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Comparing Outcomes in Transcatheter Embolization for the Management of Penetrating versus Blunt Trauma

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Abstract

Objectives This article assesses potential factors associated with successful embolization and/or mortality benefit among patients with penetrating (PT) compared to those with blunt abdominal trauma (BT) undergoing emergent angiography.

Materials and Methods A retrospective study of arterial embolization for BT and PT at a tertiary care academic center in an urban setting between 2018 and 2020 was conducted. Fischer's exact and Student's *t*-tests were used to assess differences between PT and BT, regarding technical success, in-hospital mortality, number of vessels embolized, and requirement of Operating Room (OR) for bleeding control after embolization.

Results Forty-three patients underwent embolization. Twenty-three presented with BT versus 20 with PT. There was no difference in the rate of success between the two groups (91.3% vs. 100%; $p = 0.49$). No difference was observed in mean days of survival among BT and PT patients treated by embolization (mean [standard deviation]: 13.7 [2.6] vs. 19.1 [2.79] days; $p = 0.160$). There was no difference in mortality between the two groups (13.0% vs. 10.5%; $p = 1.00$). Mean number of vessels embolized was higher in the BT group compared to PT (2.26 [1.32] vs. 1.44 [1.03], $p = 0.044$). The rate of BT patients who required subsequent OR intervention for hemorrhage control after embolization was similar to those with PT (8.7% vs. 10.5%; $p = 0.84$).

Conclusion The rate of mortality, technical success, and requirement of subsequent OR intervention for hemorrhage control was comparable between BT and PT. BT was associated with a higher mean number of vessels embolized compared to PT. Our case series may provide insight in the use of embolization for PT, but further investigation is needed with larger cohorts.

Keywords
- blunt
- embolization
- penetrating
- trauma

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Introduction

Historically intra-abdominal arterial bleeding has been an indication for laparotomy, accounting for 20 to 35% of patients who fail nonoperative treatments. This approach is, however, associated with additional complications and hospital resources.[1] More recent advances in emergency interventional radiology have resulted in utilization of angiographic techniques for embolization of involved arteries. This includes coiling and proximal gelfoam embolization techniques, which can be used as a stand-alone or adjunct procedure to surgical intervention to return patients to hemodynamic stability.[2,3] Patients who are less hemodynamically stable may need additional treatment such as laparotomy.[4] Nonoperative management of blunt trauma (BT) has been highlighted extensively in the literature.[4–6] As for penetrating trauma (PT), there is a greater paucity of literature regarding optimal endovascular management. Biagioni et al demonstrated the successful use of stent grafts in PT, although embolization was not a focus of this study.[7] It is difficult to ascertain the type of treatment that would most likely result in the success of bleeding control, especially for retroperitoneal organs.[8]

There have been numerous studies that highlight the different types of operative and nonoperative management strategies, and recent literature has demonstrated the efficacy of embolization for BT.[4–6,9] However, there is a lack of data regarding endovascular management for PT. Herein, this study analyzed data regarding patients who underwent embolization for penetrating abdominal trauma at a single institution to assess differences in outcomes compared to BT. Additionally, factors that may be predictors of mortality and successful embolization were assessed.

Methods

Institutional Review Board approval was obtained to perform this retrospective study. Between January 2018 and December 2020, 43 patients (38 male and 5 female, average age: 36.6 years old, standard deviation [SD]: 17.0, range: 4–73) received arterial embolization for either BT or PT injury in a tertiary care academic center in an urban setting with preponderance of PT.

Data Collection

Electronic medical chart review was performed to document demographic information (age and gender), clinical history, location of trauma, procedural course (OR prior to embolization, computed tomography angiography [CTA], bleeding arterial vessels, number of vessels embolized, embolics used, fluoroscopy time, lab values pre- and 24 hours postprocedure), and hospital course (date of admission and discharge, days of survival).

Embolization Technique

All embolization procedures were performed by a board-eligible or board-certified fellowship-trained interventional radiologist. Patients were brought to interventional radiology from the emergency room or operating room following BT or PT. Routine protocol prior to intervention was to obtain preintervention CTA for all patients deemed hemodynamically stable to document active bleeding and procedure planning.

In the angiography suite, angiography was performed from a femoral approach and angiography of the affected body was performed to identify the site of vascular injury. Subsequently, selective catheterization of the bleeding vessel was performed with the use of a microcatheter (2.4–2.8 Fr). Embolization was performed with a combination of microcoils and/or gelfoam slurry based on operator preference and clinical scenario. Technical success was defined as the arrest of any active sites of extravasation seen on pre-embolization angiography.

Statistical Analysis

All statistical analysis was performed using JMP software (JMP, Version 16, SAS Institute Inc., Cary, North Carolina, United States, 1989–2021). Collected patient data were analyzed to compare profiles of BT and PT. Additionally, factors associated with mortality was assessed. Number of vessels was analyzed both as continuous and categorical (0, 1, and $\geq$ 2) variables. Categorical variables were assessed using Fischer's exact and Pearson's chi-square test and are represented as *n* (%). Continuous variables were evaluated using Student's *t*-test and Wilcoxon rank sum test and are represented as mean (SD).

Results

A total of 23 patients with BT and 20 patients with PT received arterial embolization. Patients with BT were older than those with PT (42.3 [17.08] vs. 30.0 [14.5]; $p = 0.015$). Preprocedural hemoglobin was higher for patients with BT compared to PT (12.25 [2.28] vs. 10.6 [2.37]; $p = 0.028$). Postprocedural hemoglobin was similar for patients with BT compared to PT (10.32 [1.46] vs. 10.82 [1.92]; $p = 0.357$). Change in hemoglobin was higher for patients with BT compared to PT (–1.93 [2.37] vs. 0.33 [1.54]; $p = 0.003$). Type of injuries that patients with BT suffered included motor vehicle collisions ($n = 18$; 78.26%), falls ($n = 4$; 17.39%), and a straddle injury ($n = 1$; 4.35%). Type of injuries that patients with PT suffered included gunshot wounds ($n = 17$; 85.0%) and stabs ($n = 3$; 15.0%). Embolized vessels of those with BT included pelvic ($n = 12$; 54.55%), abdominal ($n = 7$; 31.82%), vertebrae ($n = 2$; 9.09%), and lower extremity ($n = 1$; 4.55%) vessels. Embolized vessels of those with PT included abdominal ($n = 8$; 44.44%), pelvic ($n = 4$; 22.22%), thoracic ($n = 3$; 16.67%), vertebrae ($n = 1$, 5.56%), back ($n = 1$; 5.56%), and lower extremity ($n = 1$; 5.56%) vessels. Mean number of vessels embolized was higher in the BT group compared to PT (mean [SD]: 2.26 [1.32] vs. 1.44 [1.03], $p = 0.044$). Out of all 43 patients who underwent embolization, 40 (93.0%) had technical success. There was a total of 16 patients (37.2%) who had control for bleeding surgically prior to embolization and 4 (9.30%) after embolization. Additional results are displayed in ►**Table 1**.

Table 1 Descriptive analysis for patients with blunt or penetrating trauma

	Blunt ($n = 23$)		Penetrating ($n = 20$)		*p*-Value
Age, mean (SD)	42.30	17.08	29.95	14.55	0.015
Fluoroscopy time (in min), mean (SD)	25.15	13.99	20.30	9.93	0.204
Radiation dose (mGy), mean (SD)	1282.02	1199.70	.	.	
Preprocedure hemoglobin, mean (SD)	12.25	2.28	10.59	2.37	0.028
Postprocedure hemoglobin (next morning), mean (SD)	10.32	1.46	10.82	1.92	0.357
Days of survival, mean (SD)	13.70	2.60	19.10	2.79	0.160
Gender					1.000
Female	3	13.04%	2	10.00%	
Male	20	86.96%	18	90.00%	
Type of injury					< 0.001
Fall	4	17.39%	0	0%	
Gunshot wound	0	0%	17	85%	
Motor vehicle collision	18	78.26%	0	0%	
Stab	0	0%	3	15%	
Straddle	1	4.35%	0	0%	
OR prior to embolization	4	17.39%	12	60.00%	0.005
CTA done before embolization	18	78.26%	15	75.00%	1.000
Number of vessels embolized, mean (SD)	2.26	1.32	1.44	1.03	0.044
Number of vessels embolized (≥ 2 or < 2)					0.422
0	1	4.35%	2	10.53%	
1	6	26.09%	8	42.11%	
≥ 2	16	69.57%	9	47.37%	
Type of vessel embolized					< 0.001
Back	0	0.00%	1	5.56%	
Lower extremity	1	4.55%	1	5.56%	
Pelvic	12	54.55%	4	22.22%	
Thorax	0	0.00%	3	16.67%	
Vertebrae	2	9.09%	1	5.56%	
Abdominal (breakdown below)	7	31.82%	8	44.44%	
Renal	1		2		
Splenic	4		0		
Gastric	1		0		
Hepatic	1		6		
Gelfoam used?	17	73.91%	11	55.00%	0.219
Coils used?	18	78.26%	11	55.00%	0.191
Embolization targeted or prophylactic or both					0.654
None	1	4.55%	0	0.00%	
Prophylactic	0	0.00%	1	5.56%	
Targeted	17	77.27%	15	83.33%	
Both	4	18.18%	2	11.11%	
Technical success	21	91.30%	19	100.00%	0.493
Return for repeat angiography	3	13.04%	3	15.00%	1.000
Required OR for bleeding control after embolization	2	8.70%	2	10.53%	0.841
Mortality	3	13.04%	2	10.53%	1.000

Abbreviations: CTA, computed tomography angiography; SD, standard deviation; OR, Operation Room.

Death postembolization was not associated with age ($p = 0.50$), type of trauma ($p = 1.00$), OR prior to embolization (dead: 40.0% vs. alive: 35.1%, $p = 1.00$), multiple (≥ 2) vessels embolized (100% vs. 54.1%, $p = 0.50$), mean number of vessels embolized (mean [SD]: 0.81 [SD: 1.26] vs. 0.82 [0.41]; $p = 0.072$), use of gelfoam embolic (80% vs. 64.9%, $p = 0.65$), use of coils (40.0% vs. 70.3%, $p = 0.31$), prophylactic or targeted embolization (targeted: 82.9% vs. 50.0%; $p = 0.29$), and use of repeat angiography (40.0% vs. 10.8%, $p = 0.14$) and radiation dose (mean [SD]: 1276.13 [1630.75] vs. 1282.9 [1177.54] mGy, $p = 0.99$). Patients with more severe cases requiring OR for bleeding control after embolization were associated with a higher likelihood of failure and death (40.0% vs. 5.56%, $p = 0.038$). Technical success of embolization was not associated with death (80.0% vs. 97.2%, $p = 0.23$). Additional results are displayed in ►**Table 2**.

Discussion

Among those who underwent embolization for BT and PT, there was no difference in demographics (gender) and intraoperative characteristics (coils, gelfoam, CTA use). Additionally, there was no difference in in-hospital mortality and technical success. Overall, there were 93.0% ($n = 40$ out of 43) of patients with successful embolization and a 12% ($n = 5$ out of 43) rate of mortality.

Cherian et al conducted a multi-institutional study for embolization after blunt abdominal injury to the spleen, liver, and kidneys. Out of 45 patients, 13.3% died which was similar to our rate of 13.2% among our cohort of BT. However, their mean length of stay was 5.2 days while our BT cohort was 13.7 days.[10] Hemodynamic instability is an indication for operative management of BT; Cherian et al

Table 2 Descriptive analysis for mortality

	Alive ($n = 37$)		Dead ($n = 5$)		p-Value
Age, mean (SD)	36.00	16.93	41.60	19.96	0.500
Fluoroscopy time (in min), mean (SD)	21.87	11.65	29.64	17.74	0.196
Radiation dose (mGy), mean (SD)	1282.90	1177.54	1276.13	1630.75	0.990
Preprocedure hemoglobin, mean (SD)	11.33	2.48	12.74	2.22	0.238
Postprocedure hemoglobin (next morning), mean (SD)	10.47	1.57	10.60	2.40	0.873
Days of survival, mean (SD)	14.60	9.76	25.40	25.36	0.072
Gender					0.099
Female	3	8.11%	2	40.00%	
Male	34	91.89%	3	60.00%	
Type of trauma					1.000
Blunt	20	54.05%	3	60.00%	
Penetrating	17	45.95%	2	40.00%	
OR prior to embolization	13	35.14%	2	40.00%	1.000
CTA done before embolization	28	75.68%	4	80.00%	1.000
Number of vessels embolized, mean (SD)	0.81	1.26	0.82	0.41	0.072
Number of vessels embolized (≥ 2 or < 2)					0.358
0	3	8.11%	0	0.00%	
1	14	37.84%	0	0.00%	
≥ 2	20	54.05%	4	100.00%	
Gelfoam used	24	64.86%	4	80.00%	0.650
Coils used	26	70.27%	2	40.00%	0.313
Embolization targeted or prophylactic or both					0.290
None	1	2.86%	0	0.00%	
Prophylactic	1	2.86%	0	0.00%	
Targeted	29	82.86%	2	50.00%	
Both	4	11.43%	2	50.00%	
Return for repeat angiography	4	10.81%	2	40.00%	0.141
Required OR for bleeding control after embolization	2	5.56%	2	40.00%	0.038
Technical success	35	97.22%	4	80.00%	0.232

Abbreviations: CTA, computed tomography angiography; SD, standard deviation.

corroborates with our study that shows that a high rate of success for embolization persists among patients with upper abdominal BT. It is also effective for lower abdominal BT; Bertelli et al demonstrated this in a case series of mesenteric bleeding among patients with BT.[11] Additionally, their literature review has indicated a technical success of 96%. Furthermore, Velez investigated the use of nonoperative management in his cohort of 281 patients. Of them, 183 patients underwent angiography and 166 (91%) underwent embolization. A total of 7 patients also underwent embolization of multiple vascular territories, which all achieved technical success. This demonstrates the safety and efficacy of angioembolization in patients with severe BT.[12] In this study's cohort, 24 patients had more than 2 vessels embolized; 4 of them had a failure of embolization or mortality. Regarding types of embolization, we found no difference in the association of gelfoam ($p = 0.65$) or coil ($p = 0.31$) with death. Similarly, in a meta-analysis by Rong et al[13], they found no difference in the success rate of embolization when using coil compared to gelfoam (odds ratio: 1.41, $p = 0.39$). However, they demonstrated that coiling was associated with lower odds of severe complications compared to gelfoam (odds ratio: 0.48, $p = 0.02$).

O Dell et al described techniques in approaching patients with PT and discussed two cases that had technical success. They have demonstrated that decisions regarding which artery to embolize and the embolics used are decided during the procedure; an interventionist should have gelfoam, coils, and glue ready to be selected and used for embolization. They also recommend using angiography prior to embolization to plan access to distal feeding arteries.[14] Meanwhile, in this study's cohort of 20 patients with PT, 75% of them underwent CTA prior to embolization. Additionally, the presented data indicated similar rates of technical success and death for those who underwent embolization for PT compared to BT. As emphasized by O Dell et al, the literature regarding embolization for PT is scarce.[14] Additionally, a recent position statement from the Society of Interventional Radiology regarding endovascular treatment of trauma focused on management of specific organs rather than the type of trauma.[9] This study's data has shown the similarity in preoperative characteristics, intraoperative aspects, and outcomes of PT compared to BT, indicating that embolization for PT may have equivalent results as embolization for BT. Both groups in our cohort were similar with respect to gender, type of embolization (targeted vs. prophylactic), technical success, and mortality among others. Therefore, embolization for PT may have similar efficacy as for BT and that it is worth investigating in larger studies.

Although our study holds valuable data regarding novel intervention for PT, there are several limitations. Patients with PT mostly had single-territory bleeds, lower mean number of vessels embolized, and higher preprocedural hemoglobin. This may confound studied outcomes; there is a possibility that PT patients were more hemodynamically stable compared to BT. However, this may support our hypothesis that PT may have similar efficacy compared to BT for selected cases. Sixty percent of PT patients went to the OR prior to embolization; this is due to hospital protocol with severe organ injury in which patients underwent CTA and immediately were placed on the OR table while radiology reviews the CT scan.[15] However, it can be inferred that the PT cohort may have been more unstable than BT yet shows similar outcomes. Additionally, this study had a low sample size of 43 patients with a difference in involved organs, decreasing statistical power and increasing heterogeneity of presentation among patients.

In conclusion, the rate of mortality, technical success, and requirement of subsequent OR intervention for hemorrhage control was comparable between BT and PT. BT was associated with a higher mean number of vessels embolized compared to PT. Our case series may provide insight in the use of embolization for PT, but further investigation is needed with larger cohorts.

Ethics Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards

IRB Approval

This study has obtained IRB approval from University of Chicago and the need for informed consent was waived.

Consent for Publication

For this type of study consent for publication is not required.

Funding

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Conflict of Interest

O.A. is a speaker for Cook, Penumbra, Bard, and Inari. O.A. is a Consultant/Advisory board member for Boston Scientific, Johnson and Johnson, Argon, Medtronic, and Asahi.

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