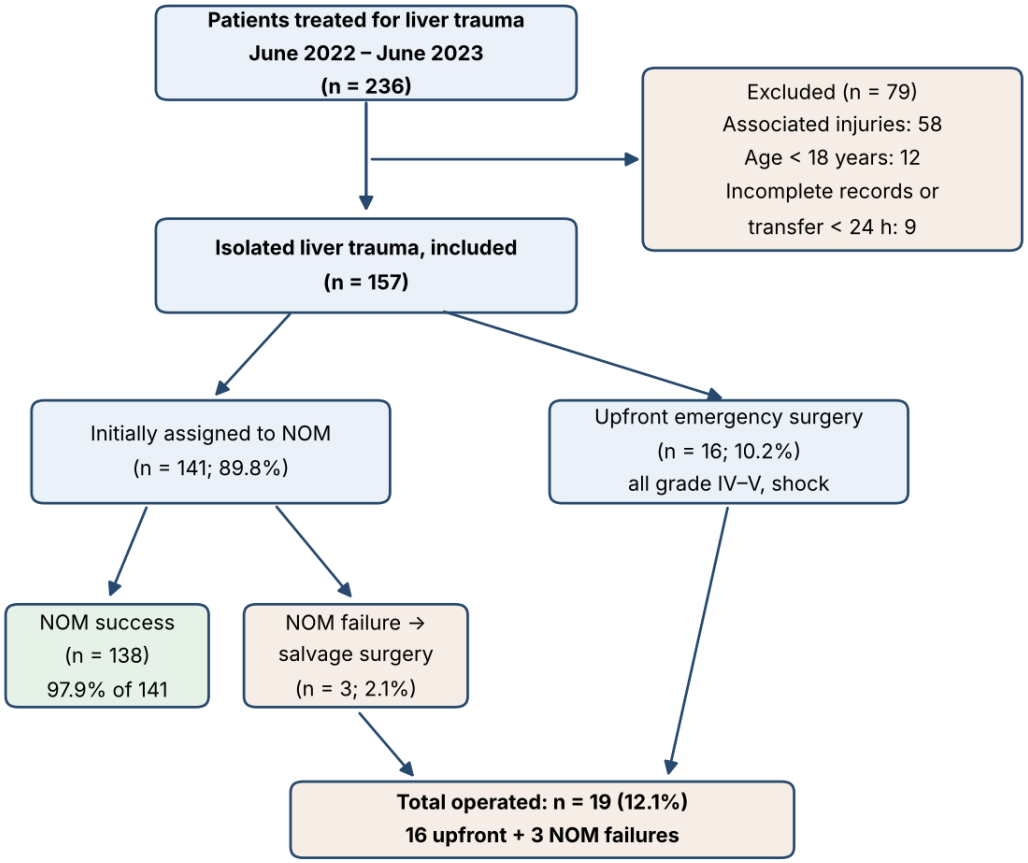


Fig. 1. STROBE flow diagram of patient selection and management

The mean age of the patients was 34.6 years in the NOM group and 41.2 years in the surgical group (P = 0.081), and most patients in both groups were men (90.8% and 93.8%, respectively; P = 1.000). Traffic collisions were the most common cause of injury in both groups. The NOM group had a more diverse range of mechanisms, including falls, industrial accidents, sports and recreational activities, assaults, and penetrating injuries (Table 1). Five patients (3.2%) had penetrating (stab) injuries (3 in the NOM group and 2 in the surgical group).

Table 1. Patient characteristics according to the management first performed

Characteristic	NOM (n = 141)	Surgery (n = 16)	P value
Age, years (mean ± SD)	34.6 ± 10.2	41.2 ± 13.8	0.081
Male sex, n (%)	128 (90.8)	15 (93.8)	1.000
Mechanism of injury, n (%)			**0.21**
Traffic collision	66 (46.8)	9 (56.3)	
Fall from height	24 (17.0)	2 (12.5)	
Industrial/occupational	22 (15.6)	2 (12.5)	
Sports/recreational	14 (9.9)	0 (0.0)	
Assault	12 (8.5)	1 (6.3)	
Penetrating injury	3 (2.1)	2 (12.5)	
AAST grade of liver injury, n (%)			**< 0.001**
Grade I	28 (19.9)	0 (0.0)	
Grade II	44 (31.2)	0 (0.0)	
Grade III	45 (31.9)	0 (0.0)	
Grade IV	20 (14.2)	9 (56.3)	
Grade V	4 (2.8)	7 (43.8)	
Hemoperitoneum, ml (mean ± SD)	412 ± 268	1,846 ± 512	< 0.001

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NOM, non-operative management; AAST, American Association for the Surgery of Trauma; SD, standard deviation. P values were calculated with Welch's t-test (continuous variables) and Fisher's exact or Fisher–Freeman–Halton tests (categorical variables). The grade comparison refers to grade IV–V versus grade I–III injuries.

The severity of liver trauma was clearly higher in the surgical group. All patients who underwent immediate surgery had grade IV or V injuries, whereas grade IV–V injuries represented only 17.0% (24 of 141) of the NOM group, which was distributed across all grades (P < 0.001). The mean volume of hemoperitoneum was also higher in the surgical group (1,846 ml) than in the NOM group (412 ml; P < 0.001). Surgery was thus reserved for the most severe injuries, whereas NOM was applied across a broad range of severity.

Table 2. Vital signs and laboratory findings on arrival in the Emergency Department

Parameter	NOM (n = 141)	Surgery (n = 16)	P value
Pulse rate, beats/min	88 ± 14	118 ± 16	< 0.001
Systolic blood pressure, mmHg	126 ± 17	84 ± 15	< 0.001
Arterial pH	7.36 ± 0.05	7.21 ± 0.08	< 0.001
Lactate, mmol/L	2.4 ± 1.1	6.8 ± 2.4	< 0.001
Hemoglobin, g/dL	12.9 ± 1.8	9.1 ± 1.9	< 0.001
White cell count, $\times 10^9$/L	13.1 ± 4.2	17.9 ± 5.1	0.002

Data are mean ± SD. P values were calculated with Welch's t-test. NOM, non-operative management.

On arrival, patients who underwent immediate surgery were tachycardic (118 ± 16 vs. 88 ± 14 beats/min) and hypotensive despite initial resuscitation (systolic blood pressure 84 ± 15 vs. 126 ± 17 mmHg), and had more marked metabolic acidosis (pH 7.21 ± 0.08 vs. 7.36 ± 0.05), higher lactate levels (6.8 ± 2.4 vs. 2.4 ± 1.1 mmol/L), lower hemoglobin levels (9.1 ± 1.9 vs. 12.9 ± 1.8 g/dL), and a higher white cell count (17.9 ± 5.1 vs. 13.1 ± 4.2 × 10^9/L) than patients selected for NOM (P < 0.001 for all, except for white cell count, P = 0.002). In the NOM group, the mean values were within or close to the normal range, with mild elevation of lactate and leukocytosis, as expected after injury.

NOM success. NOM was successful in 138 of the 141 patients initially assigned to NOM (intention-to-treat; 97.9%; 95% CI 93.9–99.3%). All 117 patients with grade I–III injuries were successfully treated without surgery (100%), as were 18 of 20 patients with grade IV injuries (90.0%) and 3 of 4 patients with grade V injuries (75.0%). One patient with a grade IV injury died in hospital of septic shock from a hepatic abscess without having undergone surgery; by definition this patient is counted as a NOM success, and when death was also counted as failure (sensitivity analysis), NOM success was 137 of 141 (97.2%; 95% CI 92.9–98.9%). The three failures were all high-grade injuries and occurred within the first 30 hours after admission: two patients (one grade IV and one grade V) had undergone angioembolization before developing recurrent hemorrhage with hemodynamic deterioration, and one patient with a grade IV injury became unstable without a bleeding focus that was amenable to embolization. All three underwent laparotomy.

Table 3. Invasive non-surgical interventions among patients successfully treated with NOM (n = 138)

AAST grade	No invasive procedure	Percutaneous drainage only	Angiography without embolization	Angioembolization (± drainage)	Total
I	28	0	0	0	28
II	34	1	4	5	44
III	15	4	8	18	45
IV	1	1	2	14	18
V	0	0	0	3	3
Total	**78**	**6**	**14**	**40**	**138**

Data are numbers of patients. Patients who underwent both embolization and percutaneous drainage are counted in the angioembolization column. Two additional patients with NOM failure (one grade IV and one grade V) also underwent angiography with embolization, giving 56 angiographies and 42 embolizations among all 141 patients initially assigned to NOM.

Among all 141 patients who started NOM, angiography was performed in 56 (39.7%) because of contrast extravasation or pseudoaneurysm on CT, and embolization was required in 42 (29.8%), including two of the three patients who later required surgery; these two NOM failures are not included in Table 3, which explains the difference between 56 and 42 here and 54 and 40 in Table 3. Overall, 78 of the 138 successfully treated patients (56.5%) required no invasive procedure, and the need for angioembolization increased with the grade of injury, reaching 77.8% (14 of 18) in grade IV and all 3 patients in grade V.

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Table 4. Post-treatment complications according to the management finally performed

AAST grade	NOM (n = 138)	Surgery (n = 19)
I	0 / 28	No patients
II	1 / 44 (2.3%) 1 biloma	No patients
III	5 / 45 (11.1%) 4 biloma, 1 pseudoaneurysm	No patients
IV	6 / 18 (33.3%) 3 biloma, 2 biliary fistula, 1 hepatic abscess	4 / 11 (36.4%) 2 biliary fistula, 1 intra-abdominal abscess, 1 postoperative hemorrhage, 1 persistent bleeding after embolization
V	2 / 3 (66.7%) 1 biloma, 1 biliary fistula	6 / 8 (75.0%) 2 biliary fistula, 2 postoperative hemorrhage, 1 intra-abdominal abscess, 1 abdominal compartment syndrome, 1 persistent bleeding after embolization
Total	**14 / 138 (10.1%)**	**10 / 19 (52.6%)**

Data are number of patients with a complication / number of patients in the grade (%). Numerators are numbers of patients with at least one complication; the complications listed are individual events, and a patient could have more than one (each NOM patient had one; the 10 operated patients had 12 events). The surgical group includes the 16 patients who underwent upfront surgery and the 3 patients with NOM failure (two grade IV and one grade V). Complications occurred in 14 of the 138 patients successfully treated with NOM (10.1%; 95% CI 6.1–16.3%). No complications were observed in patients with grade I injuries, and only one patient with a grade II injury developed a biloma. The incidence of complications rose with the injury grade: 11.1% in grade III, 33.3% in grade IV, and 2 of 3 patients in grade V. Biloma was the most frequent complication (9 patients), followed by biliary fistula (3 patients), pseudoaneurysm (1 patient), and hepatic abscess (1 patient). Every complication in this group received an intervention (Table 5): percutaneous drainage in 13 patients (9 bilomas, 3 biliary fistulas, and 1 hepatic abscess) and angioembolization in 1 (pseudoaneurysm); the patient with the hepatic abscess also received antibiotics and supportive care. No patient in this group required surgery. The patient with the hepatic abscess died of septic shock despite drainage and antibiotics. In the surgical group, 10 of 19 patients (52.6%) had complications (12 events), which were more severe than in the NOM group: biliary fistula (4), postoperative hemorrhage (3), intra-abdominal abscess (2), persistent bleeding after embolization in two NOM failures (one grade IV and one grade V), and abdominal compartment syndrome (1, grade V); two patients who underwent upfront surgery had more than one complication. Among patients who underwent upfront surgery, three required re-laparotomy and one required decompression laparotomy (Table 5). The complication rate was 36.4% (4 of 11) in grade IV and 75.0% (6 of 8) in grade V. Overall, the likelihood of complications was closely related to the severity of the liver injury in both groups.

Table 5. Key outcomes, complications, and interventions by management group

Outcome	Upfront surgery (n = 16)	NOM failure (n = 3)	All operated (n = 19)	NOM success (n = 138)	P value
Mortality, n/N (%)	6/16 (37.5)	1/3 (33.3)	7/19 (36.8)	1/138 (0.7)	< 0.001
Patients with ≥1 complication, n/N (%)	8/16 (50.0)	2/3 (66.7)	10/19 (52.6)	14/138 (10.1)	< 0.001
Complications (number of patients; % of group)					
Biloma	0	0	0	9 (6.5)	-
Biliary fistula	4 (25.0)	0	4 (21.1)	3 (2.2)	-
Postoperative or secondary hemorrhage	3 (18.8)	0	3 (15.8)	0	-
Intra-abdominal or hepatic abscess	2 (12.5)	0	2 (10.5)	1 (0.7)	-
Abdominal compartment syndrome	1 (6.3)	0	1 (5.3)	0	-
Pseudoaneurysm	0	0	0	1 (0.7)	-
Persistent bleeding after embolization	0	2 (66.7)	2 (10.5)	0	-

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Outcome	Upfront surgery (n = 16)	NOM failure (n = 3)	All operated (n = 19)	NOM success (n = 138)	P value
Interventions for complications (number of patients)					
Percutaneous drainage	2	0	2	13	-
Antibiotics and supportive care	4	0	4	1	-
Angioembolization	0	0	0	1	-
Salvage laparotomy / re-exploration	3	3	6	0	-
Decompression laparotomy	1	0	1	0	-
ICU admission, n/N (%)	15/16 (93.8)	3/3 (100.0)	18/19 (94.7)	22/138 (15.9)	< 0.001
Packed red cell transfusion, n/N (%)	16/16 (100.0)	3/3 (100.0)	19/19 (100.0)	29/138 (21.0)	< 0.001
Hospital stay, days, median (IQR)	19 (13–28)	15 (11–22)	18 (12–27)	6 (4–9)	< 0.001

P values compare all operated patients (n = 19) with patients successfully treated with NOM (n = 138), using Fisher's exact test (categorical variables) and the Mann–Whitney U test (hospital stay); they describe associations from an as treated (not intention-to-treat) comparison and are subject to confounding by indication. Upfront surgery (n = 16) and NOM failure (n = 3) are shown separately. The complication and intervention rows show numbers of patients (percentage of the group); a patient could have more than one complication or intervention, so these rows do not sum to the number of patients with at least one complication. Post-embolization persistent bleeding denotes recurrent hemorrhage after angioembolization that led to NOM failure. Salvage laparotomy/re-exploration denotes the index salvage operation in NOM failures and re-laparotomy for hemorrhage in patients who underwent upfront surgery. Antibiotics and supportive care denotes conservative management of biliary fistulas after upfront surgery and, in the NOM group, treatment of the hepatic abscess in addition to drainage. ICU, intensive care unit; IQR, interquartile range.

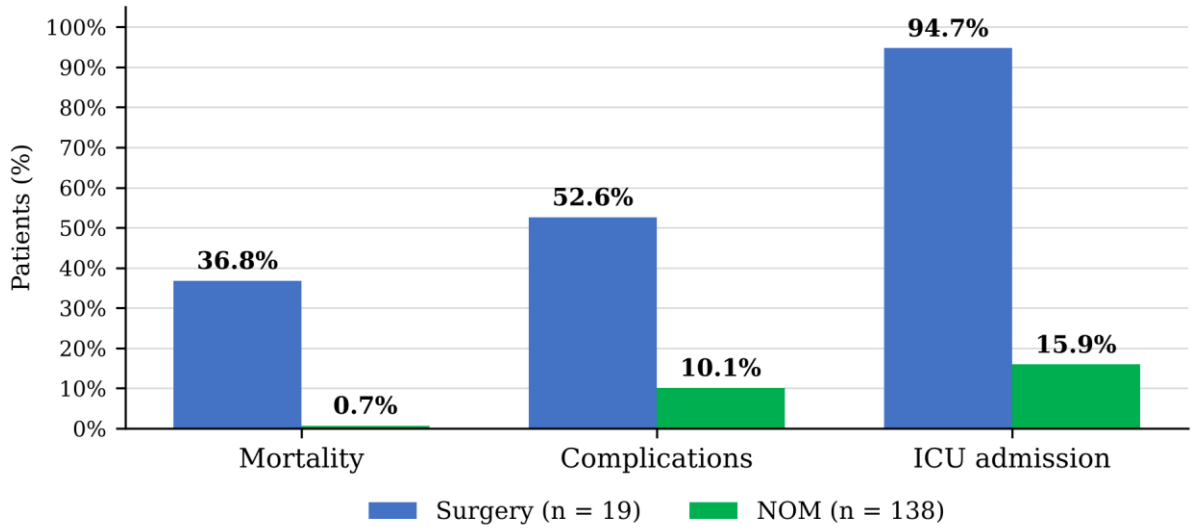


Fig. 2. Mortality, complications, and ICU admission rates in all operated patients (n = 19) and in patients successfully treated with NOM (n = 138) (as-treated comparison)

Overall in-hospital mortality in the cohort was 5.1% (8 of 157 patients). Mortality was higher among all operated patients (7 of 19 patients, 36.8%: 6 of 16, 37.5%, after upfront surgery and 1 of 3 after NOM failure; 2 of 11 in grade IV and 5 of 8 in grade V) than among patients successfully treated with NOM (1 of 138 patients, 0.7%; P < 0.001; Figure 2). The only death in the NOM group occurred in a 74-year-old patient with a grade IV injury who developed a hepatic abscess and died of septic shock on day 19; because this patient did not undergo surgery, the death is counted under NOM success by definition and is addressed in the sensitivity analysis. Complications (52.6% vs. 10.1%), ICU admission (94.7% vs. 15.9%), and transfusion of packed red cells (100% vs. 21.0%) were also more frequent in the surgical group (P < 0.001 for all), and

the median hospital stay was longer (18 vs. 6 days; $P < 0.001$; 19 days after upfront surgery and 15 days after NOM failure). These differences mainly reflect the greater severity of injury and the physiological derangement of the patients who required surgery.

4. DISCUSSION

In this 13-month cohort of 157 patients with isolated liver trauma, nearly nine of ten patients were initially managed non-operatively, and NOM was successful in 97.9% of them (138 of 141; 3 patients required salvage surgery). All patients with grade I–III injuries were treated without surgery, and success remained high in grade IV injuries (90.0%) and in the few grade V injuries (75.0%). These findings support the current recommendation that NOM is the treatment of choice for hemodynamically stable patients with liver injuries irrespective of the grade of injury [3,4,8]. They also confirm that the shift from mandatory laparotomy to selective NOM, which has occurred over the past decades, [5] is feasible in the setting of a modern private tertiary healthcare group in the United Arab Emirates. In our cohort, 91% of the patients were men, the mean age was in the mid-thirties, and traffic collisions were the leading mechanism, followed by falls and occupational injuries. The marked male predominance is probably related to the demographic composition of the working population exposed to road traffic and occupational hazards, although this explanation cannot be tested with our data. The choice between NOM and surgery was determined by hemodynamic status rather than by injury grade alone. Patients who underwent immediate laparotomy had grade IV–V injuries, but also lower blood pressure, higher heart rate, lower pH and hemoglobin, and higher lactate on arrival, and a larger hemoperitoneum. This agrees with the principles of the WSES and EAST guidelines and the Western Trauma Association algorithm, which indicate that hemodynamic instability, peritonitis, or failure of resuscitation, rather than the radiological grade, mandate operative treatment [3,4,8] and with the conclusion of the study from Abu Dhabi that management should depend on the hemodynamic status of the patient rather than on the injury grade [6]. Because these two groups were selected on clinical grounds, the differences in outcomes between them cannot be attributed to the treatment itself. Comparisons between these groups therefore describe association rather than causation. The NOM success rate in our series (97.9%) was higher than the approximately 81% reported by the earlier study from Abu Dhabi, in which NOM succeeded in only 5 of 10 patients with grade IV injuries [6], although this previous series included patients with associated injuries and covered an earlier period (2014–2016). The difference may be explained by the exclusion of polytrauma patients, in whom associated injuries are a frequent reason for laparotomy; the standardized protocol with early CT; and the on-site availability of interventional radiology at all times. In our series, 56 of 141 patients (39.7%) underwent angiography and 42 (29.8%) embolization, and the need for embolization increased steadily with the injury grade, reaching 75.0% (15 of 20) of the patients with grade IV injuries and all four patients with grade V injuries (these figures include NOM failures; among successfully treated patients the corresponding numbers were 14 of 18 and 3 of 3, Table 3). These figures are consistent with the evidence that angioembolization is an important adjunct that extends the applicability of NOM to high-grade injuries, even though surgeons are still required for patients who are unstable [4,9]. The three failures in our series were all high-grade injuries, occurred early, and were related to recurrent or uncontrolled hemorrhage. Close monitoring with immediate access to the operating room is therefore needed during the first 24 to 48 hours in patients with grade IV–V injuries [4,8]. Complications after NOM were relatively infrequent (10.1%) and were mostly biliary: bilomas and biliary fistulas accounted for 12 of the 14 events. The incidence rose with the injury grade, from no complications in grade I to one third of the patients with grade IV injuries, a gradient that has been described in other series and in the guidelines [4,5,8]. Nearly all of these complications (13 of 14) were treated with percutaneous drainage, and none required surgery, which supports the strategy of follow-up imaging and a low threshold for drainage in symptomatic patients. The single death in the NOM group was caused by a hepatic abscess with septic shock in an elderly patient with a high-grade injury, which indicates that infectious complications deserve attention even after successful hemostasis. In the surgical group, complications were more frequent (52.6%) and more severe, with postoperative hemorrhage, persistent bleeding after embolization, intra-abdominal abscess, and abdominal compartment syndrome in addition to biliary fistulas. These patients had exsanguinating injuries, and a high morbidity after damage-control and definitive surgery for grade IV–V injuries has been described in other series [9]. Mortality was low in patients successfully treated with NOM (0.7%) and high among operated patients (36.8%). The overall mortality of our cohort (5.1%) is comparable to that reported in a 17-year time-trend analysis of blunt hepatic and splenic injury, in which overall mortality was 4.8% (11% in patients managed operatively and 3.5% in those managed non-operatively) and in which a progressive decrease in mortality was observed over the study period [10]. The higher mortality in our operated patients is probably explained by the selection of patients with isolated but exsanguinating grade IV–V injuries and shock on arrival, whereas the earlier study included a wide range of injury severities and associated injuries. The surgical group also required more ICU admissions, transfusions, and a longer hospital stay, whereas more than 80% of the patients treated non-operatively did not need intensive care.

Comparison with previous studies. The main findings of the present cohort are compared with those of previous studies published up to 2022 in Table 6. The NOM success rate in our series (97.9%) is consistent with the high rates reported from neighboring Gulf countries. In a prospective four-hospital registry from Kuwait that included 117 patients with blunt liver trauma, NOM succeeded in 96% of the patients treated non-operatively (4 failures), 16.2% of all patients went directly

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to laparotomy because of instability, and overall mortality was 3.4%; [11] these figures are close to our rates of NOM success and upfront surgery (10.2%), although our overall mortality was slightly higher (5.1%), driven by the six deaths after upfront surgery for exsanguinating grade IV–V injuries. In an Omani review of abdominal trauma managed non-operatively between 2001 and 2011, NOM succeeded in all hemodynamically stable patients with isolated liver injury, whereas the overall success across all organs was 89.9%, [12] which agrees with our observation that failure of NOM is uncommon when patients are properly selected. The success rate in our series is also similar to the 96.7% reported for blunt liver and splenic injuries in Innsbruck over 17 years [10] and clearly higher than the approximately 81% reported in the earlier Abu Dhabi experience [6]. Studies from outside the Gulf region gave comparable results. In an Italian series of 145 consecutive patients with blunt liver trauma managed by a single team, 59.3% were treated non-operatively with no conversion to surgery, and complications occurred in 10.5% of the patients managed non-operatively and in 23.7% of those managed surgically [13]. The complication rate after NOM in our cohort (10.1%) is similar, and the direction of the difference with surgery is the same, although the higher complication rate in our operated patients (52.6%) reflects the shock and severe injuries of our upfront surgery group. The lower proportion of NOM in the Italian series (59.3% versus 89.8% in ours) probably reflects, at least in part, that extrahepatic injuries were present in 85.5% of their patients, whereas we restricted the analysis to isolated liver injuries. Our NOM failure rate (2.1%) was lower than the 11.5% reported by Rouy et al. in 494 patients with blunt liver injury from three French trauma centers between 2013 and 2021, in whom hemoperitoneum, severe injury (AAST grade IV–V), and angioembolization on the day of admission were independent predictors of NOM failure; [14] only 16.2% of their patients had an isolated liver injury, which probably explains part of the difference. In our series, all three failures were high-grade injuries and two of them had undergone angioembolization before recurrent hemorrhage, which is in line with these predictors and suggests that patients with active bleeding require particularly close observation. Likewise, a systematic review of eight prospective studies including 410 patients reported a pooled NOM failure rate of 9.5% (range 0–24%) and identified shock, a higher Injury Severity Score, associated intra-abdominal injuries, and peritoneal signs as factors associated with failure; [15] the lower failure rate in our cohort is probably attributable to the exclusion of patients with associated injuries and to early CT-based selection, in addition to the small number of events.

Table 6. Comparison of the present study with previous studies of non-operative management of liver trauma

Study (country)	Design and period	Patients (n)	Initial NOM	NOM success (failure)	Mortality
Present study (UAE)	**Retrospective; 2022–2023**	**157**	**89.8%**	**97.9% (2.1%)**	**5.1%**
Alkatary et al., 2017 (UAE) (6)	Retrospective; 2014–2016	75	NR	~81%	NR
Asfar et al., 2014 (Kuwait) (11)	Prospective registry, 4 hospitals	117	83.8%†	96% (4%)	3.4%
Raza et al., 2013 (Oman) (12)	Abdominal trauma; 2001–2011	1,071 managed non-operatively (320 with isolated liver injury)	NR	100% in stable isolated liver injury (89.9% overall)	NR
Fodor et al., 2019 (Austria) (10)	Retrospective; 2000–2016	368 liver (731 liver/spleen)	93.5% (liver)	96.7% (3.3%)‡	4.8%‡
Schembari et al., 2020 (Italy) (13)	Single team; 10 years	145	59.3%	100% (0%)	NR
Rouy et al., 2022 (France) (14)	Multicenter retrospective; 2013–2021	494	88.1%	88.5%† (11.5%)	NR
Boese et al., 2015 (systematic review) (15)	8 prospective studies	410	NR	90.5%† (9.5%)	NR

NOM, non-operative management; NR, not reported in the cited source. † Calculated from the reported data. ‡ Liver and splenic injuries combined. For Rouy et al., the success rate is the complement of the reported 11.5% NOM failure rate among patients initially managed non-operatively (88.1%). Definitions of NOM success and failure differ among studies, so the figures are not strictly comparable. In practice, NOM was associated with favorable outcomes in most patients with isolated liver trauma where 24-hour CT, interventional radiology, an operating room, and intensive care are available. Selection should rest on the hemodynamic response to resuscitation rather than on injury grade alone; high-grade injuries warrant close monitoring in a high-dependency setting, with a low threshold for angiography and a clear pathway to

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laparotomy; and structured follow-up is needed to detect and treat biliary and infectious complications early.

Strengths. The strengths of this study include the consecutive inclusion of patients, the use of a standardized management protocol, the grading of all injuries according to the current AAST scale, and the restriction to isolated liver injuries, which reduces confounding by associated injuries.

Limitations. The retrospective, single-center design introduces selection bias and limits generalizability, and the upfront surgical group comprised patients with decompensated shock, reflecting confounding by indication. The small surgical cohorts (n = 16 upfront and n = 3 NOM failures) precluded multivariable adjustment, so all between-group comparisons are descriptive and hypothesis-generating. Only five patients (3.2%) had penetrating injuries, and patients with associated injuries or younger than 18 years were excluded, so the findings apply mainly to isolated blunt injuries in adults. One in-hospital death in the NOM group (hepatic abscess, no surgery) was classified as NOM success; if death were counted as failure, the success rate would be 137 of 141 (97.2%; 95% CI 92.9–98.9%). Prospective multicenter studies are needed to develop validated selection criteria.

5. CONCLUSION

Non-operative management, supported by rapid contrast-enhanced CT imaging and transcatheter arterial embolization, was successful in 97.9% of hemodynamically stable patients with isolated liver trauma, including selected high-grade injuries, and patients successfully treated with NOM had low mortality (0.7%) and morbidity (10.1%). Because 3 patients failed NOM and required salvage surgery, and because patients undergoing upfront surgery were hemodynamically unstable with more severe injuries, outcome comparisons with surgery should be interpreted as association rather than causation. The frequency of complications increased with the grade of injury in both groups. Hemodynamic stability, rather than anatomical injury grade alone, should guide decision-making, supported by close monitoring, immediate access to interventional radiology and the operating room, and structured follow-up. Future prospective multicenter studies with standardized data collection on resource utilization and NOM failure are warranted.

DECLARATIONS

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and applicable institutional and regulatory requirements. The study protocol was reviewed and approved by the Institutional Review Board of Burjeel Hospitals, UAE (approval no. BURJ/RERC/2022/28).

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Informed Consent Statement: Written informed consent was obtained from all participants before enrolment and randomization, after the study objectives, procedures, potential risks, and the use of their clinical data and photographs for research and publication had been explained. The study was approved by the Institutional Review Board and was conducted in accordance with the Declaration of Helsinki.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable institutional, ethical, and patient-confidentiality requirements.

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Author Contributions: AL, AM: manuscript preparation, protocol, data collection and management, manuscript editing. AA, AA: Data acquisition, data analysis and management, manuscript editing. MM, TA, MA: Manuscript editing, project development, data analysis, and project development. All the authors have read and approved the manuscript.

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