

Salvage Superselective Vesical Artery Embolization for Intractable Hematuria Refractory to Conservative and Endoscopic Management: Angiographic Patterns and Short-Term Outcomes by Etiology

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Abstract

Background/Objective: Intractable bladder hematuria may persist despite continuous bladder irrigation and endoscopic hemostasis, exposing frail patients to repeated transfusions and the morbidity associated with urinary diversion or palliative cystectomy. This study evaluated the outcomes and safety of salvage microcatheter-based superselective vesical artery embolization (SVAE) in patients refractory to conservative and endoscopic management and described the angiographic patterns across malignant, radiation-induced, and non-malignant etiologies. **Materials and Methods:** This retrospective single-center series included 16 consecutive patients (13 men, 3 women; mean age 67.7 years) who underwent SVAE between January 2015 and December 2025. All patients had hematuria refractory to a stepwise protocol of bladder irrigation, transfusion support, cystoscopy, and endoscopic hemostasis with electrocautery and/or transurethral resection. Demographics, digital subtraction angiography findings, embolization details, hemoglobin values, and 30-day adverse events graded by the modified Society of Interventional Radiology classification were analyzed using the Wilcoxon signed-rank test and exact binomial 95% confidence intervals (CIs). **Results:** Technical success was achieved in all procedures (16/16, 100%; 95% CI, 79.4–100); bilateral embolization was performed in 10 patients (62.5%). Hematuria control during the observed follow-up period was achieved in all patients (16/16, 100%; 95% CI, 79.4–100); none required repeat embolization, urinary diversion, or palliative cystectomy. The mean hemoglobin level increased from 8.38 ± 0.82 to 10.36 ± 0.92 g/dL ($p < 0.001$), although this increase was partly attributable to peri-procedural transfusion. Two patients (12.5%) developed mild post-embolization syndrome; no moderate-or-worse 30-day adverse events occurred. Median clinical follow-up was 7.5 months (range, 1–24 months). **Conclusion:** Salvage microcatheter-based SVAE was associated with encouraging short-term bleeding control and a low 30-day adverse-event burden in this cohort. These hypothesis-generating findings require confirmation in larger prospective studies with longer follow-up, particularly in radiation-induced cases.

Keywords: Angiography, Digital Subtraction; Embolization, Therapeutic; Hematuria; Salvage Therapy; Urinary Bladder

1. Introduction

Intractable hematuria of bladder origin is a potentially life-threatening condition. Common causes include bladder carcinoma, radiation cystitis, cyclophosphamide-induced cystitis, severe infection, and advanced pelvic malignancies involving the bladder.¹⁻³ In hematopoietic stem cell transplantation recipients, BK virus-associated hemorrhagic cystitis is another recognized cause of severe vesical bleeding.⁴ Standard management begins with clot evacuation and continuous bladder irrigation through a three-way catheter.^{1,2} When irrigation fails, cystoscopic fulguration, intravesical agents, and hyperbaric oxygen therapy may be used in selected cases.^{1,3,5,6} However, some patients continue to bleed despite these measures and may ultimately require urinary diversion or palliative cystectomy, both of which carry substantial morbidity in the elderly and comorbid population that usually presents with this condition.^{1,2,5}

Transcatheter arterial embolization is a minimally invasive alternative. Early proximal techniques, including unilateral hypogastric and bilateral internal iliac artery embolization, improved hemostasis but were associated with serious ischemic complications such as buttock or perineal pain, bladder necrosis, and gluteal skin necrosis.^{2,5,7,8} Superselective vesical artery embolization using microcatheter systems enables targeted occlusion of vesical branches while preserving the remaining internal iliac territory and has therefore become the preferred technique.^{2,8-12} Recent series have reported high technical success and encouraging clinical control, but recurrence rates and outcome definitions remain heterogeneous across studies.^{9,13-15}

Current evidence is based almost entirely on small, retrospective series. Important questions remain regarding embolic material selection, unilateral versus bilateral treatment, durability of hemostasis, and angiographic patterns seen across different etiologies.^{8,9,11,15} Detailed descriptions of prior failed conservative and endoscopic management are also scarce. Therefore, this study primarily aimed to evaluate the clinical outcomes and safety of salvage microcatheter-based SVAE in patients with intractable hematuria refractory to conservative and endoscopic management and secondarily to describe the digital subtraction angiography patterns encountered across malignant, radiation-induced, and non-malignant etiologies.

2. Materials and Methods

2.1. Study design and population

This retrospective, single-center clinical series was conducted at a tertiary referral center. The study protocol was approved by the Baškent University Institutional Review Board (Project No: KA26/137; decision letter no: E-94603339-604.01-564021) on 11 March 2026, and was supported by the Baškent University Research Fund (Project No: KA26/137). This study was conducted in accordance with the Declaration of Helsinki. The medical records of all patients who underwent attempted SVAE for intractable hematuria between January 2015 and December 2025 were reviewed for this study. The analytic cohort comprised all identified patients in whom SVAE was attempted during the study period, and no patient was excluded after case identification. Written informed consent for the embolization procedure was obtained from all the patients. The institutional review board approved the retrospective data analysis.

Sixteen patients (13 men and 3 women) were included in the study. Intractable hematuria was defined as macroscopic hematuria refractory to a structured stepwise approach consisting of (1) continuous bladder irrigation via a three-way catheter with clot evacuation, (2) cystoscopic evaluation with localization of the bleeding source, and (3) attempted endoscopic hemostasis using electrocautery and/or transurethral resection of the bladder tumor, when applicable. Patients were classified as having malignancy-associated hematuria (n=7), radiation-induced hemorrhagic cystitis (n=6), or other non-malignant bladder bleeding etiologies (n=3; vesical arteriovenous malformation, n=1; infectious hemorrhagic cystitis, n=2). All 16 patients presented with severe gross hematuria with clot formation and required continuous bladder irrigation, transfusion support, and/or endoscopic clot evacuation procedures.

2.2. Stepwise treatment algorithm

All patients were managed using a standardized stepwise protocol. The initial treatment consisted of a three-way Foley catheter and continuous bladder irrigation. Persistent hematuria prompted cystoscopy under intravenous sedation. The bleeding source was characterized as tumor bleeding, mucosal fragility, telangiectatic lesions or diffuse venous oozing. Endoscopic hemostasis was attempted using monopolar electrocautery, and selected malignant lesions underwent transurethral resection. Patients with persistent or recurrent hematuria after conservative and endoscopic management were referred for SVAE. The overall stepwise pathway from initial conservative management to SVAE is illustrated in Figure 1. In this study, "salvage" was used operationally to denote SVAE performed after failure of continuous bladder irrigation and endoscopic hemostasis; it does not imply that every available intravesical or adjunctive treatment had been exhausted. Intravesical alum irrigation was attempted in nine of the 16 patients but failed to control hematuria, after which SVAE was performed. In the remaining patients, the urgency of ongoing bleeding and clinical frailty precluded further intravesical treatment. Intravesical formalin and hyperbaric oxygen therapy are not part of the routine institutional salvage algorithm and were not administered.

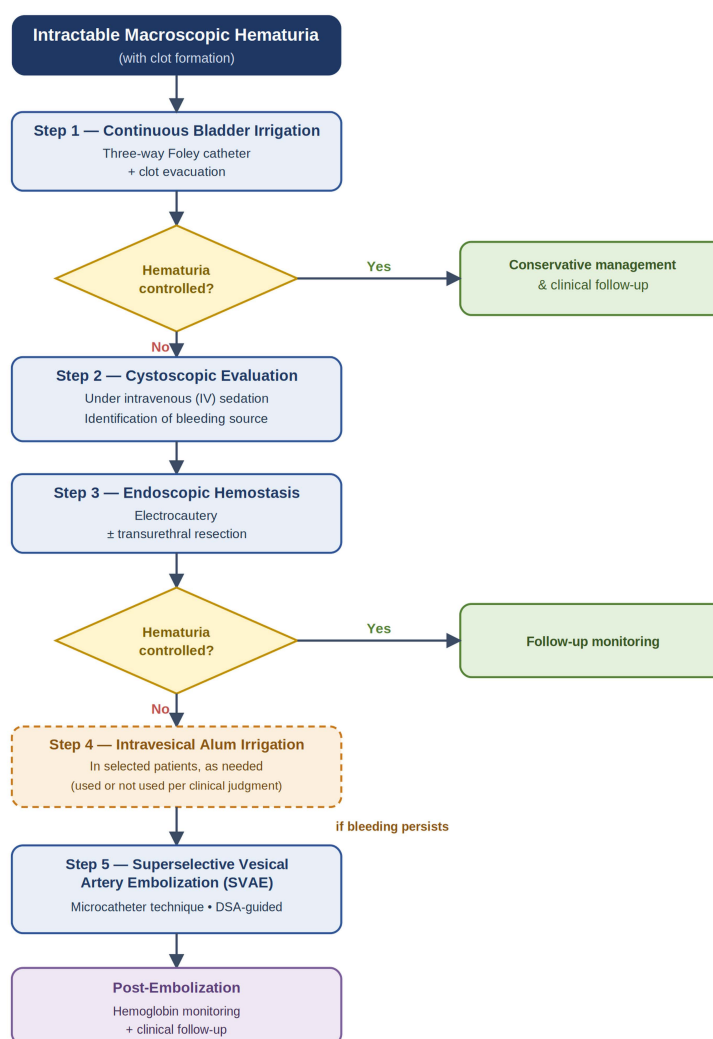


Figure 1. Stepwise treatment algorithm for intractable macroscopic hematuria. Initial management comprised continuous bladder irrigation through a three-way Foley catheter and clot evacuation, followed by cystoscopic evaluation and endoscopic hemostasis when bleeding persisted. In selected patients, intravesical alum irrigation was attempted before embolization (used or omitted according to clinical judgment). Patients with persistent or recurrent bleeding then underwent DSA-guided superselective vesical artery embolization, hemoglobin monitoring, and clinical follow-up. DSA, digital subtraction angiography.

2.3. Embolization technique

All procedures were performed by experienced interventional radiologists using a monoplane DSA system. Under local anesthesia, common femoral arterial access was obtained, and a 5- or 6-F sheath was placed. Pelvic arteriography was performed using a 5-F diagnostic catheter, followed by selective catheterization of both internal iliac arteries to delineate the vesical arterial anatomy. Superselective catheterization of the superior and/or inferior vesical arteries was achieved using a 2.4- or 2.8-F microcatheter over a 0.018-inch guidewire.

The DSA findings were classified as hyperemia/hypervascularity, dysplastic or tortuous branches, tumoral staining, and active intravesical extravasation. These categories were not mutually exclusive: hyperemia/hypervascularity was defined as increased arterial density with a diffuse or persistent bladder-wall blush; dysplastic or tortuous branches as irregular vessel caliber with excessive distal tortuosity; tumoral staining as a focal persistent contrast blush corresponding to a tumor; and active extravasation as contrast leakage into the bladder lumen on arterial- or delayed-phase images. Angiographic patterns were assigned to these operational categories, used for the retrospective review, by two experienced interventional radiologists who reviewed the digital subtraction angiography images independently; discrepancies were resolved by consensus. Embolic agents were selected based on angiographic findings and vascular anatomy and included calibrated microspheres (100–500 μm), n-butyl-2-cyanoacrylate (NBCA) mixed with Lipiodol, and detachable microcoils, alone or in combination. The angiographic endpoint was stasis within the target vesical branches, with preservation of the remaining internal iliac territory. The decision for unilateral versus bilateral embolization was based on cystoscopic, cross-sectional imaging, and DSA findings; bilateral treatment was preferred for diffuse mucosal involvement or bilateral vascular abnormalities.

2.4. Data collection and outcomes

The collected variables included demographics, etiology, cystoscopic findings, failed endoscopic interventions, DSA findings, embolization laterality, target vessels, embolic agents, transfusion requirements, follow-up, and adverse events. The pre-embolization hemoglobin value was defined as the last measurement obtained before embolization, and the post-embolization value was defined as the first follow-up value recorded during the same hospitalization. Because most patients received transfusion support before embolization and the timing of transfusion relative to the first post-embolization hemoglobin measurement could not be adjusted granularly, hemoglobin change was interpreted as a supportive secondary marker rather than a stand-alone measure of procedural effects.

Technical success was defined as the cessation of extravasation and/or stasis within the target vesical branches on completion DSA.¹¹ Clinical success was defined as sustained resolution of macroscopic hematuria throughout the follow-up period without repeat embolization, urinary diversion, or palliative cystectomy. Follow-up status was determined from the index hospitalization and subsequent institutional inpatient and outpatient medical records. Rebleeding was classified as early when it occurred within 30 days and late when it occurred thereafter. Procedure-related adverse events (AEs) within 30 days were graded according to the modified Society of Interventional Radiology (SIR) classification.¹⁶

2.5. Statistical analysis

Statistical analyses were performed using R statistical software (version 4.4.2; R Foundation for Statistical Computing, Vienna). Continuous variables are presented as mean $\pm$ standard deviation, median (interquartile range [IQR]), or median (range), as appropriate. Normality was assessed using the Shapiro–Wilk test. Because the paired differences in hemoglobin levels were not normally distributed ($p=0.049$), the Wilcoxon signed-rank test was used for pre/post comparisons. Subgroup analyses were exploratory; groups with at least six patients underwent the same paired test,

whereas smaller groups were described without formal statistical testing. Categorical variables are presented as frequencies and percentages, and exact binomial 95% confidence intervals were calculated for technical and clinical success rates. Because the timing of transfusion relative to the first post-embolization hemoglobin measurement could not be standardized, the change in hemoglobin was treated as a supportive secondary endpoint rather than a stand-alone measure of procedural effect. Because no recurrence, repeat embolization, or rescue procedure occurred, no event-based time-to-event estimate was calculated. Instead, the number of patients remaining under observation at prespecified follow-up intervals was reported to make the rapidly diminishing follow-up explicit. A two-sided p value <0.05 was considered statistically significant.

3. Results

3.1. Patient demographics and prior endoscopic interventions

During the study period, 16 patients (13 men and 3 women) with a mean age of 67.7 years (range, 48–88 years) underwent SVAE. The etiologies were malignancy-associated hematuria in seven patients (43.8%), radiation-induced hemorrhagic cystitis in six (37.5%), and other non-malignant bladder bleeding etiologies in three (18.8%). All patients had severe macroscopic hematuria with clot formation and had undergone at least one cystoscopic attempt at electrocautery before the embolization.

In the malignancy group, cystoscopy most often revealed papillary or necrotic tumoral lesions with active bleeding. In the radiation-induced group, diffuse mucosal fragility, telangiectatic changes, and petechial bleeding were typical. The non-malignant group exhibited focal bleeding sites, diffuse venous oozing, and one vesical arteriovenous malformation. Hemostasis could not be achieved or sustained endoscopically in any of the patients (Table 1).

Table 1. Patient demographics, hemoglobin values, transfusion requirements, and details of prior failed endoscopic interventions

No	Age	Sex	Etiology	Hb Pre (g/dL)	Hb Post (g/dL)	TF	Prior Endoscopic Intervention & Cystoscopic Findings
1	51	M	Vesical AVM-associated bleeding	7.90	11.90	4 pRBC	Clot evacuation & irrigation; cystoscopy: no tumor; vesical AVM identified at right inferior bladder wall; electrocautery attempted; hemostasis not achieved
2	60	F	Radiation-induced HC	8.58	9.50	1 pRBC	Clot evacuation & irrigation; right trigonal hyperemic/fragile mucosa identified; electrocautery performed; bleeding not controlled
3	64	M	Infectious HC	8.20	9.80	4 pRBC	Infectious HC confirmed (positive urine culture); active bleeding focus at dome cauterized; diffuse venous oozing persisted; hemostasis not achieved
4	88	M	Malignancy	8.45	10.36	2 pRBC	Clot evacuation; irrigation; left papillary lesion and right-sided mass with petechial bleeding identified; electrocautery performed; bleeding not controlled
5	84	M	Infectious HC	10.30	12.01	3 (2 FFP + 1 pRBC)	Infectious HC confirmed (positive urine culture); bladder base bleeding foci identified; electrocautery attempted; hemostasis not achieved
6	78	M	Malignancy	7.40	9.50	4 pRBC	Clot evacuation; irrigation; papillary lesion and left-sided mass with petechial bleeding identified; electrocautery performed; bleeding not controlled
7	53	M	Radiation-induced HC	8.40	10.44	3 pRBC	Clot evacuation & irrigation; fragile/erythematous mucosa; electrocautery performed; bleeding not controlled

8	68	M	Radiation-induced HC	8.80	10.40	2 pRBC	Clot evacuation & irrigation; telangiectatic/punctate lesions; electrocautery performed; bleeding not controlled
9	59	F	Radiation-induced HC	7.55	10.55	6 (4 pRBC + 2 FFP)	Clot evacuation & irrigation; petechial/fragile mucosa; electrocautery performed; bleeding not controlled
10	71	M	Radiation-induced HC	7.25	9.18	3 pRBC	Clot evacuation; irrigation; electrocautery performed; bleeding not controlled
11	68	M	Malignancy	8.23	10.16	3 pRBC	Organized clot; papillary/necrotic tumor at trigone extending leftward; electrocautery performed; bleeding not controlled
12	88	M	Radiation-induced HC	8.70	10.00	2 pRBC	Petechial bleeding + fragile tissue; radiation-type mucosal changes; electrocautery performed; bleeding not controlled
13	63	M	Malignancy	9.70	12.20	6 (2 pRBC + 4 FFP)	Bladder neck resection attempted; partial resection + cauterization; endoscopic control insufficient; referred for embolization
14	58	F	Malignancy	8.90	10.30	4 (3 pRBC + 1 FFP)	Posterior wall + trigone necrotic/hemorrhagic mass; irrigation + electrocautery; bleeding not controlled
15	48	M	Malignancy	8.30	9.80	2 pRBC	Massive clot burden; irrigation + electrocautery; bleeding not controlled
16	82	M	Malignancy	7.40	9.60	3 pRBC	Clot evacuation; necrotic/hemorrhagic tumor areas; electrocautery performed; bleeding not controlled

AVM, arteriovenous malformation; FFP, fresh frozen plasma; Hb, hemoglobin; HC, hemorrhagic cystitis; pRBC, packed red blood cell (erythrocyte suspension) unit; TF, transfusion.

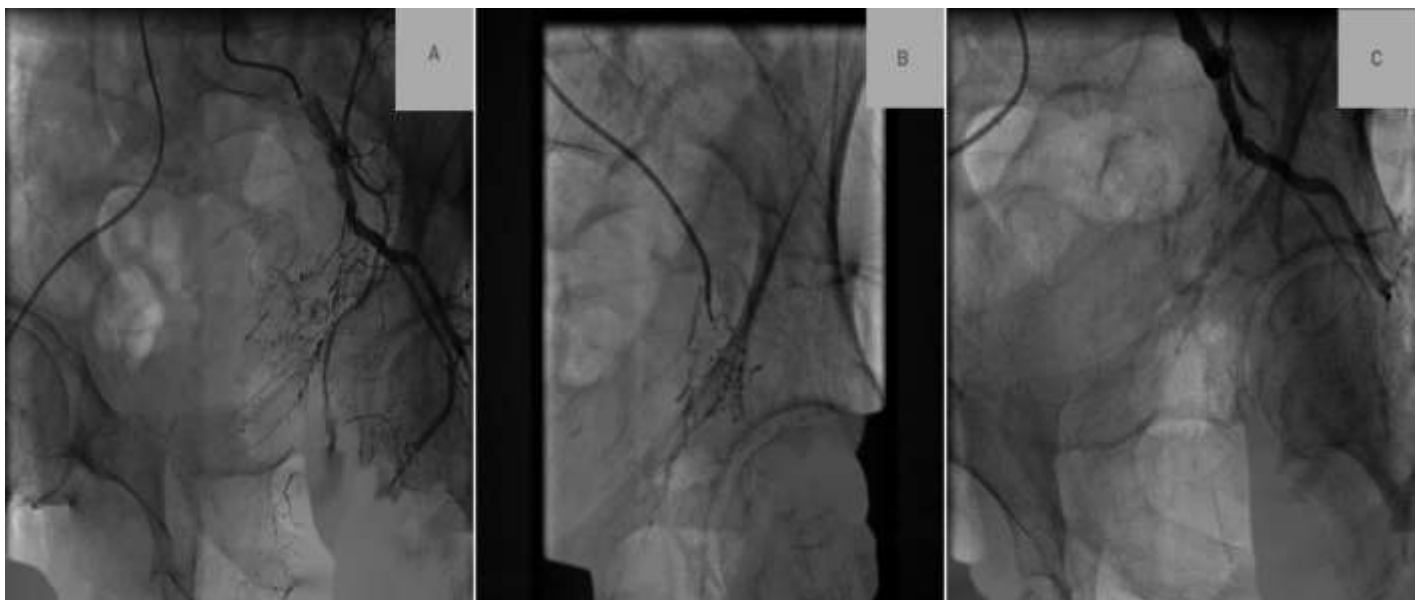


Figure 2. Representative malignant case (Patient 11). (A) Pre-embolization left internal iliac artery angiography shows tumoral staining, neovascularity, and active extravasation from the left vesical artery. (B) Fluoroscopic image during embolization with 300–500 μm microspheres. (C) Post-embolization control angiography shows stasis and disappearance of tumoral staining.

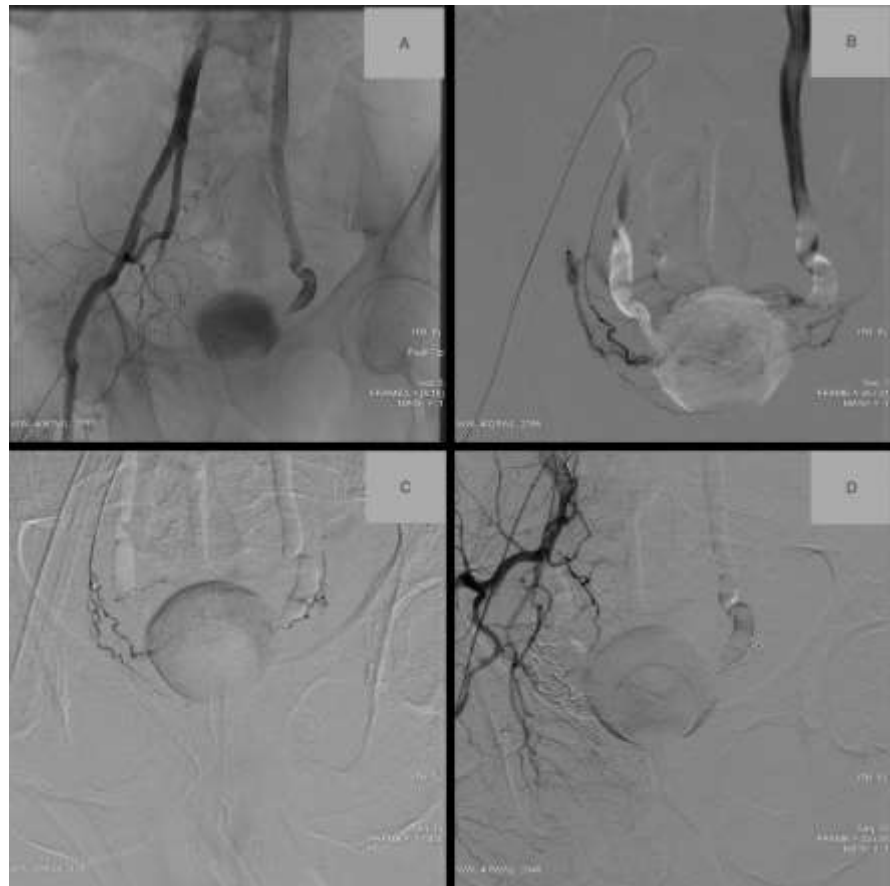


Figure 3. Representative radiation-induced hemorrhagic cystitis case (Patient 7). (A) Pelvic arteriography via the right internal iliac artery shows vesical arterial anatomy. (B) Superselective right superior vesical artery angiography shows diffuse hyperemia with dysplastic tortuous distal branches and retrograde collateral filling. (C) Fluoroscopic image after sequential embolization with 100–300 μ m microspheres and NBCA-Lipiodol. (D) Post-embolization angiography confirms occlusion of target branches with preservation of the remaining internal iliac territory. NBCA, *n*-butyl-2-cyanoacrylate.

3.2. Angiographic findings and embolization details

DSA revealed at least one angiographic abnormality in all 16 patients. Malignant cases were characterized by tumoral staining, neovascularity, and occasional active extravasation. Radiation-induced hemorrhagic cystitis showed diffuse hyperemia with dysplastic and tortuous distal vesical branches, with late-phase extravasation in some patients. The non-malignant group showed more focal abnormalities, and the AVM case demonstrated a nidus with tortuous feeding arteries and early venous drainage. Representative malignant and radiation-induced patterns are presented in Figures 2 and 3, respectively.

Technical success was achieved in all procedures (16/16, 100%; exact 95% CI, 79.4–100). Bilateral embolization was performed in 10 (62.5%) patients and unilateral embolization in six (37.5%) patients. The superior vesical artery was the most frequent target artery. The embolic agents included microspheres alone (n=9), NBCA-Lipiodol alone (n=3), microspheres plus NBCA-Lipiodol (n=2), microspheres plus microcoils (n=1), and a combination of microspheres, microcoils, and NBCA-Lipiodol (n=1) (Table 2).

Table 2. Digital subtraction angiography findings, embolization targets, embolic agents, 30-day adverse events, and follow-up.

No	DSA Angiographic Findings	Embolization Target	Embolic Agent	30-day AE (SIR)	FU (mo)
1	Hyperemia and neovascularity of vesical arterial territory; vesical AVM at right inferior bladder wall with nidus formation, tortuous/dysplastic feeding arteries, and early venous return	Right SVA + Right IVA	300–500 µm microspheres + NBCA-Lipiodol	None	8
2	Right hemi-bladder/base hyperemia + neovascularity + dysplastic branches	Right SVA	300–500 µm microspheres	None	24
3	Upper contour extravasation + dysplastic branches	Bilateral SVA	NBCA-Lipiodol	None	1
4	Right-sided tumoral staining with neovascularity	Right SVA	400 µm microspheres	None	12
5	Base extravasation + dysplastic branches	Bilateral IVA	400 µm microspheres	None	7
6	Hyperemia + neovascularity + extensive dysplastic branches + extravasation	Bilateral SVA	100–300 µm microspheres + microcoil	None	6
7	Hyperemia + neovascularity + dysplastic/tortuous distal branches	Right SVA	100–300 µm microspheres + NBCA-Lipiodol	Mild AE (PES)	12
8	Dysplastic branching + hyperemia + neovascularity	Bilateral SVA	300–500 µm microspheres + microcoil + NBCA-Lipiodol	None	7
9	Diffuse hyperemia + neovascularity + late-phase extravasation	Bilateral SVA	NBCA-Lipiodol	None	1
10	Diffuse hyperemia + neovascularity + dysplastic branches + distal tortuous segments	Bilateral SVA	400 µm microspheres	None	24
11	Left vesical artery tumoral staining + neovascularity + extravasation	Left SVA	300–500 µm microspheres	None	4
12	Dome + trigone bilateral hyperemia + neovascularity + dysplastic branches	Bilateral SVA + Bilateral IVA	100–300 µm microspheres	None	3
13	Left SVA/IVA tumoral staining + neovascularity + extravasation	Left SVA + Left IVA	250 µm microspheres	None	5
14	Tumoral staining + neovascularity + dysplastic vessels	Bilateral SVA	NBCA-Lipiodol	None	8
15	Neovascularity + dysplastic + tortuous distal branches + intraluminal extravasation	Bilateral SVA	100–300 µm microspheres	None	12
16	Tumoral staining + neovascularity + extravasation	Bilateral SVA + Left IVA	100–300 µm microspheres	Mild AE (PES)	8

AE, adverse event; AVM, arteriovenous malformation; DSA, digital subtraction angiography; FU, follow-up; IVA, inferior vesical artery; mo, months; NBCA, n-butyl-2-cyanoacrylate; PES, post-embolization syndrome; SIR, Society of Interventional Radiology; SVA, superior vesical artery.

3.3. Clinical outcomes

Clinical success during the observed follow-up period was documented in all 16 patients (100%; exact 95% CI, 79.4–100). No rebleeding or rescue intervention was documented. However, only 11 patients remained under observation at 6 months, 5 at 12 months, and 2 at both 18 and 24 months; therefore, these findings describe early follow-up and do not establish long-term durability. The mean hemoglobin level increased from 8.38 ± 0.82 g/dL before embolization to 10.36 ± 0.92 g/dL after embolization ($p < 0.001$), corresponding to a mean Δ Hb of $+1.98 \pm 0.73$ g/dL (median, +1.92 g/dL; IQR, 1.58–2.13). Transfusion exposure before and around embolization was substantial and non-uniform (mean, 3.3 blood-product units per patient, including a mean of 2.7 packed red blood cell

units). Because the timing of transfusion relative to the first post-embolization hemoglobin measurement could not be standardized, the independent effect of embolization on the hemoglobin change could not be isolated in this single-arm cohort. The observed increase is therefore reported only as a supportive secondary marker rather than a direct estimate of the treatment effect.

Two patients (12.5%) developed mild post-embolization syndrome, one with transient low-grade fever and the other with nausea and fever that resolved with symptomatic therapy. No moderate-or-worse procedure-related AEs occurred within 30 days, and no procedure-related mortality or major ischemic sequelae were observed. The mean follow-up period was 8.9 months (median, 7.5 months; range, 1–24 months).

3.4. Exploratory subgroup analysis by etiology

Exploratory subgroup findings were broadly similar across etiologies. No rebleeding was documented in any etiologic subgroup during the available follow-up; however, the small subgroup sizes and transfusion-related confounding preclude comparative efficacy conclusions. In the malignancy group (n=7), the mean hemoglobin level increased from 8.34 ± 0.81 to 10.27 ± 0.91 g/dL ($\Delta\text{Hb} = +1.93 \pm 0.39$ g/dL; $p=0.016$). In the radiation-induced group (n=6), it increased from 8.21 ± 0.65 to 10.01 ± 0.56 g/dL ($\Delta\text{Hb} = +1.80 \pm 0.72$ g/dL; $p=0.031$). In the non-malignant subgroup (n=3), the mean increased from 8.80 ± 1.31 to 11.24 ± 1.25 g/dL ($\Delta\text{Hb} = +2.44 \pm 1.36$ g/dL); however, this subgroup was described without formal statistical testing because of the small sample size. Hematuria control during the observed follow-up period was documented in all subgroups, with no moderate-or-worse 30-day AEs or reinterventions (Table 3).

Table 3. Subgroup analysis of clinical characteristics, hemoglobin values, and outcomes according to etiology.

Parameter	Malignancy (n=7)	Radiation-induced HC (n=6)	Non-malignant bleeding (n=3)*	Overall (n=16)
Mean age (years)	69.3	66.5	66.3	67.7
Male/Female	6/1	4/2	3/0	13/3
Mean Hb pre $\pm$ SD (g/dL)	8.34 ± 0.81	8.21 ± 0.65	8.80 ± 1.31	8.38 ± 0.82
Mean Hb post $\pm$ SD (g/dL)	10.27 ± 0.91	10.01 ± 0.56	11.24 ± 1.25	10.36 ± 0.92
Mean $\Delta\text{Hb} \pm$ SD (g/dL)	$+1.93 \pm 0.39$	$+1.80 \pm 0.72$	$+2.44 \pm 1.36$	$+1.98 \pm 0.73$
p-value (Wilcoxon)	0.016	0.031	—†	<0.001
Mean total blood-product units	3.4	2.8	3.7	3.3
Mean packed red blood cell units	2.7	2.5	3.0	2.7
Bilateral embolization	4/7 (57%)	4/6 (67%)	2/3 (67%)	10/16 (63%)
Prior endoscopic failure	7/7 (100%)	6/6 (100%)	3/3 (100%)	16/16 (100%)
Hematuria control during observed follow-up	7/7 (100%)	6/6 (100%)	3/3 (100%)	16/16 (100%)
Moderate-or-worse 30-day AEs	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mild 30-day AEs (PES)	1/7 (14.3%)	1/6 (16.7%)	0/3 (0%)	2/16 (12.5%)
Reintervention	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mean follow-up (months)	7.9	11.8	5.3	8.9

AE, adverse event; HC, hemorrhagic cystitis; Hb, hemoglobin; ΔHb , change in hemoglobin; PES, post-embolization syndrome; SD, standard deviation. *The non-malignant subgroup included vesical AVM-associated bleeding (n=1) and infectious HC (n=2). †Statistical testing was not performed for the non-malignant subgroup because of small sample size. Mild AEs: Patient 7 (radiation-induced HC), low-grade fever; Patient 16 (malignancy), nausea and fever for 2 days. Blood-product units include packed red blood cell and fresh frozen plasma units.

4. Discussion

The main clinical message of the present study is that once continuous bladder irrigation and endoscopic hemostasis have failed, salvage microcatheter-based superselective vesical artery embolization can provide an encouraging short-term signal of bleeding control in a highly selected cohort with intractable hematuria. In our series, no patient required repeat embolization, urinary diversion, or palliative cystectomy during follow-up; hemoglobin increased during the index hospitalization,

although this secondary marker should be interpreted cautiously in the context of transfusion exposure; and adverse events were limited to two mild SIR AEs. However, these findings should be interpreted within the constraints of a retrospective single-center clinical series with a small sample size and heterogeneous follow-up. Accordingly, the apparent 100% technical and short-term clinical success rates should not be read as definitive evidence of long-term durability, especially in radiation-induced hemorrhagic cystitis, in which late rebleeding may occur after longer intervals of follow-up. In comparative context, Delgal et al.⁸ reported primary clinical success of 83.3% with late rebleeding in 28.6%, Tsitskari et al.¹¹ reported 85% clinical success at a mean follow-up of 35 months, Mohan et al.¹² reported complete cessation of hematuria within 48 hours in all nine patients treated for hemorrhagic cystitis, and Chen et al.¹⁵ in a pooled analysis of 201 patients, reported 99.0% technical success, 80.9% clinical success, 5.5% major complications, and first-month rebleeding in 4.5%.

All procedures in our series were performed at the level of the superselective vesical artery using the microcatheter technique. Earlier proximal embolization approaches had substantially higher ischemic complication rates, and the transition to superselective catheterization has been associated with improved safety and efficacy across multiple series.^{2,8,11,17} Prasad et al.¹⁷ described a coil-protection strategy for unfavorable anatomy. The rich collateral supply¹² also supports bilateral treatment when diffuse or bilateral feeders are observed. Bilateral embolization was performed in 10 of 16 patients (62.5%); however, our sample size was too small for an efficacy comparison. Comparative evidence regarding unilateral versus bilateral embolization remains limited,⁹ and our series was not powered to assess whether treatment laterality affects recurrence. Unilateral embolization may remain reasonable when angiography demonstrates a clearly lateralized bleeding source.^{8,11}

Different embolic agents were used in our series: calibrated microspheres, NBCA-Lipiodol, and microcoils, selected according to the angiographic findings and vascular anatomy of each case. No embolic material has been shown to be clearly superior to another, and existing studies are too small and heterogeneous to allow meaningful comparisons.^{2,9,15} Delgal et al.⁸ favored permanent particulate agents and calibrated microspheres; the pooled analysis by Chen et al.¹⁵ showed broad variability in agent selection; and Sahin et al.¹⁸ illustrated the pragmatic use of NBCA-Lipiodol after persistent bleeding following initial particle embolization. In this series, microspheres were generally used for diffuse hyperemic or neovascular lesions, NBCA-Lipiodol for active extravasation, and microcoils as adjuncts for proximal flow control.

Angiographic findings varied by etiology. Malignancy-associated cases were characterized by tumoral staining, neovascularity, and occasional active extravasation. Radiation-induced hemorrhagic cystitis showed diffuse hyperemia with dysplastic and tortuous distal vesical branches, whereas the non-malignant subgroup showed more focal abnormalities. The AVM-associated case demonstrated a focal nidus with tortuous feeding arteries and an early venous return. Loffroy et al.² noted that abnormal hypervascularity or a mass may be seen on angiography, whereas active extravasation is unusual. Tsitskari et al.¹¹ described diffuse neovascularity in patients undergoing superselective embolization, and Mohan et al.¹² reported hypervascularity and contrast blush without a discrete bleeding point in patients with hemorrhagic cystitis. Although exploratory, these etiology-specific patterns may help frame the selection of embolic agents and the anticipated extent of embolization.

Procedure-related AEs were infrequent in this study. Two patients (12.5%) developed mild post-embolization syndrome; no moderate-or-worse procedure-related AEs occurred within 30 days. No procedure-related mortality or major ischemic sequelae, including bladder necrosis or gluteal ischemia, were documented during this period. This profile is consistent with recent superselective series: Delgal et al.⁸ reported minor complications in 10% of patients, Mohan et al.¹² reported post-embolization syndrome in one of nine patients, and Kayali et al.¹⁹ reported post-embolization syndrome in 23% of patients without major complications. A pooled analysis by Chen et al.¹⁵ reported a 5.5% major complication rate. Serious ischemic events remain possible, however, particularly with less selective or more proximal techniques, as illustrated by Tsitskari et al.¹¹ and older literature summarized by Loffroy et al.² For this reason, we graded events according to the modified

SIR adverse event classification, which provides an interventional-radiology-specific severity framework and avoids the ambiguity of traditional major/minor complication language.¹⁶

When placed within the broader salvage treatment landscape, SVAE represents a less invasive alternative to more anesthesia-dependent options. Abt et al.⁵ summarized response rates of 71–100% for intravesical formalin, 50–100% for alum irrigation, 50–100% for hydrostatic bladder distention, and 75–100% for embolization. Formalin and hydrostatic distention generally require regional or general anesthesia and can be associated with clinically important toxicity.²⁰ Mihailidis and Davenport recently noted that, in United Kingdom practice, intravesical alum and formalin are no longer listed in the British National Formulary.⁶ Consistent with this, the National Institute for Health and Care Excellence (NICE) recommends considering hypofractionated radiotherapy or embolization for intractable bleeding caused by incurable bladder cancer.²¹ In a direct comparison between SVAE and intravesical formalin in bladder cancer, Sonmez et al.²² found higher first-session control with formalin but similar overall success after repeat therapy, with significantly fewer complications after SVAE. Consistent with the variable efficacy reported for intravesical agents, alum irrigation had failed to control bleeding in the subset of patients in whom it was attempted. Although these patients were by definition refractory and this observation is not a controlled comparison, it illustrates why escalation to embolization was required and supports the role of SVAE as a salvage step when selected intravesical measures fail or are not clinically feasible. These data support SVAE as a reasonable salvage option in frail or high-risk patients who are poor candidates for anesthesia or major surgery, even though standardized treatment pathways remain incompletely defined.^{6,20}

Exploratory descriptive findings were similar across the etiologic subgroups during the available short-term follow-up. The radiation subgroup deserves particular caution: Delgal et al.⁸ reported late rebleeding in all patients with radiation cystitis despite bilateral embolization, and contemporary review data emphasize that chronic radiation cystitis may evolve through progressive endarteritis, ischemia, neoangiogenesis, and fragile telangiectatic change years after pelvic radiotherapy.²⁰ No rebleeding occurred in our radiation subgroup, but follow-up in that group was limited (mean, 11.8 months; median, 9.5 months; range, 1–24 months), which is biologically insufficient to exclude late recurrence.²⁰ Because radiation-induced injury may recur beyond the first post-treatment year, substantially longer, multi-year follow-up is needed to assess durability.²⁰ The present subgroup findings should therefore be interpreted only as an early bleeding-control signal.

This study had several limitations. Its retrospective design, small sample size, and single-center setting limit its generalizability. The cohort was etiologically heterogeneous, and the non-malignant bladder bleeding subgroup was too small for formal statistical comparison. The follow-up duration was uneven across patients, and although clinical success was ascertained from index hospitalization data and subsequent institutional follow-up records, events managed entirely at outside hospitals could have been missed. Moreover, the mean follow-up of 8.9 months does not allow a full assessment of long-term durability and, in radiation-induced hemorrhagic cystitis, is biologically insufficient to exclude late recurrence. Most importantly, peri-procedural transfusion is a major confounding factor for hemoglobin analysis: post-embolization hemoglobin was analyzed only as a peri-hospitalization secondary marker, could not be separated from concurrent transfusion, and could not be attributed to embolization. Therefore, it must be interpreted in the context of substantial, non-uniform transfusion exposure before and around embolization and the limited granularity regarding transfusion timing relative to the first post-embolization measurement. Finally, the variety of embolic agents precluded meaningful comparisons between materials, and the absence of a control group limited comparisons with other salvage strategies.

5. Conclusion

In this retrospective single-center clinical series, salvage microcatheter-based superselective vesical artery embolization showed encouraging short-term bleeding control with a low 30-day adverse-event burden in this small, highly selected cohort with intractable hematuria refractory to conservative and endoscopic management. These findings are hypothesis-generating rather than

confirmatory, and the observed short-term success should not be interpreted as evidence of durable long-term efficacy, particularly in radiation-induced hemorrhagic cystitis. This procedure may help avoid more invasive rescue interventions, such as urinary diversion or palliative cystectomy, in selected patients. Distinct angiographic patterns were observed across the etiological groups; however, these findings remain exploratory. Larger prospective studies with standardized outcome definitions and longer-term follow-up are needed to clarify the long-term recurrence risk and to better define the role of SVAE within the clinical management pathway of intractable hematuria.

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Informed Consent Statement: Written informed consent for the embolization procedure was obtained from all participants. Retrospective data analysis was approved under the same institutional review board protocol.

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