Wang et al. BMC Medical Imaging (2025) 25:39
https://doi.org/10.1186/s12880-025-01564-w

BMC Medical Imaging

RESEARCH

Open Access

Impact of early arterial-phase multidetector CT in blunt spleen injury: a clinical outcomes-oriented study

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Abstract

Background Blunt spleen injuries (BSI) present significant diagnostic and management challenges in trauma care. Current guidelines recommend arterial-phase contrast-enhanced multidetector computed tomography (CT) for a detailed assessment. However, the direct impact of add-on arterial phase CT on clinical outcomes remains unclear. This study investigated the impact of early arterial-phase imaging via multidetector CT on the clinical outcomes of patients with blunt splenic injuries.

Methods A retrospective case-control study was conducted to analyze the data of adult patients with BSI treated at a single institution between 2019 and 2022. Patients were divided based on the CT phase performed: portal vein phase only or add-on arterial phase. Management methods were divided according to the initial treatment intent: nonoperative management observation (NOM-Obs), transarterial embolization (TAE), and splenectomy. NOM failure refers to either NOM-Obs or TAE failure leading to splenectomy. NOM-Obs failure refers to cases initially managed with observation only, but later requiring either TAE or splenectomy. Transarterial embolization (TAE) failure refers to cases initially treated with TAE, but subsequently requiring splenectomy. Inverse probability of treatment weighting (IPTW) was used to balance baseline differences and compare outcomes between the two groups.

Results Of 170 patients assessed, 147 met the inclusion criteria and were divided into two groups: those receiving portal vein phasic-only CT ($N=104$) and those receiving add-on arterial phasic CT ($N=43$). The overall NOM failure rate was 3.0% (4/132), the NOM-OBS failure rate was 6.7% (4/60), and the TAE failure rate was 4.1% (3/73). After adjusting for covariates using inverse probability of treatment weighting (IPTW), the comparison between the add-on arterial phase and portal phase CT groups revealed similar overall NOM failure rates (3.0% vs. 2.2%, $p=0.721$), NOM-OBS failure rates (3.8% vs. 6.2%, $p=0.703$), and intra-abdominal bleeding-related mortality rates (4.8% vs. 2.1%, $p=0.335$). Among the 43 patients who underwent add-on arterial CT, only one was diagnosed with a tiny pseudoaneurysm (0.7 cm) attributable to the inclusion of the arterial phase.

Conclusion Dual-phase CT within 24 h of presentation offers no added value over single-phase CT in managing blunt splenic injuries in terms of clinical outcomes.

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Keywords Blunt spleen injury, Computed tomography, Arterial-phase CT, Nonoperative management

Introduction

The spleen has been identified as the most common site of injury in blunt abdominal trauma, accounting for approximately 60% of such incidents [1]. Traditionally, the management of splenic injuries has evolved significantly from splenectomy to a predominantly non-operative management (NOM) approach [2–4]. This shift includes the use of transarterial embolization (TAE) to enhance the rate of spleen preservation and mitigate the complications associated with splenectomy [5, 6]. Common complications following splenectomy include increased susceptibility to infections due to the role of the spleen in filtering bacteria and other pathogens from the blood; increased risk of thromboembolic events, such as pulmonary embolism and deep vein thrombosis; and potential long-term complications, including an increased risk of certain cancers [7–10].

In 1995, Schurr et al. highlighted the importance of identifying and embolizing pseudoaneurysms in patients with blunt splenic injuries. Their findings suggested that the presence of pseudoaneurysms may significantly increase the success rate of NOM by indicating a risk factor for NOM failure, thereby necessitating embolization. Subsequent studies proposed that incorporating an arterial phase into abdominal computed tomography (CT) protocols can enhance the detection rate of pseudoaneurysms [11–13]. In 2018, the American Association for the Surgery of Trauma (AAST) recommended inclusion of the arterial phase in the evaluation of patients with blunt abdominal trauma [14]. Moreover, several studies have advocated follow-up CT to monitor the delayed formation of pseudoaneurysms [15, 16].

However, there is a lack of a direct correlation between CT protocol findings and NOM success, particularly concerning the immediate implementation of arterial-phase CT scans. This study investigates whether the inclusion of arterial-phase CT within the first 24 h post-injury can increase the success rate of NOM and reduce patient mortality in cases of splenic trauma.

Materials and methods

Study design and patient selection

This study was a single-center, retrospective, case-control analysis conducted at the Chang Gung Memorial Hospital (CGMH) with approval obtained from the Institutional Review Board (IRB) under IRB No. 202201550B0. The data set was sourced from the Chang Gung Memorial Hospital Trauma Database between January 2019 and February 2022. The selected cohort comprised patients who had experienced blunt splenic injuries (BSI) and underwent contrast-enhanced abdominal CT within the first 24 h of admission. An in-depth review of patients' electronic medical records was performed to gather a comprehensive array of data. This included demographic details, specifics of the contrast-enhanced CT scans, emphasizing both phasic and radiological findings, and findings from arteriography (transarterial embolization, TAE) along with the treatment methodologies employed, complications encountered, and mortality statistics. All imaging findings were based on initial reports from the radiologist and were subsequently reviewed by an additional radiologist specializing in trauma for confirmation and further analysis.

The exclusion criteria were precisely delineated to concentrate on the significance of early arterial-phase CT and arteriographic findings in the management of blunt splenic injuries. Accordingly, the study excluded patients with penetrating trauma, those who died prior to hospital admission, pediatric patients (under 16 years of age), and individuals who received definitive treatment outside the study's timeline. Furthermore, to align with the study's objective of evaluating the benefit of the initial 24-hour add-on arterial phasic CT, patients admitted beyond 24 h after sustaining their injuries were also omitted.

Facility management protocol for blunt splenic injury (BSI)

Our facility's treatment protocol aligns with the World Society of Emergency Surgery (WSES) guidelines [17] and includes modifications tailored to address the specific needs of our patient population and the resources of our institution (Fig. 1). Upon presentation, patients with blunt abdominal trauma receive initial management, including fluid resuscitation and an extended focused assessment for trauma with sonography (EFAST). Patients with positive EFAST findings were managed based on their hemodynamic stability. Hemodynamically unstable patients undergo exploratory laparotomy immediately, whereas hemodynamically stable patients undergo contrast-enhanced computed tomography (CT) to evaluate suspected intra-abdominal solid organ injury. This consisted of both arterial- and venous-phase imaging. After the primary survey, decisions were mainly based on the physician's judgment, dangerous mechanisms of injury, severely injured patients (e.g., obvious flail chest, open chest injury, multiple long bone fractures), patients with unclear consciousness, and patients with multiple injuries (e.g., suspected combined chest and abdominal injuries). Whole-body CT scans, including only non-contrast and venous phases, were performed. Further evaluation of the vascular injuries was conducted in hemodynamically stable patients diagnosed with splenic injuries. In cases where no vascular injury

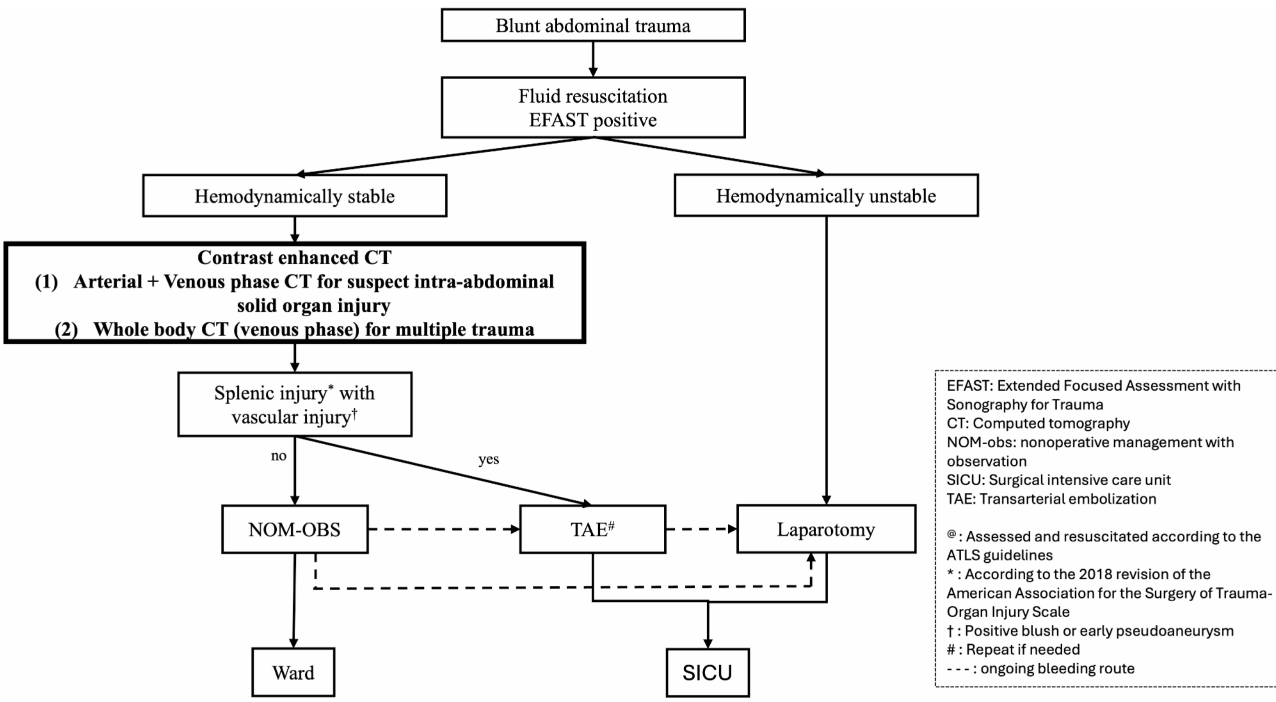

Fig. 1 Management algorithm for blunt splenic injury. Decision pathway for blunt splenic injury, outlining initial assessment with EFAST and subsequent management based on hemodynamic status. Hemodynamically stable patients receive CT imaging, while unstable ones may require immediate laparotomy. Options for splenic injuries include observation or embolization, with patient outcomes leading to ward or SICU admission

was detected, nonoperative management with observation (NOM-OBS) was initiated. Conversely, the presence of vascular injury or active bleeding warrants transarterial embolization (TAE).

Definition of treatment failure

The treatment cohort was stratified into three groups based on the initial treatment approach: nonoperative management with observation (NOM-OBS), transarterial embolization (TAE), and splenectomy. Initial treatment failure was defined as ongoing bleeding leading to hemodynamic instability or abdominal compartment syndrome at any time during admission. Failure of NOM-OBS was defined as the subsequent need for TAE or splenectomy prompted by progression to hemodynamic instability or the requirement for ongoing blood transfusions. However, TAE following the identification of a pseudoaneurysm on follow-up CT was not classified as NOM-OBS failure. Follow-up CT was not routinely performed; the decision was based on the clinician's judgment, typically around 7 days after the accident. TAE failure was characterized by the necessity for either repeat TAE or splenectomy due to hemodynamic deterioration or continuous blood transfusion needs. Overall failure of NOM was defined as the eventual requirement of the patient requiring a splenectomy.

CT imaging protocol, phasing definitions and grouping

The dynamic CT studies were performed using a 320-detector CT scanner (Canon Aquilion One TSX-301 C; Canon Medical Systems Corporation, Otawara, Japan). A venous catheter (18–20 gauge) was placed in the antecubital vein, and 100 mL of non-ionic contrast material (Omnipaque 350; GE HealthCare Ireland, Ireland) was administered at a rate of 3 mL/second with a power injector. The dynamic CTA scan slice thickness was 1 mm with an interval of 0.8 mm, reconstructed into 5 mm axial slices and 3 mm coronal and sagittal slices for physician interpretation. The arterial phase was performed within 30–40 s, and the venous phase was performed within 60–70 s following the initiation of contrast medium injection. The venous-phase CT group consisted of patients who underwent abdominal CT only during the venous phase. The arterial plus venous phase CT group consisted of patients who underwent abdominal CT, including both arterial and venous phase imaging. The analysis excluded the phases before contrast administration (precontrast phase) and after a delay (delay phase).

Statistical analysis

SPSS 29.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Descriptive statistics were presented as numbers and percentages for categorical variables and as means, standard deviations, minima, and maxima for numerical variables. For comparisons between the two groups, an independent T test was used for numerical variables, Pearson's chi-square test for large-sample-sized categorical variables, and Fisher's exact test for small-sample-sized categorical variables. To mitigate selection bias between the venous phase CT group and the group undergoing both arterial- and venous-phase CT scans, the Inverse Probability of Treatment Weighting (IPTW) was employed. Following the application of IPTW, the risk (odds ratio) of adverse effects associated with the additional arterial phase was calculated using univariate logistic regression analysis.

Result

Between 2019 and 2022, 170 patients with splenic injuries who underwent abdominal CT were registered in the Chang Gung Trauma Database. Of these, 147 patients diagnosed with blunt splenic injury through contrast-enhanced CT met the inclusion criteria (Fig. 2).

For all the 147 patients, the average age was 36.7 ± 19.0 years (range 16–91). The cohort consisted predominantly of males (71.4%). The most common mechanism of injury was a motorcycle collision (79.6%). The average Injury Severity Score (ISS) was 28.5 ± 10.9, and the average Revised Trauma Score (RTS) was 7.18 ± 1.20. Overall, 23.8% of patients had a head injury of AIS ≥ 3, 76.2% had a chest injury of AIS ≥ 3, 70.1% had an abdominal injury of AIS ≥ 3, and 27.9% had an extremity injury of AIS ≥ 3. Spleen injuries were graded according to the AAST-OIS 2018, with 12.9% grade 1, 21.8% grade 2, 11.6% grade 3, 42.2% grade 4, and 11.6% grade 5 injuries. Regarding the initial treatment intention, 40.8% underwent nonoperative management with observation (NOM-OBS), 49.7% underwent transarterial embolization (TAE), and 9.5% underwent splenectomy. The overall mortality rate was 6.8%, with bleeding-related mortality accounting for 4.7% of cases. Overall, severe complications (grade ≥ 3 by Clavien–Dindo classification) occurred in 21.9% of patients. The overall NOM failure rate leading to splenectomy was 3.0%, the NOM-OBS failure rate was 6.7%, and the TAE failure rate was 4.1% (Table 1). The mean time from the first treatment to treatment failure requiring further management was 2.25 days, with a range of 0–7 days.

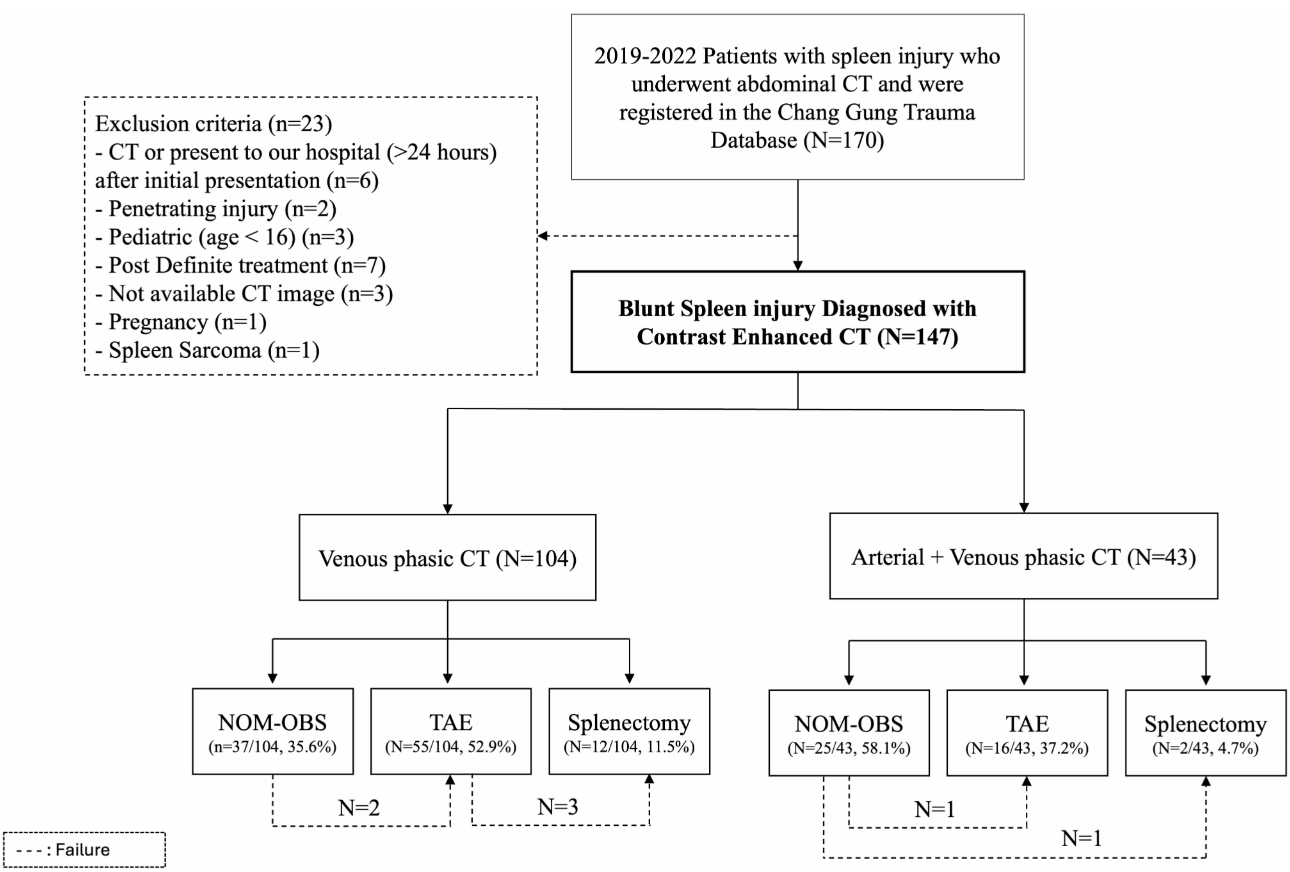

Fig. 2 Inclusion criteria and patient distribution in spleen injury study. Flowchart depicting the inclusion process and distribution of patients with spleen injury from 2019 to 2022 in the Chang Gung Trauma Database. Out of 170 registered patients, 147 were diagnosed with blunt spleen injury via contrast-enhanced CT after applying exclusion criteria. The chart further breaks down the management approaches into venous phase CT, arterial plus venous phase CT, and the subsequent interventions of NOM-OBS, TAE, and splenectomy, along with associated patient numbers and outcomes

Table 1 Characteristic of blunt spleen injury patients who diagnosed with contrast enhanced CT ($N = 147$)

Variables	N(%), Mean ± SD (Min-Max)
Age	36.7 ± 19.0 (16–91)
Gender (male/female)	105 (71.4%)/ 42 (28.6%)
Mechanism	
Motor vehicle collision	9 (6.1%)
Fall	15 (10.2%)
auto vs. pedestrian collision	4 (2.7%)
motorcycle collision	117 (79.6%)
Other	2 (1.4%)
Injury severity score	28.5 ± 10.9 (4–50)
Revised Trauma Score	7.18 ± 1.20 (0.00-7.84)
Head Injury (AIS[a] ≥ 3)	35 (23.8%)
Chest Injury (AIS[a] ≥ 3)	112 (76.2%)
Abdomen Injury (AIS[a] ≥ 3)	103 (70.1%)
Extremities Injury (AIS[a] ≥ 3)	41 (27.9%)
Spleen Injury (AAST-OIS[b] 2018 grade)	
1	19 (12.9%)
2	32 (21.8%)
3	17 (11.6%)
4	62 (42.2%)
5	17 (11.6%)
Initial treatment intention	
NOM-OBS[c]	60 (40.8%)
TAE[d]	73 (49.7%)
Splenectomy	14 (9.5%)
Mortality	10 (6.8%)
Bleeding related mortality	7 (4.7%)
Severe complication[e]	32 (21.9%)
NOM failure[f]	4/132 (3.0%)
NOM-OBS[g] failure	4/60 (6.7%)
TAE failure[h]	3/73 (4.1%)
Length of hospital stay	13.4 ± 10.8 (0–72)
Length of ICU stay	5.8 ± 6.5 (0–37)

a: Abbreviated injury scale, ***b***: American Association for the Surgery of Trauma-Organ Injury Scale, ***c***: Nonoperative management with observation only, ***d***. Transarterial splenic artery embolization, ***e***. Clavien–Dindo classification, grade ≥ 3, ***f.*** Either NOM-OBS or TAE failure and leading to splenectomy, ***g***. NOM-OBS failure leading to either TAE or splenectomy, ***h.*** TAE failure leading to splenectomy

The 147 eligible patients were further divided into two groups based on the CT protocol used: 104 patients underwent venous phase CT scans, and 43 patients underwent both arterial and venous phase CT scans. In the venous-phase CT group, nonoperative management with observation (NOM-OBS) was the initial treatment in 37 patients (35.6%), transarterial embolization (TAE) was performed in 55 patients (52.9%), and splenectomy was necessary in 12 patients (11.5%). There were two cases of NOM-OBS failure and three cases of TAE failure in this group. In the arterial plus venous phase CT group, 25 patients underwent NOM-OBS (58.1%), 16 underwent TAE (37.2%), and 2 underwent splenectomy (4.7%). This group experienced one NOM-OBS and one TAE failure (Fig. 2).

Table 2 Comparison of baseline conditions, treatments, and outcomes between portal phase CT and arterial phase CT patients

	Venous Phasic CT ($n = 104$)	Arterial + Venous Phasic CT ($n = 43$)	P-value
Age	35.1 ± 18.4	40.4 ± 19.9	0.123
Gender (male/female)	74 (71.2)/ 30 (28.8%)	31 (72.1%)/ 12 (27.9%)	0.909
Initially Glasgow Coma Scale < 9	20 (19.2%)	2 (4.7%)	0.024
Initially shock status[a]	20 (19.2%)	3 (7.0%)	0.063
Respiratory failure[b]	22 (21.2%)	4 (9.3%)	0.087
ISS	29.27 ± 11.16	26.6 ± 10.27	0.180
Head Injury (AIS[c] ≥ 3)	27 (26.0%)	8 (18.6%)	0.341
Chest Injury (AIS[c] ≥ 3)	79 (76.0%)	33 (76.7%)	0.919
Abdomen Injury (AIS[c] ≥ 3)	75 (72.1%)	28 (65.1%)	0.399
Extremities Injury (AIS[c] ≥ 3)	33 (31.7%)	8 (18.6%)	0.106
Severe liver laceration[d]	11 (10.6%)	5 (11.6%)	1.000
Pelvic fracture	17 (16.3%)	8 (18.6%)	0.740
Spleen Injury grade[e]			0.051
1	14 (13.5%)	4 (9.3%)	
2	22 (21.2%)	13 (30.2%)	
3	10 (9.6%)	9 (20.9%)	
4	42 (40.4%)	16 (37.2%)	
5	16 (15.4%)	1 (2.3%)	
Spleen vascular lesion or active bleeding[f]	47 (45.2%)	12 (27.9%)	0.041
pRBC(48 h)(U)	9.4 ± 11.97	6.14 ± 8.09	0.099
Initial treatment intention			0.097
NOM-OBS[g]	37 (35.6%)	23 (53.5%)	
TAE[h]	55 (52.9%	18 (41.9%)	
Splenectomy	12 (11.5%)	2 (4.7%)	
Mortality	8 (7.7%)	2 (4.7%)	0.724
Bleeding related mortality	6 (5.8%)	1 (2.3%)	0.674
Severe complication[i]	23 (22.3%)	9 (20.9%)	1.000
NOM failure[j]	3 (3.3%)	1 (2.4%)	1.000
NOM-Obs failure[k]	2 (5.4%)	2 (8.7%)	0.634
TAE failure[l]	3 (5.5%)	0 (0.0%)	0.570
Length of hospital stay	13.57 ± 11.12	13.00 ± 9.98	0.759
Length of ICU stay	5.9 ± 5.88	5.6 ± 7.77	0.767

a: shock defined as systolic blood pressure < 90 mmHg; **b**: Respiratory defined as patient need Intubation and mechanical ventilator support, **c**: Abbreviated injury scale, **d**: Severe liver laceration defined as American Association for the Surgery of Trauma Organ Injury Scale (AAST-OIS) 2018 grade ≥ 3, **e**: According to AAST-OIS 2018 **f**: Contrast extravasation or pseudoaneurysm, **g**: Nonoperative management with observation only, **h**: Transarterial splenic artery embolization, **i**: Clavien–Dindo classification, grade ≥ 3, **j**: Either NOM-OBS or TAE failure and leading to splenectomy, **k**: NOM-OBS failure leading to either TAE or splenectomy, **l**: TAE failure leading to splenectomy

Table 2 compared patients with venous phase CT scans to those with arterial plus venous phase scans. Age, gender, ISS, and injury patterns were similar across groups. The arterial plus venous phase group had fewer initial Glasgow Coma Scale scores below 9 (4.7%) compared to the venous group (19.2%) ($p = 0.024$), although shock and respiratory failure rates did not differ significantly. The venous group had a higher incidence of spleen injury grades and vascular lesions (45.2%) versus the arterial plus venous phase group (27.9%) ($p = 0.041$). Regarding treatments, 35.6% in the venous group received NOM-OBS and 52.9% TAE, while 53.5% and 41.9% in the arterial plus venous phase group received NOM-OBS and TAE, respectively; splenectomy rates were 11.5% for venous and 4.7% for arterial plus venous phase. Mortality and severe complications were comparable. Treatment failure rates—NOM (venous: 3.3%, arterial plus venous: 2.4%), NOM-OBS (venous: 5.4%, arterial plus venous: 8.7%), and TAE (venous: 5.5%, arterial plus venous: 0%)—showed no significant difference.

We further conducted Inverse Probability of Treatment Weighting (IPTW) analysis to adjust for multiple confounding factors, including initially low Glasgow Coma Scale scores, initial shock status, respiratory failure, spleen laceration grade, liver laceration grade, pelvic fractures, severe head injury (AIS ≥ 3), severe chest injury (AIS ≥ 3), and Clavien–Dindo classification for complications (grade ≥ 3). Table 3 shows the odds ratios for adverse outcomes in patients who underwent early arterial CT adjusted for IPTW. Post-adjustment results indicated no significant differences in mortality (OR 0.76, 95% CI 0.28–2.06, $p = 0.590$), bleeding-related mortality (OR 0.46, 95% CI 0.12–1.82, $p = 0.341$), or severe complications (OR 0.94, 95% CI 0.52–1.69, $p = 0.835$). Additionally, IPTW-adjusted analyses showed no significant increase in the odds of NOM failure (OR 1.10, 95% CI 0.22–5.57, $p = 1.000$), NOM-OBS failure (OR 2.30, 95% CI 0.43–12.31, $p = 0.447$), or TAE failure (OR 0.57, 95% CI 0.49–0.67, $p = 0.264$). Length of hospital stay (MD 0.18, 95% CI -2.15–2.52, $p = 0.877$) and ICU stay (MD 0.35, 95% CI -1.21–1.91, $p = 0.659$) were also not significantly affected according to the IPTW-adjusted model.

Table 3 Odds ratios for adverse outcomes in patients undergoing early arterial CT, adjusted using inverse probability of treatment weighting (IPTW)

	Unadjusted		**Adjusted**[b]	
	Odds Ratio (95% CI)	**P-value**	**Odds Ratio (95% CI)**	**P-value**
Mortality	0.59 (0.12–2.88)	0.724	0.76 (0.28–2.06)	0.590
Bleeding related mortality	0.39 (0.05–3.33)	0.674	0.46 (0.12–1.82)	0.341
Severe Complication[c]	0.92 (0.39–2.20)	1.000	0.94 (0.52–1.69)	0.835
NOM failure[d]	0.74 (0.08–7.35)	1.000	1.10 (0.22–5.57)	1.000
NOM-Obs failure[e]	1.67 (0.22–12.73)	0.634	2.30 (0.43–12.31)	0.447
TAE failure [f]	0.74 (0.65–0.85)	0.570	0.57 (0.49–0.67)	0.264
	MD[a] (95% CI)		MD[a] (95% CI)	
Length of stay	-0.58 (-4.45–3.30)	0.769	0.18 (-2.15–2.52)	0.877
Length of ICU stay	-0.35 (-2.68–1.98)	0.767	0.35 (-1.21–1.91)	0.659

a:Mean difference, ***b***:IPTW adjust with Initially Glasgow Coma Scale < 9; initially shock status; respiratory failure; spleen laceration grade; liver laceration grade, pelvic fracture, Severe head injury (AIS ≥ 3), Severe chest injury (AIS ≥ 3), ***c***: Clavien–Dindo classification, grade ≥ 3, ***d***: Either NOM-Obs or TAE failure and leading to splenectomy, ***e***: NOM-Obs failure leading to either TAE or splenectomy, ***f***: TAE failure leading to splenectomy

Table 4 meticulously catalogs the vascular lesions in 12 patients in the arterial plus venous phase CT scan group. In 11 of these 12 patients, vascular lesions detectable in the arterial phase (Fig. 3a) were visible in the venous phase (Fig. 3b). Only one patient had a vascular lesion, a small pseudoaneurysm that (0.7 cm), was exclusively detected in the arterial phase (Fig. 3c) but was not visible in the venous phase (Fig. 3d), suggesting that the addition of arterial-phase CT may offer a marginal benefit

Table 4 Comprehensive classification of spleen vascular injury types observed in patients undergoing arterial CT scans

Patient no.	**Spleen injury grade (anatomic)** [a]	**Vascular lesion**		**Additional finding in arterial phase**	**Treatment**	**Angiography finding**
		Arterial phase	**venous phase**			
1	3	PsA + CE	PsA + CE	No	TAE	PsA + CE
2	4	PsA	PsA	No	TAE	PsA
3	2	PsA + CE	PsA + CE	No	TAE	PsA
4	4	PsA	PsA	No	Splenectomy	
5	3	PsA + CE	PsA + CE	No	TAE	PsA + CE
6	3	CE	CE	No	Splenectomy	
7	3	PsA	PsA	No	TAE	PsA
8	5	CE	CE	No	Splenectomy	
9	**2**	**PsA**	**0**	**Yes**	**TAE**	**PsA**
10	4	CE	CE	No	TAE	AVF
11	3	CE	CE	No	TAE	CE
12	4	PsA + CE	PsA + CE	No	TAE	PSA/AVF

a. Based on the AAST-OIS 2018 grading, excluding the impact of vascular lesions. **PsA**: pseudoaneurysm; **CE**: contrast extravasation; **TAE**: splenic artery embolization

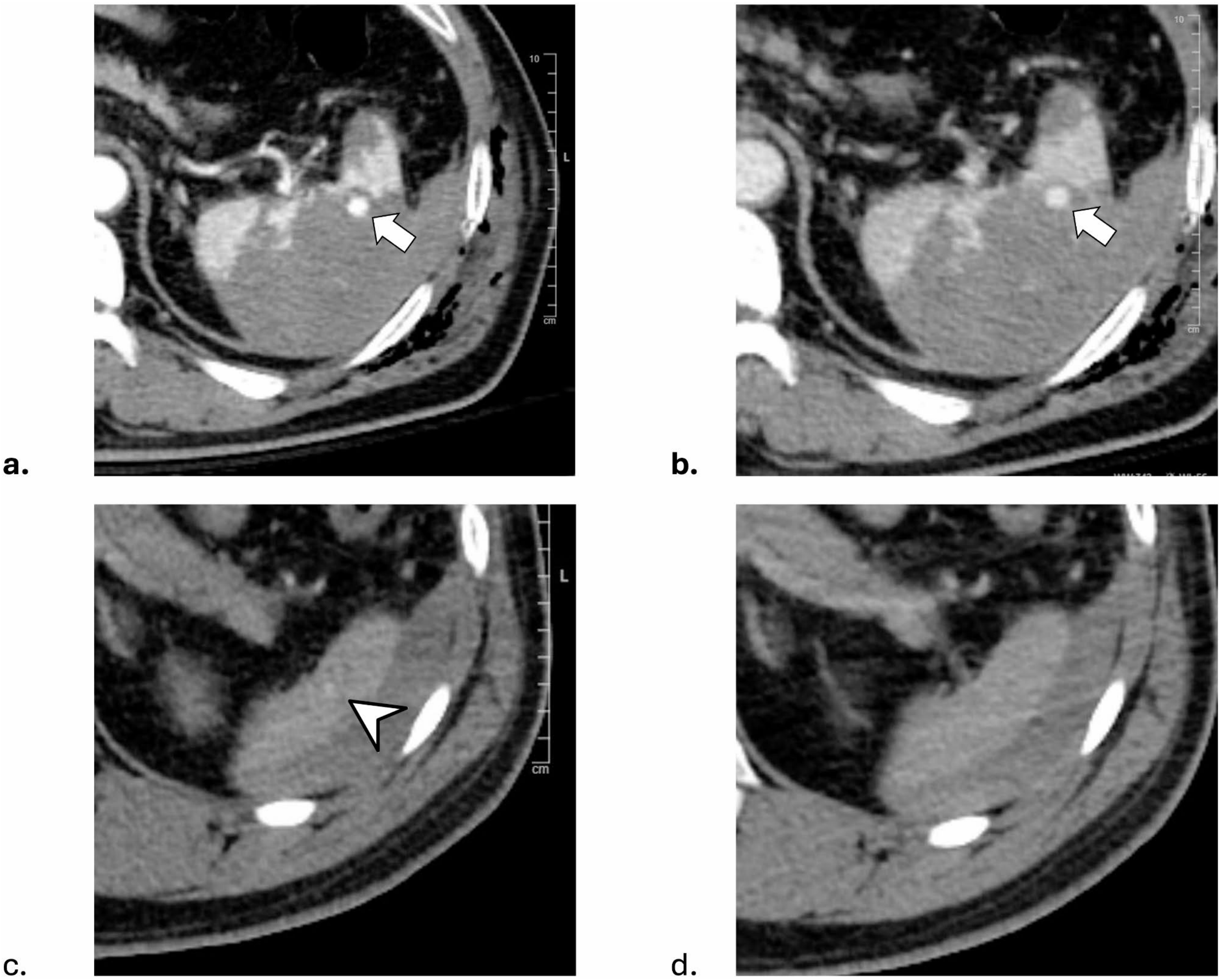

Fig. 3 Pseudoaneurysm appearance across different phases. A large splenic pseudoaneurysm (arrow) is visible in both (**a**) arterial-phase contrast-enhanced CT and (**b**) venous-phase CT, characterized by a high-density contrast collection. Only one patient in this cohort had a vascular lesion, a small pseudoaneurysm (0.7 cm) (arrowhead), which was exclusively detected in the arterial phase (**c**) but not visible in the venous phase (**d**)

in identifying certain vascular lesions not apparent in venous-phase imaging.

Discussion

To our knowledge, this is the first study to clarify the link between the addition of an arterial phase to abdominal CT scans and patient outcomes of blunt splenic injuries. The 2018 guidelines from the American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) advocate for arterial-phase abdominal CT in cases with intra-abdominal solid organ injury to improve the detection of splenic pseudoaneurysms [14]. Numerous studies have indicated that embolizing pseudoaneurysms can increase the success rate of nonoperative management (NOM) [18–22]. Theoretically, including the arterial phase should boost the success of NOM by allowing early identification and treatment of pseudoaneurysms. However, our results did not demonstrate the expected increase in NOM success. This discrepancy prompts a reevaluation of the actual clinical benefits of routine arterial phase imaging, especially when venous phase imaging has already provided a high diagnostic value.

In our study, we found that only one of 43 patients benefited from the additional arterial-phase CT, where a small pseudoaneurysm measuring 7 mm was identified solely during the arterial phase. The relationship between pseudoaneurysm size and risk of bleeding or adverse outcomes in blunt splenic injury (BSI) remains unclear. Notably, in a separate cohort of 200 patients, all 16 patients with nonbleeding vascular lesions, such as pseudoaneurysms, successfully underwent observation [23]. Although numerous studies have highlighted the advantages of arterial-phase CT for detecting pseudoaneurysms, inconsistent identification rates have been reported, with high variability (56.3%) between clinical and expert radiologist interpretations [11–13, 23–25].

However, upon meticulous review by experienced trauma radiologists, we observed that most vascular lesions are identifiable through contrast stasis during the venous phase.

In addition to its role in enhancing pseudoaneurysm detection, multiphase CT is useful for distinguishing between contrast extravasation (CE) and pseudoaneurysms in cases of splenic injury. However, according to our treatment protocol, the ability to differentiate between these conditions did not alter the subsequent management strategies. Regardless of whether the finding is CE or Pseudoaneurysm, the approach remains consistent, leaning towards transarterial embolization (TAE). This consistency in the treatment approach, irrespective of the specific imaging findings, may explain why additional arterial phase imaging did not improve mortality rates.

We reported a mortality rate of 6.8% at our facility, which is consistent with previously reported rates ranging from 6 to 18% [17, 26]. Additionally, the failure rate of NOM-Observation (NOM-OBS) in our study was 3%, failure rate of Transarterial Embolization (TAE) was 2%, and overall failure rate of NOM leading to splenectomy was 3%. These rates corroborate the existing literature, suggesting that our facility's BSI treatment protocol was effective [27, 28].

While adhering to these guidelines, we aimed to apply them in real-world clinical scenarios. In practice, although advances in medical imaging have made such situations increasingly rare and modern CT machines now allow whole-body CT scans, including an arterial phase, to be feasible and even routine in polytrauma patients, there are still occasional cases where only venous-phase CT is performed due to factors such as facility protocols or configurations for whole-body CT scans. This raises the following question: after identifying a splenic injury on a completed CT scan, is it necessary to immediately conduct an additional arterial plus venous phase CT within 24 h to detect small pseudoaneurysms? Studies have indicated that pseudoaneurysms can still form within 1–8 days post-injury [29, 30]. In other words, a patient would still require a follow-up CT a week later. If we proceed with an immediate repeat of arterial plus venous phase CT alongside the initial scan and a follow-up scan, typically approximately a week later, the patient will undergo three high-radiation dose exams. In addition, the risk of acute kidney injury (AKI) due to repeated contrast exposure must be considered. Our study suggests that repeated arterial- and venous-phase CT during this period for increased pseudoaneurysm detection does not improve patient outcomes.

The limitations of our study are its single-institution, retrospective design, and small sample size, which might limit the generalizability of our findings. We also did not exclude for other significant injuries that could have impacted patient outcomes, such as severe head injury, which may have introduced a bias. It is important to note that the impact of add-on arterial-phase CT on other solid organs such as the liver and kidneys was not assessed in our study; our focus was solely on the spleen. Additionally, the choice to perform venous-phase CT alone or add-on arterial-phase CT was primarily based on the clinical judgment of the attending physician at the time, without a strict criterion. Furthermore, we did not record or analyze the size of pseudoaneurysms or whether contrast medium extravasation extended into the peritoneum. Future research might need to conduct further analyses to compare arterial- and venous-phase CT and angiography findings, including lesion size, to elucidate the comprehensive effects of our findings.

Conclusion

In conclusion, our study found no evidence of improved outcomes when employing arterial plus venous phase CT scans within the first 24 h compared to venous-only phase CT scans for the evaluation of blunt splenic injury. Consequently, we suggest that there is no definite benefit in repeating CT with arterial and venous phases within 24 h if venous phase CT has already been performed.

Acknowledgements
We would like to express our sincere gratitude to the data managers of the Chang Gung Trauma Database, Fen-Ping Kao, Chun-Ju Chen, and Hui-Chen Tien, for their invaluable assistance in managing and providing access to the data that were crucial for our study. Their expertise and support have been instrumental in the completion of this research.

Author contributions
Conceptualization: C.H. and Y.W.; methodology: Y.W., Y.T. and C.L.; formal analysis and investigation: Y.W., H.C., and C.C.; writing—original draft preparation: Y.W.; writing—review and editing: C.H.; supervision: C.H., C.F., and H.C.

Funding
The authors state that this work has not received any funding.

Data availability
The datasets analyzed in the current study are not publicly available because of issues related to institutional policy but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study protocol was reviewed and approved by the Institutional Review Board of the Chang Gung Medical Foundation (approval number 202201550B0), which waived the requirement for written informed consent owing to the retrospective nature of the study and the use of anonymized data. All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional research committee and the 2024 Helsinki Declaration.

Consent for publication
NA.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

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Received: 3 October 2024 / Accepted: 22 January 2025
Published online: 04 February 2025

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