Outcomes of Proximal Versus Distal Splenic Artery Embolization After Trauma: A Systematic Review and Meta-Analysis

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Abstract: The objective of this systematic review and meta-analysis was to assess the outcomes after angioembolization in blunt trauma patients with splenic injuries and to examine specifically the impact of the technique used. Studies evaluating adult trauma patients who sustained blunt splenic injuries managed by angioembolization were systematically evaluated. The following data were required for inclusion: grade of splenic injury, indication for embolization, and site of embolization (proximal [main splenic artery] or distal [selective]). In addition, major (requiring splenectomy) or minor (not requiring splenectomy) rebleeding, infarction, and infection in relation to the site of embolization (proximal vs. distal) was required. Pooled outcomes were compared between proximal and distal embolizations. To eliminate between-study heterogeneity, a sensitivity analysis was conducted on three reduced sets of studies. Fifteen of 147 evaluated studies were included for analysis. All were retrospective cohort studies and incorporated a total of 479 embolized patients. The overall failure rate of angioembolization was 10.2% (range, 0.0–33.3%). Injury severity and basic demographics did not differ among the study populations. However, the indications for angioembolization (contrast extravasation, large amount of hemoperitoneum, or high-grade splenic injury) differed between the populations but were not associated with a change in the failure rates. Rebleeding was the most common reason for failure; however, it did not differ statistically between the used techniques, and with the 95% confidence interval crossing the 5% zone of clinical indifference, this result was inconclusive. Minor complications occurred statistically and clinically more often after distal than after proximal embolization. The available literature is inconclusive regarding whether proximal or distal embolization should be used to avoid significant rebleeding and larger prospective cohort studies are required. However, both techniques have an equivalent rate of infarctions and infections requiring splenectomy. Minor complications occur more often after distal embolization. This is primarily explained by the higher rate of segmental infarctions after distal embolization.

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The nonoperative management (NOM) of patients with blunt splenic injuries has gained widespread acceptance with excellent success rates and is now the standard of care.[1–6] Currently, up to 80% of hemodynamically stable trauma patients with blunt splenic injury are successfully treated nonoperatively.[1] This development was facilitated in part by the liberal use of computed tomography and the introduction of angioembolization.[7–12]

Although there is a growing body of literature suggesting that the use of angiography and transcatheter embolization can increase splenic salvage, different techniques of embolization have been used, and very little is known about the complications associated with them. Proximal (main) splenic artery embolization and selective distal embolization have been described. However, in most studies, a limited number of embolized patients were available for analysis, making a meaningful study and analysis of the clinical impact of the different sites of embolization on the outcomes impossible. The objective of this systematic review and meta-analysis was to assess the outcomes and complications after angioembolization in trauma patients with splenic injuries and to examine specifically the impact of the technique used.

MATERIALS AND METHODS

Search Strategy

Published literature on the use of angioembolization in trauma patients with splenic injuries in the following databases was searched: PubMed (US National Library of Medicine, Bethesda, MD), Embase (Reed Elsevier, Amsterdam, the Netherlands), and the Cochrane Library (2009, Issue 3). There was no limitation of publication years for all searched databases. The search terms were "splenic," "spleen," "embolization," and "trauma". In PubMed, the "related articles" algorithm was used to identify additional articles. Bibliographies of original reports and reviews were screened for additional citations.

Exclusion Criteria

Case reports or case series of ≤5 embolized patients, pediatric patients, editorial letters, and reviews were excluded. Non–English-language publications were also excluded. Data from duplicate studies (overlap of study period and site) were analyzed only once.

Inclusion Criteria

Studies evaluating adult trauma patients who sustained splenic injuries and which included angioembolization as a treatment option were evaluated. For the subgroup of patients who underwent primary splenic embolization, the following data were required for inclusion: (1) American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) grade of splenic injury; (2) indication for embolization (contrast blush beyond or within the parenchyma, an associated large hemoperitoneum, or a high-grade [AAST-OIS grade ≥3] splenic injury); (3) site of embolization (proximal [main splenic artery], distal [selective, within the splenic parenchyma], or the combination of both). In addition, only studies that addressed the following outcomes in relation to the site of embolization (proximal vs. distal) were included: major complications including rebleeding, infarction, and infection requiring splenectomy or splenorrhaphy; minor complications including rebleeding, infarction, and infection not requiring splenectomy. Finally, only studies that provided data from a specified inhospital radiologic follow-up were included into the analysis on minor complications. These strict inclusion criteria were used to enhance patient population homogeneity.

Literature Search and Study Selection

Two reviewers (B.S. and A.K.) independently conducted literature searches, screened, and reviewed articles. Preliminary screening was performed using titles and abstracts. The full-length articles of potentially appropriate studies were retrieved for further screening. In case of duplicated publications, only the one containing more information or higher number of patients was used. If data were not presented in the articles, the corresponding authors were contacted by email to specifically ask for the missing information. If all required numbers were obtained, the study was included. Any discrepancy between the two reviewers was assessed and resolved by panel consensus.

Data Extraction

The following data elements were extracted from each article by two independent reviewers (B.S. and A.K.) and reviewed for accuracy by another reviewer (T.L.): publication year and site, number of embolized patients, age, gender, Injury Severity Score (ISS), grade of splenic injury according to the AAST-OIS, indication and site of embolization (proximal, distal, or the combination of both), and major and minor complications after embolization in relation to the site of embolization.

Statistical Analysis

The primary outcome measures were rebleeding, infarction, and infection requiring splenectomy or splenorrhaphy; these were categorized as major complications. Secondary outcome measures were the rates of rebleeding, infarction, and infection not requiring splenectomy; these were categorized as minor complications.

The characteristics of the patient populations among the included studies were compared. Continuous variables (age, ISS, and grade of splenic injury) were tested using one-way analysis of variance, and proportions (gender, contrast blush, large amount of hemoperitoneum, and high-grade splenic injury) were tested using the χ^2 test for contingency table analysis.

To assess the potential impact on outcomes as a result of between-study heterogeneity, a sensitivity analysis was conducted on three reduced sets of studies.[13] First, all studies were analyzed that met the inclusion criteria (first study set). Sequentially, studies were reanalyzed excluding those that lacked data on ISS, age, and gender or had outliers in the grade of splenic injury (second study set) and then studies with detailed data regarding only major or minor complications (third study set).

The association of contrast extravasation, large amount of hemoperitoneum, and high-grade splenic injury with the reported failure rates after embolization was analyzed between the studies using linear regression (meta-regression). Pooled rates of major and minor complications were compared between patients who underwent proximal and distal embolization using the χ^2 test.

To assess the clinical significance of the differences in outcomes between patients who underwent proximal and distal embolization, the 95% confidence interval (CI) for the difference was derived and evaluated using the zone of clinical indifference: CI falling within the zone of clinical indifference were considered as evidence of no difference between techniques, whereas those outside the zone were considered as having an effect on outcomes; for CI that crossed into the zone of indifference, the effect of the different techniques on outcomes could not be established. For major and minor complications, the zone of clinical indifference for a 5% effect size was used.[14,15]

Because of the relatively low number of patients who underwent both proximal and distal embolizations, an analysis of this subgroup was not performed. The Statistical Package for Social Sciences (SPSS Windows), version 16.0 (SPSS, Chicago, IL) was used for all analyses.

RESULTS

Study Selection

After screening 147 abstracts, 29 studies were identified that fell within the scope of this review.[8–10,16–41] Of the 29 studies, 11 studies were included[10,16–20,22–24,27,28] without further follow-up, 7 were excluded because of the overlap with other study populations,[10,29,31–33,37,40] and authors of the remaining 11 studies were contacted by email requesting additional data regarding embolized patients.[8,9,25,26,30,34–36,38,39,41] Based on these responses, four additional studies were included.[8,25,26,35] The remaining seven studies were excluded because of the lack of detailed information regarding complications or unknown site or technique of embolization (Fig. 1).

Study Quality and Characteristics

No randomized, controlled trials or prospective cohort studies investigating different techniques of splenic artery embolization were identified. All 15 studies that were included were retrospective cohort studies. The publication years ranged from 1995[24] to 2008[26–28,35] (Table 1). Overall,

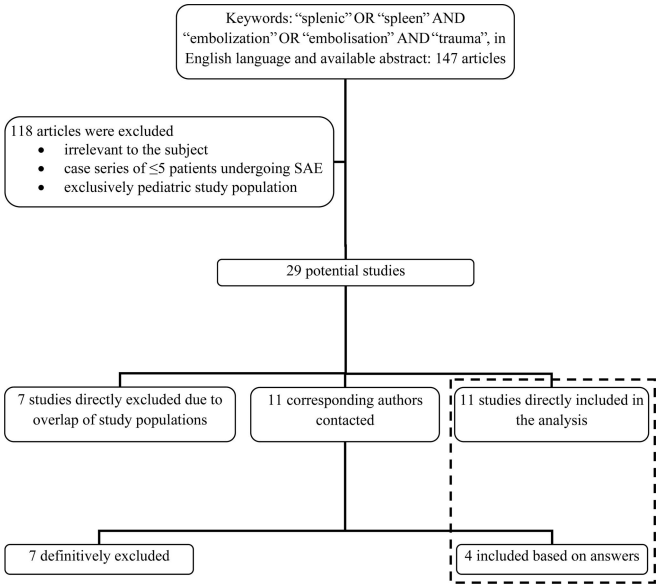

Figure 1. Study selection process. SAE, splenic artery embolization.

479 embolized patients were included. The mean ± SD number of embolized patients per study was 31.9 ± 34.3 (range, 6–140). The overall failure rate of angioembolization was 10.2% (range, 0.0–33.3%; Table 1).

All included study populations consisted of patients who sustained blunt mechanism of injury. In addition, the ISS, age, and gender did not differ significantly among the patient populations in the studies (Table 2). However, the overall mean AAST-OIS grade of splenic injuries was 3.5 ± 0.6 and differed significantly among the studies (range, 2.8–4.4; $p < 0.001$, analysis of variance; Table 2). Therefore, a sensitivity analysis was performed. This difference in the grade of splenic injury was not significant based on the third set of studies ($p = 0.097$).

In all studies, the indications for splenic embolization were a contrast blush beyond or within the splenic parenchyma (64%), an associated large hemoperitoneum (68%), or a high-grade splenic injury (91%). More than one indication per patient could occur. However, the distribution of these individual indications for embolization differed significantly in the first study set (Table 2). However, within the third study set, the proportion of patients with a large hemoperitoneum or high-grade splenic injury did not differ significantly ($p = 0.429$ and $p = 0.143$, respectively).

By linear regression, the failure rates were assessed in relation to the indications for embolization. With increasing

TABLE 1. Studies Included Into the Analysis

Author	Embolized Trauma Patients	Proximal	Distal	Combination	Material	Failure, % (n)	Radiological Follow-up	Major Complications Reported	Minor Complications Reported
Bessoud et al.[16]	37	37	0	0	Coils	2.7 (1)	CT	Yes	Yes
Cooney et al.[17]	9	6	3	0	Coils/gelatin particles	33.3 (3)	—	Yes	No
Davis et al.[18]	20	0	20	0	Coils/polyvinyl alcohol particles	0.0 (0)	—	Yes	No
Dent et al.[19]	13	0	13	0	Coils/polyvinyl alcohol particles	7.7 (1)	—	Yes	No
Ekeh et al.[20]	15	10	1	4	Coils/gelatin particles	6.7 (1)	CT	Yes	Yes
Gaarder et al.[8]	27	21	2	4	Coils/gelatin particles	3.7 (1)	CT	Yes	Yes
Haan et al.[21]	140	83	48	9	—	12.9 (18)	CT	No	Yes
Hagiwara et al.[22]	15	9	1	5	Coils/gelatin particles	0.0 (0)	CT/scintigraphy	Yes	Yes
Kaseje et al.[35]	11	8	3	0	—	18.2 (2)	—	Yes	No
Liu et al.[23]	6	0	6	0	Coil/gelatin particles	16.7 (1)	CT/scintigraphy	Yes	Yes
Sclafani et al.[24]	60	58	0	2	Coils/gelatin particles	6.7 (4)	CT	Yes	Yes
Smith et al.[25]	41	27	9	5	Coils/gelatin particles	22.0 (9)	CT	Yes	Yes
Wei et al.[26]	51	14	37	0	—	2.0 (1)	CT	Yes	Yes
Widlus et al.[27]	13	13	0	0	Amplatzer vascular plug	15.4 (2)	CT	Yes	Yes
Wu et al.[28]	21	3	16	2	Coils/gelatin particles	23.8 (5)	CT/sonography	Yes	Yes
Total	479	289 (60.3%)	159 (33.2%)	31 (6.5%)		10.2 (49)			

CT, computed tomography.

TABLE 2. Demographic Characteristics of Embolized Patients, Grade of Splenic Injuries, and Indications for Embolization

Author	Total Patients	Mechanism of Injury	ISS (Mean ± SD)	Age (Mean ± SD)	Male (%)	Grade of Splenic Injury (Mean ± SD)	Contrast Extravasation Beyond or Within Parenchyma or Pseudoaneurysm (%)	Large Hemoperitoneum (%)	Grade of Splenic Injury ≥3 (%)
Bessoud et al.[16]	37	Blunt	29 ± 3	40 ± 17	76	3.7 ± 0.7	38	—	100
Cooney et al.[17]	9	Blunt	24 ± 3	39 ± 7	67	3.1 ± 0.4	67	—	100
Davis et al.[18]	20	Blunt	—	—	—	2.8	100	—	—
Dent et al.[19]	13	Blunt	26 ± 13	41	—	3.7 ± 0.6	69	—	92
Ekeh et al.[20]	15	Blunt	24 ± 12	36 ± 21	73	3.5 ± 0.7	53	47	93
Gaarder et al.[8]	27	Blunt	31 ± 12	31	77	3.5 ± 0.7	51	—	—
Haan et al.[21]	140	Blunt	20	33	76	3.5	44*	83	87
Hagiwara et al.[22]	15	Blunt	33 ± 11	36	75	4.0 ± 0.5	100	75	100
Kaseje, et al.[35]	11	Blunt	27	33	—	4.4 ± 0.5	100	—	100
Liu et al.[23]	6	Blunt	—	44 ± 15	67	3.7 ± 0.5	33	50	100
Sclafani et al.[24]	60	Blunt	18	34	75	2.9 ± 0.9	100	—	—
Smith et al.[25]	41	Blunt	—	—	—	3.1 ± 1.0	—	58%	66
Wei et al.[26]	51	Blunt	29 ± 11	47 ± 19	—	3.8 ± 0.5	69	45	100
Widlus et al.[27]	13	Blunt	—	31	79	3.7 ± 0.7	100	—	100
Wu et al.[28]	21	Blunt	26 ± 13	43 ± 22	57	3.4 ± 0.5	48	52	100
Total	479	Blunt	24	36	74	3.5	64	68	91
p†			0.142	0.326	0.904	<0.001	<0.001	<0.001	<0.001

* Forty-four percent had a contrast extravasation and 33% pseudoaneurysm (there were patients with both, pseudoaneurysm and contrast extravasation; however, this number is not clarified).

† One-way ANOVA for continuous variables, χ^2 test for proportions.

rates of contrast extravasation, large amount of hemoperitoneum, or high-grade injury, no increased failure rates after embolization were found (Fig. 2, A–C).

Overall, proximal embolization was performed significantly more often than distal embolization (60.3% vs. 33.2%; $p < 0.001$). A combination of both techniques was applied in only 6.5% (31 of 479) of patients. Exclusively proximal embolization was performed in two studies,[16,27] and only distal embolization was used in three studies.[18,19,23] In 7 of the remaining 10 studies, the technique of embolization was based on the attending interventional radiologist's discretion, and in 3, an algorithm was used.[8,22,24] Radiologic follow-up was specified in 73.3%[11] of the studies (Table 1).

Outcomes of Proximal Versus Distal Embolization

Major Complications Requiring Splenectomy or Splenorrhaphy

In all three study sets, the overall failure rate did not differ significantly between distal and proximal embolization (Fig. 3). Within the three study sets, the rates of failure because of rebleeding ranged from 4.7% to 9.0% and occurred more frequently after distal when compared with the proximal embolization. However, this trend did not reach statistical or clinical significance.

The rate of major infarcts ranged within the three study sets from 1.6% to 3.8% for patients who underwent distal and from 0.0% to 0.5% for patients who underwent proximal embolization. Only one patient suffered a significant splenic infarction after proximal embolization (Table 3). Interestingly, this complication occurred after the proximally placed coil became dislodged and propagated distally.[24] This trend toward a higher infarction rate after distal embolization did not reach statistical significance because of the overall low incidence of affected patients.

Infectious complications requiring splenectomy occurred in a total of four patients after proximal embolization, described by three different investigators (Table 3).[20,24,26] After distal embolization, no major infections occurred in the studies included. This difference between distal and proximal embolizations in the infection rate did not reach statistical or clinical significance in any of the three analyzed study sets.

Minor Complications

Infarction was the most common complication and ranged within the three study sets from 0.0% to 8.4% for proximal and from 14.3% to 19.8% for distal embolization (Fig. 4). This higher incidence of splenic infarction after distal embolization was statistically significant in all three study sets and clinically significant in the first and second study set. These minor splenic infarctions were found in three of the studies (Table 4).[20,21,28] However, minor infarction after proximal embolization was described by only one author.[21]

Rebleeding was described by 5 investigators in a total of 11 patients.[8,16,20,21,26] They were all treated by reembolization. Rebleeding ranged within the three study sets from 2.2% to 2.8% for proximal and from 1.6% to 4.5% for distal embolization. In the first and second study sets, there was a trend toward a higher incidence of rebleeding after distal embolization. However, in the third study set, this trend

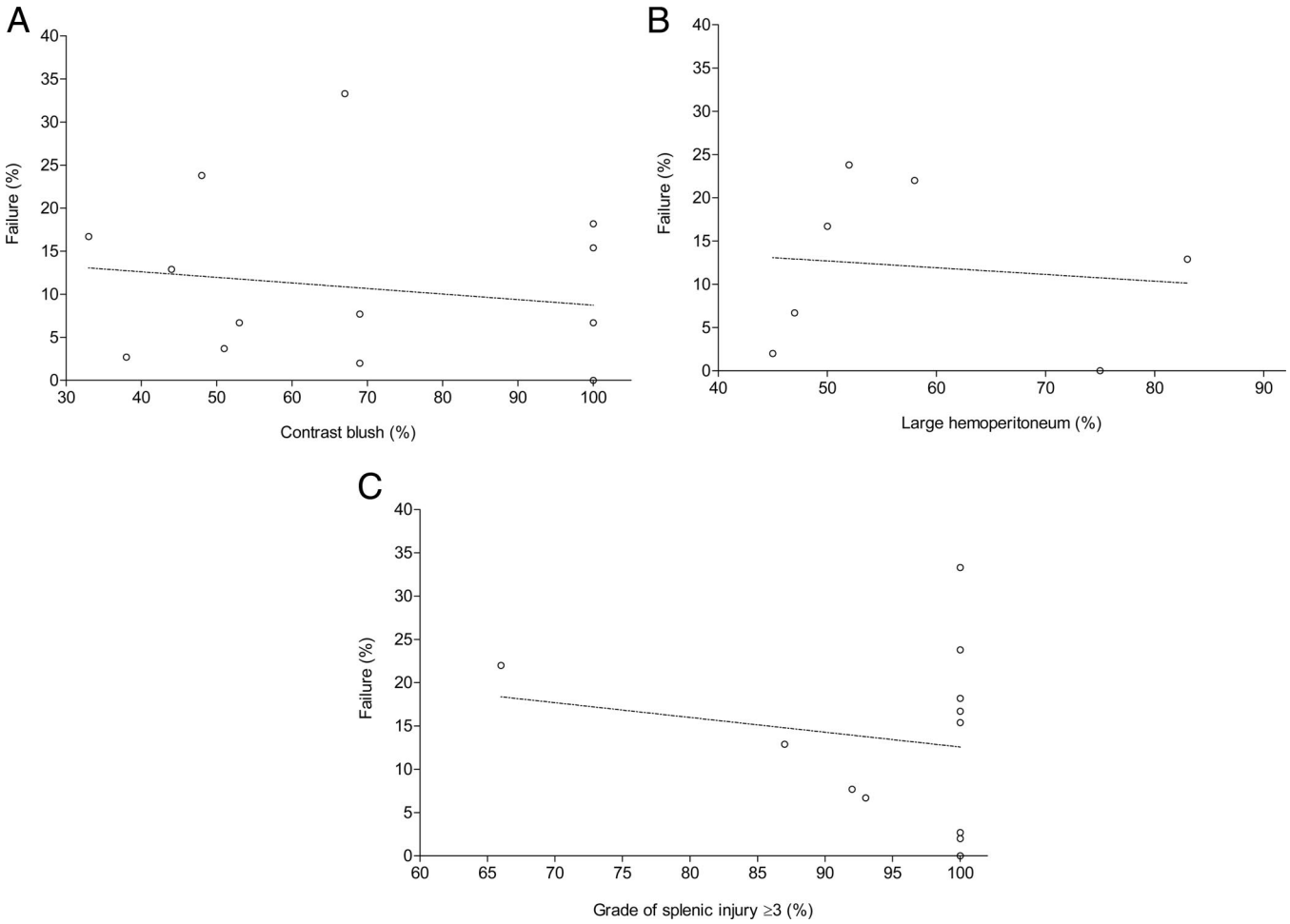

Figure 2. (*A*) Failure rate in relation to the percentage of patients with a contrast blush (regression analysis: $p = 0.562$, $r^2 = 0.029$). (*B*) Failure rate in relation to the presence of a large hemoperitoneum (regression analysis: $p = 0.795$, $r^2 = 0.015$). (*C*) Failure rate in relation to the proportion of patients with high-grade splenic injuries (regression analysis: $p = 0.597$, $r^2 = 0.029$).

changed toward proximal embolization. None of these trends reached statistical or clinical significance (Fig. 4).

There was only one patient who suffered an infectious complication treated nonoperatively.[21] This patient was readmitted with staphylococcal septicemia and a splenic abscess after distal embolization and was treated with 1 month of intravenous antibiotics.[21]

DISCUSSION

Angioembolization has been associated with an increased success rate in the NOM of splenic injuries.[1–6] Embolization may be performed proximal, in the main splenic artery, distal, in the small arterial branches within the splenic parenchyma, or can use the combination of both techniques. These procedures are usually performed using steel coils or plugs and/or gelatin or polyvinyl alcohol particles.

In 7 of the 15 studies included in this meta-analysis, the technique used was at the attending interventional radiologists' discretion, and the specific reasons for the choice of technique were not available for analysis. In addition, the indications for angioembolization differed significantly between the individual studies. This discrepancy may be partly because a clear understanding of the outcomes with respect to the different embolization techniques is lacking. Many investigators have published their success rates with NOM in blunt splenic trauma, including subgroups of patients that underwent angioembolization. However, in most studies only a limited number of embolized patients were available for analysis, making a meaningful evaluation of the different embolization techniques impossible. The purpose of this meta-analysis was to pool and analyze this aggregate data in an attempt to assess the outcomes as they relate to the site of embolization.

Study Quality

To date, no prospective randomized or even cohort studies comparing proximal and distal embolization are available. In fact, only one retrospective cohort study is available at present, which included enough patients to draw any conclusion regarding complications related to the different

Major Re-bleeding	Proximal	Distal	*p*-value	Odds ratio (95% CI)
1st study set	6.3% (13/206)	9.0% (10/111)	0.377*	1.47 (0.62-3.47)
2nd study set	5.3% (6/113)	6.3% (5/79)	0.765*	1.21 (0.36-4.10)
3rd study set	4.7% (5/107)	6.3% (4/63)	0.728*	1.38 (0.36-5.35)
Major Infarction				
1st study set	0.5% (1/206)	2.7% (3/111)	0.125**	1.02 (0.99-1.06)
2nd study set	0.0% (0/113)	3.8% (3/79)	0.068**	1.04 (1.00-1.09)
3rd study set	0.0% (0/107)	1.6% (1/63)	0.371**	1.02 (0.99-1.05)
Major Infection				
1st study set	1.9% (4/206)	0.0% (0/111)	0.302**	0.98 (0.96-1.00)
2nd study set	1.8% (2/113)	0.0% (0/79)	0.513**	0.98 (0.96-1.01)
3rd study set	1.9% (2/107)	0.0% (0/63)	0.531**	0.98 (0.96-1.01)
Total Major				
1st study set	8.7% (18/206)	10.8% (12/111***)	0.548*	1.27 (0.59-2.73)
2nd study set	7.1% (8/113)	8.9% (7/79***)	0.651*	1.28 (0.44-3.68)
3rd study set	6.5% (7/107)	6.3% (4/63***)	1.000*	0.97 (0.27-3.45)

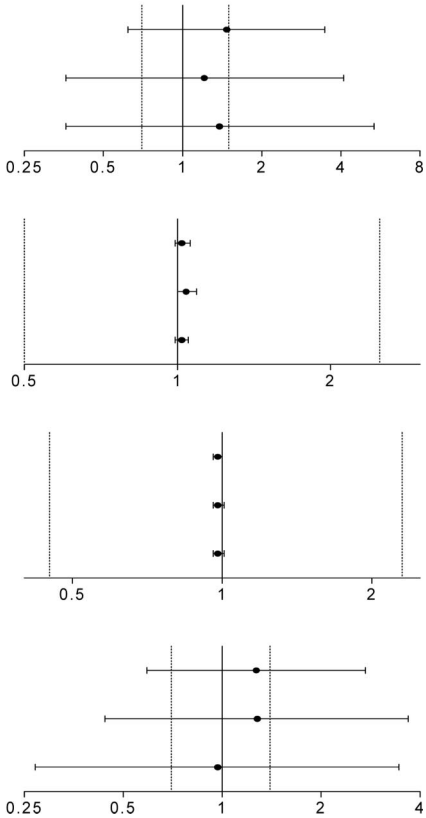

Figure 3. Proximal versus distal embolization: major complications. *χ^2 test, **Fisher's exact test, ***One patient had both bleeding and infarction requiring splenectomy. *Dotted line*: zone of clinical indifference, 5% effect size. First study set: all 15 studies that met the inclusion criteria. Second study set: first study set minus four studies without data on ISS, age, and gender[18,25] or outliers in the grade of splenic injury.[24,35] Third study set: second study set minus three studies with only obtainable detailed data about either major[21] or minor complications.[17,19]

sites of embolization.[21] These investigators reviewed 114 embolized patients from 4 centers in the United States over a 6-year study period. This study is also embedded into the first and second study sets of the current meta-analysis investigating minor complications. However, it was excluded from the assessment of major complications because the specific sites of embolizations were not obtainable for those patients who required splenectomy because of rebleeding or infarcts.

All included 15 studies are retrospective (level III evidence). As expected, there was considerable variation in the injury characteristics between the study populations and missing data in the demographics. Therefore, to reduce the intrastudy heterogeneity, a sensitivity analysis was conducted on three reduced sets of studies (first–third study sets). By doing this, the differences in the grades of splenic injuries and the differences in the indications for angioembolization could be eliminated from the third study set. This study set is the one with lowest potential for in-between study heterogeneity, and the conclusions of this meta-analysis are based on the third study set.

Failure After Embolization

The pooled overall failure rate after angioembolization was found to be 10.2%, ranging from 0.0% to 33.3% among studies. With the 95% CI falling within the zone of clinical indifference, proximal and distal embolizations were found to be equivalent with regards to the incidence of major infarctions and infections. The infarctions resulting after distal embolization are limited to the embolized segment, which rarely results in a splenectomy. However, the results regarding major rebleeding were inconclusive with the 95% CI crossing the 5% zone of clinical indifference. Larger studies are required to establish equivalence of this complication between proximal and distal embolizations.

In contrast to distal embolization, proximal embolization of the main splenic artery does not directly stop the hemorrhage but in theory enables clot formation by decreasing distal flow into the parenchyma.[42] In fact, a decrease in blood flow without complete loss of perfusion after proximal embolization has been affirmed by Doppler sonography.[29] There are several collateral arteries entering the splenic hilum and the upper and lower pole, preventing infarction of the spleen.[43] Because of this decrease in blood pressure within the entire splenic parenchyma, proximal embolization in theory will control splenic injuries with multiple bleeding sites. In contrast, distal embolization techniques may not be feasible in these situations.[18]

TABLE 3. Major Complications

Author	Patients Embolized Proximally	Major Complications Requiring Splenectomy or Splenorrhaphy			Patients Embolized Distally	Major Complications Requiring Splenectomy or Splenorrhaphy		
		Bleeding	Infarction	Infection		Bleeding	Infarction	Infection
Bessoud et al.[16]	37	1	0	0	0	—	—	—
Cooney et al.[17]	6	1	0	0	3	0	2	0
Davis et al.[18]	0	—	—	—	20	0	0	0
Dent et al.[19]	0	—	—	—	13	1	0	0
Ekeh et al.[20]	10	0	0	1	1	0	0	0
Gaarder et al.[8]	21	1	0	0	2	0	0	0
Hagiwara et al.[22]	9	0	0	0	1	0	0	0
Kaseje et al.[35]	8	0	0	0	3	2	0	0
Liu et al.[23]	0	—	—	—	6	1	0	0
Sclafani et al.[24]	58	1*	1†	2	0	—	—	—
Smith et al.[25]	27	6	0	0	9	3	0	0
Wei et al.[26]	14	0	0	1	37	0	0	0
Widlus et al.[27]*	13	2	0	0	0	—	—	—
Wu et al.[28]	3	1	0	0	16	3	1‡	0
Total	206	13 (6.3%)	1 (0.5%)	4 (1.9%)	111	10 (9.0%)	3 (2.7%)	0 (0.0%)

* This was a Jehovah's Witness patient who died due to ongoing bleeding after embolization and refusing transfusion and splenectomy.
† Distally dislodged proximal coil that caused a splenic infarct requiring splenectomy.
‡ This patient had both, bleeding and infarction, requiring splenectomy.

Minor Re-bleeding	Proximal	Distal	*p*-value	Odds ratio (95% CI)
1st study set	2.2% (6/275)	4.2% (5/120)	0.270*	1.95 (0.58-6.52)
2nd study set	3.2% (6/190)	4.5% (5/111)	0.548*	1.45 (0.43-4.85)
3rd study set	2.8% (3/107)	1.6% (1/63)	1.000*	0.56 (0.06-5.49)
Minor Infarction				
1st study set	5.8% (16/275)	18.3% (22/120)	<0.001*	3.63 (1.83-7.21)
2nd study set	8.4% (16/190)	19.8% (22/111)	0.004*	2.69 (1.35-5.37)
3rd study set	0.0% (0/107)	14.3% (9/63)	<0.001*	1.17 (1.06-1.29)
Minor Infection				
1st study set	0.0% (0/275)	0.8% (1/120)	0.304**	1.01 (0.99-1.03)
2nd study set	0.0% (0/190)	0.9% (1/111)	0.369**	1.01 (0.99-1.03)
3rd study set	0.0% (0/107)	0.0% (0/63)	-	1.00
Total Minor				
1st study set	8.0% (22/275)	23.3% (28/120)	<0.001*	3.50 (1.91-6.42)
2nd study set	11.6% (22/190)	25.2% (28/111)	0.002*	2.58 (1.39-4.78)
3rd study set	2.8% (3/107)	15.9% (10/63)	0.005*	6.54 (1.72-24.78)

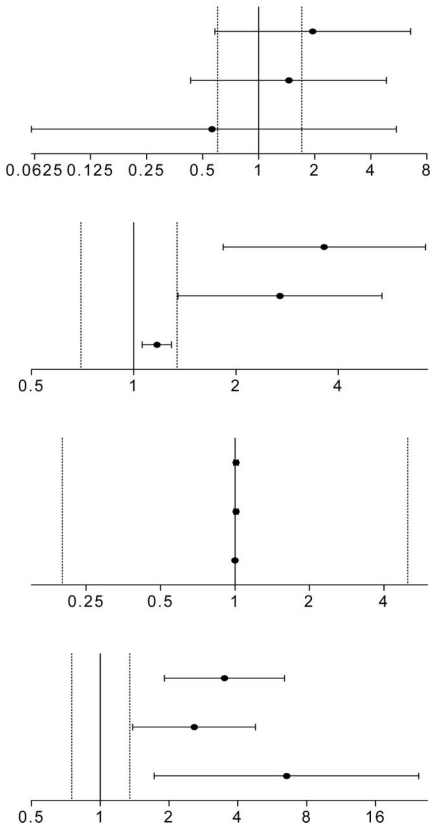

Figure 4. Proximal versus distal embolization: minor complications. Refer Figure 3 legend for explanations.

TABLE 4. Minor Complications not Requiring Splenectomy

Author	Patients Embolized Proximally	Minor Complications After Proximal Embolization			Patients Embolized Distally	Minor Complications After Distal Embolization		
		Bleeding	Infarction	Infection		Bleeding	Infarction	Infection
Bessoud et al.[16]	37	1*	0	0	0	—	—	—
Ekeh et al.[20]	10	1	0	0	1	0	1	0
Gaarder et al.[8]	21	1†	0	0	2	0	0	0
Haan et al.[21]	83	3†	16	0	48	4†	13	1
Hagiwara et al.[22]	9	0	0	0	1	0	0	0
Liu et al.[23]	0	—	—	—	6	0	0	0
Sclafani et al.[24]	58	0	0	0	0	—	—	—
Smith et al.[25]	27	0	0	0	9	0	0	0
Wei et al.[26]	14	0	0	0	37	1†	0	0
Widlus et al.[27]	13	0	0	0	0	—	—	—
Wu S et al.[28]	3	0	0	0	16	0	8	0
Total	275	6 (2.2%)	16 (5.8%)	0 (0.0%)	120	5 (4.2%)	22 (18.3%)	1 (0.8%)

* Possibly old hematoma because of initial trauma.
† Treated with reembolization.

There are also some drawbacks to the proximal embolization technique. If the splenic artery is embolized proximally to the main pancreatic artery, ischemia of the pancreas may occur. A case report of a severe acute necrotizing pancreatitis caused by inadvertent proximal embolization of the splenic artery has recently been published.[44] During the initial diagnostic run, the anatomy of the pancreatic perfusion needs to be evaluated, and if in doubt, distal embolization might be indicated. Another pitfall of the proximal technique is the potential for dislodgement of coils from proximal to distal, which may cause extensive infarction of the spleen. This was seen in one patient captured in this review.[24] Improved vascular plugs that can be applied more precisely and can make dislodgement almost impossible are under development and have been used successfully in trauma patients.[27]

Minor Complications

Many studies that were reviewed during this screening process did not define radiologic follow-up of patients who underwent embolization. These studies could not be included in the analysis. Nevertheless, in a total of 11 studies, the radiologic follow-up was obtainable and local complications, not requiring surgical intervention, were described.[8,16,20–28]

In all three study sets, a statistically and clinically significant higher rate of overall minor complications were found after distal embolization. This is primarily explained by the higher rate of splenic infarction after distal embolization. However, these infarctions are limited to the segment just distal to the site of embolization.[20,21,28] The clinical relevance of these infarctions is questionable as they seem to resolve within 6 months to 12 months.[22]

CONCLUSIONS

The success rate of angioembolization after splenic injuries is almost 90%, with rebleeding being the most common reason for failure. The currently available literature is inconclusive regarding whether proximal or distal embolization should be used to avoid significant rebleeding and larger prospective cohort studies are required. However, both techniques have an equivalent rate of major infarctions and infections requiring splenectomy. Minor complications not requiring splenectomy occur more often after distal than after proximal embolization. This is primarily explained by the higher rates of infarctions after distal embolization. However, these infarctions are limited to the segment just distal to the site of embolization, and their clinical relevance is questionable.

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