Society of Interventional Radiology Quality Improvement Standards for Percutaneous Transcatheter Embolization

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ABBREVIATIONS

BPH = benign prostatic hyperplasia, DMSO = dimethyl sulfoxide, OA = osteoarthritis, PAE = prostatic artery embolization, QI = quality improvement, TURP = transurethral resection of the prostate

INTRODUCTION

Percutaneous embolization procedures are commonly performed by interventional radiologists. This quality improvement (QI) standard was first published in 2010 (1), and this document represents the second update. Since the 2010 standards, many additional randomized controlled trials, meta-analyses, and observational studies have been published on transcatheter embolization for various disease entities, further establishing embolization as an effective treatment. Additionally, the indications of embolization have expanded with newer procedures, like prostatic embolization for benign prostatic hyperplasia (BPH), and emerging procedures, such as left gastric artery embolization for the treatment of obesity and genicular artery embolization for the treatment of pain related to osteoarthritis (OA). This revised document includes a discussion on the performance of embolization procedures in pediatric patients, emphasizes the current literature, and builds upon previous documents to provide up-to-date information to ensure effective, safe, and high-quality care.

Percutaneous transcatheter embolization is a widely practiced method of therapeutic vascular occlusion, which has been successfully applied in virtually every vascular territory to arrest hemorrhage, occlude congenital and acquired vascular abnormalities, palliate neoplasms, reduce operative blood loss, and infarct tissue. With accumulated experience and improvement in the design of embolization agents and devices, embolization is the treatment of choice for many vascular abnormalities.

This document addresses the QI standards for embolization in the bronchial, celiac, superior and inferior mesenteric, renal, hypogastric, and prostatic arterial territories. Pulmonary artery embolization, portal vein embolization before an operation, and gonadal vein embolization are discussed as

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Appendices A–D can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

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well. Specific procedures that are not discussed include intracranial embolizations, hepatic artery embolization/chemoembolization for neoplasm, and embolization of gastroesophageal or splenorenal varices. Please refer to the other SIR QI standards on these topics for more information (2,3).

The current QI standard has been developed for use in evaluating the outcomes of percutaneous transcatheter embolization in clinical practice. It is intended to be used in QI programs to assess percutaneous embolization interventions in patients. The most important processes of care are (a) patient selection, (b) performing the procedure, (c) monitoring the patient, and (d) longitudinal management of the patient after the procedure. The outcome measures or indicators for these processes are indications, success rates, and complication rates. The outcome measures are assigned threshold levels. For full information about the SIR standards division and QI document methodology, please refer to **Appendix A** (available online on the article's Supplemental Material page at *www.jvir.org*).

Starting in August 2017, with periodic updates through December 2019, the workgroup members performed a PubMed search combining all the terms of Group A (percutaneous, transcatheter, embolization, artery, vein, incompetence, coil, particle, and glue) with those of Group B (bronchial, pulmonary, renal, internal iliac, external iliac, lumbar, gastroduodenal, left gastric, splenic, portal vein, gonadal vein, varicocele, pelvic, and prostate/proststic). The search yielded 122 citations that were English language publications from 1983 to 2019 and were classified as one of the following: prospective randomized controlled study; prospective, nonrandomized study; case series; retrospective study; and review article or meta-analysis. An updated search was conducted in May 2020, specifically searching for existing systematic reviews (with or without meta-analysis) or large population-based cohort studies ($N > 500$). These references are included in a graded evidence table (**Appendix B** [available online on the article's Supplemental Material page at *www.jvir.org*]) and were used to update the document. Data from included studies (**Appendix C** [available online on the article's Supplemental Material page at *www.jvir.org*]) were used to calculate appropriate QI thresholds for success and adverse events.

DEFINITIONS

Percutaneous transcatheter embolization is defined as the intravascular placement of a device or agent (solid or liquid) to produce an intentional vessel occlusion. Embolic vascular occlusion may be performed at any level, from large arteries or veins to capillary beds, and it may be temporary or permanent.

Percutaneous transcatheter embolization may be curative, temporizing, or palliative. Depending on the indication, the degree of embolization may require partial or complete occlusion of the vascular territory, resulting in varying degrees of reduction or cessation of the blood flow of a focal lesion or an entire target organ. The indications for embolization encompass a wide range of clinical situations, from the control of hemorrhage to tumor devascularization. Embolization may be a procedure in itself or a component of an intervention for a regional drug, gene, radiation, or other biologic therapies. Embolization may be performed as a staged procedure, particularly in cases of complex or multiple lesions.

Technical success is defined by the immediate angiographic result and is typically evaluated with completion angiography.

Clinical success reflects the measured results within 30 days of embolization and is typically assessed by clinical or imaging follow-up or both. Complete clinical success is defined as the resolution of signs or symptoms that prompted the embolization procedure.

Partial clinical success is defined as a significant improvement of the signs or symptoms after the procedure, with a positive impact on the clinical course of the patient or the subsequent need for reintervention (eg, minimal blood-tinged sputum after a successful embolization for massive hemoptysis) (4).

Palliative embolization is defined as an improvement in the symptoms after the procedure (eg, decreased transfusion requirements following embolization of a pelvic malignancy).

Target area is defined as the focal lesion, vessel, vascular territory, or organ to be devascularized or occluded.

Target ischemia is defined as the clinical effects, intended or not, resulting from devascularization within the immediate vascular distribution of the target (eg, the development of duodenal stenosis after gastroduodenal artery embolization for upper gastrointestinal bleeding) (5).

Nontarget embolization is defined as the unintentional deposition of embolic material separate from the target area (eg, colonic or spinal infarction during renal embolization) (6,7).

A variety of devices and agents are available for use in embolization procedures (**Table 1**). Understanding how a given agent will behave in vivo is critically important to the safety and effective performance of any embolization procedure. Different clinical scenarios can call for the occlusion of blood vessels from arteries (up to 1–2 cm in diameter) to capillaries (5–10 μm in diameter) (8). Therefore, the selection of an appropriate embolic material for each scenario and indication is of utmost importance to deliver effective treatment while also minimizing collateral injury to adjacent structures. For example, nonclumping, smaller particles (<700 microns) will result in a higher degree of tissue necrosis and should be used with caution and only when that is the goal. Smaller particles, such as those 100–300 micron or smaller in size, will yield a higher degree of necrosis than 300–500 micron particles, and larger particles will produce less necrosis (9). Gelfoam slurry or pledgets may be used as a temporary occlusion agent, such as with postpartum hemorrhage, where preservation of future fertility is desired, or in the setting of a hemorrhage related to trauma (10). It is important to note that many, if not all, of these options are also available in a pediatric setting. However, given the

Table 1. Embolization Devices and Agents

Embolization Devices

- Coils
- Stents
- Plugs
- Balloons

Particulate Agents

Noncalibrated particles
- *Permanent*
  - Nonspherical PVA particles
  - Spherical PVA
  - Acryl gelatin microspheres
- *Temporary*
  - Gelfoam

Calibrated Particles
- *Permanent*
  - TGMS

Liquids/Gels*

Sclerosing Agents
- Ethanol#
- Sodium tetradecyl sulfate^
- Polidocanol^

In Situ
- EVOH
- Thrombin+

Shear Thinning
- *N*-butyl-2-cyanoacrylate

EVOH = ethylene vinyl alcohol copolymer; PVA = polyvinyl alcohol; TGMS = trisacryl gelatin microspheres.
*FDA indications for the use of liquid and gel embolics may be limited. Off-label use has been reported as safe and effective in multiple studies, but they require advanced training and experience to be used safely.
#Although a sclerosant, ethanol can be used for embolization purposes.
^A true sclerosant that will not be administered intra-arterially.
+An enzyme and a physiologic agent that can be used to create an autologous clot for embolization purposes in addition to direct injection to promote in situ thrombosis of pseudoaneurysms.

tremendous range in the size and weight of children, it is extremely difficult to provide strict guidelines on the type of embolic agent that may be optimal, and it is suggested that pediatric embolization procedures be performed by operators with requisite experience.

Complications can be stratified on the basis of outcomes. *Major* complications result in admission to a hospital for therapy (for outpatient procedures), an unplanned increase in the level of care, prolonged hospitalization, permanent adverse sequelae, or death. *Minor* complications result in no sequelae; they may require nominal therapy or a short hospital stay for observation (generally overnight) (**Appendix D** [available online on the article's Supplemental Material page at *www.jvir.org*]) (11).

INDICATIONS

The indications for transarterial embolization can be grouped into several broad categories:

1. Occlusion of a congenital or acquired aneurysm, pseudoaneurysm, vascular malformation, or other vascular abnormalities that have a potential to cause adverse health effects (12–15).
2. Treatment of an acute or recurrent hemorrhage (eg, hemoptysis, gastrointestinal bleeding, posttraumatic and iatrogenic hemorrhage, and hemorrhagic neoplasms). This may include the placement of a covered stent to occlude the flow in a pathologic segment of a vessel or to slow the flow in a branch that is feeding the site of a hemorrhage or fistula (16–21).
3. Devascularization of benign tumors or malignancies for palliation (eg, reduce pain, slow tumor growth, or prevent hemorrhage) or to reduce operative blood loss. The common applications are vascular hepatic malignancies, renal angiomyolipoma, renal cell carcinoma, pelvic malignancies, and bone tumors (21–25).
4. Devascularization of benign or nonneoplastic tissue that produces adverse health effects in the patient (eg, hypersplenism, chemotherapy-induced thrombocytopenia, uterine fibroids, refractory renovascular hypertension, proteinuria in endstage kidney disease, varicocele, pelvic congestion syndrome, prostatic artery embolization, priapism, and ectopic pregnancy) (26–34).
5. Flow redistribution to protect normal tissue [eg, embolization of intrahepatic accessory vessels to allow for flow redistribution to the tumor and embolization during radioembolization (35)] or facilitate other subsequent treatments [eg, right portal vein embolization to induce left lobe hypertrophy prior to surgical resection (36)].
6. Endoleak management, including direct sac puncture or collateral vessel embolization, for type II endoleaks (37,38). There is evidence for the prophylactic prevention of type II endoleak with inferior mesenteric artery embolization before stent graft placement, as well as intraoperative aneurysm sac embolization during stent graft placement, which may decrease the need for reinterventions (39–41).
7. All of the above may be applicable in the pediatric setting.

OVERALL PROCEDURE THRESHOLD

An important part of QI for embolization should be the assessment of whether the procedures are performed for 1 of these indications. There are no published thresholds for

Table 2. Technical Success Rates (18,36,44–68)[#]

Location/Pathology	Reported Success Rates (%)	Suggested Threshold
Indication: Occlusion of congenital or acquired aneurysm, pseudoaneurysm, vascular malformation, or other vascular abnormalities[*]		
PAVM[@] (44,45)		
Technical success	92.4% (90.6%–100%)	83%
Clinical success[*]		
Indication: Treatment of acute or recurrent hemorrhage (eg, hemoptysis, gastrointestinal bleeding, posttraumatic and iatrogenic hemorrhage, and hemorrhagic neoplasms)		
GI – upper (46)		
Technical success	99.2% (95% CI 98.3%–100%)	98.3%
Clinical success	82.1% (95% CI 73%–88.6%)	75%
GI – lower (46)		
Technical success	97.8% (95% CI 96%–99.6%)	96%
Clinical success	86.1% (95% CI 79.9%–90.6%)	80%
Bronchial arteries (47,48)		
Technical success	92% (81%–100%)	85%
Clinical success	88% (82%–98.5%)	83%
Splenic[^] (49–51)		
Technical success	90.1% (72.7%–100%)	89%
Clinical success[%]	85.7% (84%–87.8%)	82%
Renal arteries[^] (56)		
Technical success	83.5% (65%–100%)	75%
Clinical success	87.3% (78%–100%)	80%
Hypogastric/lumbar[^] (18,57)		
Technical success	92.6% (91%–95%)	88.6%
Clinical success[*]		
Indication: Devascularization of benign tumors or malignancies for palliation (eg, reduce pain, slow tumor growth, or prevent hemorrhage) or to reduce operative blood loss		
Preoperative spine embolization (58)		
Technical success	68.3% (95% CI 60.0%–76.6%)	60%
Clinical success[*]		
Indication: Devascularization of nonneoplastic tissue that produces adverse health effects to the patient		
Splenic (hypersplenism) (52–55)		
Technical success	99% (99%–100%)	98%
Clinical success[$]	72% (58%–96.3%)	55%
Varicocele (59–62)		
Technical success	92% (84%–95.7%)	83%
Clinical success[*]		
Prostate (63)		
Technical success	94.2% (76.7%–100%)	80%
Clinical success	87% (76.3%–100%)	80%
Pelvic congestion syndrome (64)		
Technical success	99.8% (96.2%–100%)	95%
Clinical success	84% (68.3%–100%)	68%

continued

embolization indications. The threshold for these indications is suggested by the authors as 95%. When fewer than 95% of the procedures are for these indications, the department will review the process of patient selection. Of note, when performing embolization procedures in the pediatric setting, efforts should be made to apply similar threshold criteria, recognizing the lack of published data to support this in the pediatric population.

In addition to these on-indication thresholds, a process should be set up to review the appropriateness of individual procedure indications. For example, a splenic pseudoaneurysm is an accepted indication for embolization, but the embolization of a stable 1-cm fusiform splenic true aneurysm may not be an appropriate indication (42). Similarly, the embolization of a 6-cm renal angiomyolipoma that has hemorrhaged is appropriate, but the

Table 2. Technical Success Rates (18,36,44–68)[#] *(continued)*

Location/Pathology	Reported Success Rates (%)	Suggested Threshold
Indication: Flow redistribution to protect normal tissue or facilitate other subsequent treatments (eg, right portal vein embolization to induce left lobe hypertrophy prior to surgical resection)		
Portal vein (36,65,66)		
Technical success	99.3% (99.3%–100%)	98.5%
Clinical success	96.1%	90%
Indication: Endoleak management, including direct sac puncture or collateral vessel embolization, for type II endoleaks		
Endoleak type II (67,68)		
Technical success	84% (77.2%–89.8%)	80%
Clinical success	68.4% (61.2%–75.1%)	61%

CI = confidence interval; GI = gastrointestinal; PAVM = pulmonary arteriovenous malformation.
[#]Data are based on pooled rates from systematic reviews with meta-analyses. In cases where a systematic review was not available, individual study data were pooled to calculate weighted means and thresholds.
*Limited data available to calculate clinical success threshold.
[@]An exhaustive search was not performed for vascular malformations; therefore, the success rates for pulmonary arterial vascular malformations are being used as a surrogate to represent the success rates of vascular malformations in general.
[^]Data from trauma literature.
[$]Clinical success defined as an increase in platelet count.
[%]Surrogate outcome of spleen conservation used as clinical success definition.

treatment of a 2-cm asymptomatic angiomyolipoma may not be necessary (43).

NEW DEVELOPMENTS IN PERCUTANEOUS EMBOLIZATION

The future applications of embolization are discussed in the following section. The thresholds for success are provided in **Table 2** (18,36,44–68) for prostatic artery embolization; however, sufficient evidence is not yet available to calculate the thresholds for left gastric artery embolization and genicular artery embolization.

Prostatic Artery Embolization

Since the first case reports of the treatment of BPH with prostatic artery embolization (PAE) were published in 2010 (69), many single-arm observational studies and meta-analyses have established PAE as a safe and effective procedure (70–72). Several randomized controlled trials have also been published comparing PAE to transurethral resection of the prostate (TURP). Gao et al (73) found that all functional outcomes improved from baseline in both the groups, with a comparable degree of improvement in both the groups at 12 and 24 months; however, PAE resulted in significantly higher complication rates than TURP. Similarly, another trial found that a change in International Prostate Symptom Score from the baseline between the 2 groups was not significant (74). Carnivele et al (75), however, found that TURP was associated with not only better functional and urodynamic results than PAE but also higher rates of adverse events. The results of these trials are limited by low sample sizes and potential for a selection bias, thus highlighting the need for larger, well-conducted random controlled trials with longer follow-up. Multiple interventional radiology societies have endorsed PAE as an acceptable treatment option for moderate-to-severe lower urinary tract symptoms associated with BPH (76), although the current American Urological Association guidelines only recommend PAE in the setting of a clinical trial (77).

Left Gastric Artery Embolization

Preliminary results from several nonrandomized trials have been published regarding left gastric artery embolization for the reduction of appetite in the morbidly obese. Studies so far have involved small sample sizes with limited follow-up but have suggested that the procedure is safe, feasible, and may result in appetite suppression and resultant weight loss (78–80). Randomized trials with larger sample sizes and long-term follow-up are necessary.

Genicular Artery Embolization for the Treatment of Pain Related to OA

Genicular artery embolization for OA is thought to reduce inflammation secondary to periarticular tissue angiogenesis and sensory nerve growth, resulting in pain reduction (81). Several small-sized studies have suggested that genicular artery embolization is safe, feasible, and reduces pain secondary to OA, although these studies have used a variety of embolic agents, including calibrated spheres, particles, and antibiotics (81–83). Additional larger randomized studies are needed to assess the optimal type of embolic and long-term outcomes.

CLINICAL MANAGEMENT AND CARE AFTER THE PROCEDURE

Interventional radiologists must be actively involved in patient consultation and case selection. Close follow-up, with monitoring and management of the patient after the embolization procedure, is an integral component of the safe and effective practice of embolotherapy. Postembolization syndrome is an expected result of embolization in many

patients (and not necessarily an adverse event) and may manifest as pain, fever, malaise, and leukocytosis (84). The symptoms typically resolve within 24 hours of the intervention, although in rare cases, symptoms lasting up to 14 days have been reported (85,86). Clinical follow-up after the procedure is still important to assess for the resolution of the symptoms and patient benefit. For further information about antibiotic recommendations for specific embolization procedures, please refer to the SIR standards guidelines for adult and pediatric antibiotic prophylaxis during vascular and IR procedures published in 2018 (87).

Coagulopathy, sepsis, and renal insufficiency are relative contraindications to percutaneous transcatheter embolization. Appropriate efforts should be made to correct or improve these conditions prior to the procedure. Please refer to the SIR consensus guidelines for the periprocedural management of thrombotic and bleeding risk in patients undergoing percutaneous image-guided interventions for further information (88,89). Lack of safe or appropriate access to the target is another contraindication to treatment. A stable catheter position may not be achieved in a minority of patients. In other patients, vascular communication may exist between the target and an adjacent vital structure (eg, spinal arteries arising from bronchial or arteriovenous shunting to lungs when using particle embolization), which may preclude embolization. The visualization of a spinal artery arising from a vessel targeted for embolization has been viewed as an absolute contraindication for embolization by some authors and a relative contraindication by others (4,90–94).

PEDIATRIC CONSIDERATIONS

Unique challenges may occur when performing embolization procedures in children. Each pediatric patient must be evaluated with multiple factors in mind, including local expertise and comfort in performing the requested procedure, age and weight of the patient, comorbidities, availability and willingness of institutional anesthesia services to provide sedation or general anesthesia support, and acuity of the disease. Additionally, special attention should be paid to the selection and navigation of catheters and wires in small vessels, restrictions in fluid volume able to be administered, particularly when performing particle embolization in neonates and young infants, and unique considerations when performing embolization using liquid embolic agents. For example, during ethylene vinyl alcohol embolization, the toxicity of dimethyl sulfoxide (DMSO) solvent used during these procedures should be taken into account; vasospasm and endothelial necrosis may become issues with rapid injection, and if large doses are administered, acute respiratory distress syndrome and neurotoxicity may occur rarely. In the pediatric setting, although no formal recommendations have been made regarding the ceiling dose on DMSO, as a general rule of thumb, 1.5 mL of ethylene vinyl alcohol (ie, 1 vial) per 5 kg of patient body weight has been considered acceptable in cerebral studies. This translates to a dose of 200 mg of DMSO/kg (95,96). As a result, Onyx embolization has limited applicability in children under 5 kg. Similarly, embolization with "glue" agents (ie, *N*-butyl cyanoacrylate) should take into consideration the total dose of ethiodol oil administered, which should be limited to 0.25 mL/kg. Those performing embolization procedures in children should be aware of the relevant issues and considerations of performing angiography, especially total contrast dose administration during these often lengthy embolization procedures. A total dose of 6–8 mL/kg of an iodinated contrast is felt to be safe in pediatric patients weighing under 20 kg (97).

RADIATION MEASURES/METRICS/THRESHOLDS

Operators should attempt to minimize radiation exposure for each patient while preserving acceptable image quality by following the principle of "as low as reasonably achievable" (98). Follow-up programs should be established to monitor for radiation-induced injury if a patient has exceeded the recommended radiation dose threshold. All imaging facilities should have policies and procedures to reasonably attempt to identify pregnant patients prior to the performance of any examination involving ionizing radiation. If a patient is known to be pregnant, the potential radiation risk to the fetus and clinical benefits of the procedure should be considered before proceeding with the study (99). Similarly, "Image gently" protocols are well established in the pediatric setting and should be fully utilized in order to avoid unnecessary exposure to ionizing radiation during embolization procedures.

QUALITY IMPROVEMENT

While practicing physicians should strive to achieve perfect outcomes (eg, 100% success, 0% adverse events), all physicians will fall short of this ideal to a variable extent. Thus, indicator thresholds may be used to assess the efficacy of ongoing quality improvement programs. For the purpose of these guidelines, a threshold is a specific level of an indicator that should prompt an internal review. "Procedure thresholds" or "overall thresholds" reference a group of indicators for a procedure (eg, major adverse events). Individual adverse events may also be associated with adverse event-specific thresholds. When measures, such as indications or success rates, fall below a (minimum) threshold or when adverse events exceed a (maximum) threshold, a review should be performed to determine the causes and implement changes, if necessary. For example, if the incidence of nontarget embolization is a measure of the quality of percutaneous transcatheter embolization, then values in excess of the defined threshold should trigger a review of the policies and procedures within the department to determine the causes and implement changes to lower the incidence of the adverse event. The thresholds may vary from those listed here; for example, patient referral patterns and selection factors may dictate a different threshold value for an indicator at a particular institution. *Thus, setting universal thresholds is very difficult, and each department is urged*

Table 3. Adverse Events for Percutaneous Transcatheter Embolization by Location (5,16–18,32,36,39,44–47,55,57,59,62–68,71,92,100–105)[#]

	Reported Rates (%)	Suggested Threshold
Bronchial artery embolization (16,47,92,100–102)		
Spinal infarction	0.25% (0.1%–0.3%)	0.45%
Transient chest/back pain	16.6% (3%–33.7%)	42.0%
Dysphagia	2.2% (0.9%–3.5%)	4.8%
Postembolization syndrome	21% (1.7%–31%)	43.8%*
Pulmonary artery malformations (44,45)		
Air embolus	6.58%	10%
Pleurisy	10.5%	12%
Pulmonary infarction	1.32%	3%
Nontarget embolization	0.7%	2%
Re-embolization required	9.3%	12%
Renal arteries (105)		
Nontarget embolization	6%	10%
Hypogastric/lumbar (18,57)		
Mortality (not procedure-related)	21.6% (12%–22%)	27.6%
Femoral artery occlusion at access site	1.3%	2%
Increased serum creatinine	1.3%	2%
Endoleak type II (39,67,68)		
Procedure-related mortality	1.7% (0.9%–1.8%)	2.6%
Required secondary intervention	13.4% (0.9%–14.7%)	27.2%
Secondary rupture	1.5% (0%–1.8%)	3.3%
Aneurysm-related death	0.5% (0%–0.6%)	1.1%
Conversion to open repair	4% (1.4%–4.3%)	6.9%
Gastrointestinal (UGIB) (5,17,46)		
Nontarget embolization	0.65%	
Rebleeding	15.4% (29.6%–42.6%)	28.3%
Re-embolization required	11.3% (10%–16.2%)	17.5%
Bowel ischemia	0.4%	1%
Gastrointestinal (LGIB) (46)		
Bowel ischemia	2.9%	5%
Splenic (55,103,104)		
Abscess/sepsis (splenic injury)	1.4% (0.8%–2%)	2.3%
Re-bleeding	3.3% (1.6%–4.5%)	5.0%
Infarction (major)	1.5% (0%–3.8%)	5.3%
Portal vein embolization (36,65,66)		
Portal vein occlusion (main/left)	0.8% (0.5%–1.2%)	1.4%
Varicocele (59,62)		
Nontarget embolization	0.1% (0.03%–2%)	2.1%
Pelvic congestion syndrome (32,64)		
Nontarget embolization	2.6% (2.4%–4%)	4.2%
Vessel perforation	0.7%	2%
Prostatic artery embolization (63,71)		
Bladder wall ischemia	0.1% (0.08%–0.15%)	0.2%
Hematuria	5.1% (4.4%–5.5%)	6.2%
Rectal bleeding	3.9% (3%–4.5%)	5.4%
Urinary tract infection	0.1% (0.08%–0.15%)	0.2%
Acute urinary retention	5.8% (4.5%–7.8%)	9.1%

LGIB = lower gastrointestinal bleeding; UGIB = upper gastrointestinal bleeding.

[#]Data are based on pooled rates from systematic reviews with meta-analyses. In cases where a systematic review was not available, individual study data were pooled to calculate weighted means and thresholds.

*A Delphi vote achieved 78% consensus. Postembolization syndrome is considered a general complication of most embolization procedures, as discussed in the text, and therefore, difficult to qualify, given the lack of consistent reporting. The most detailed data describing this condition were found in the bronchial artery literature. Consensus was not achieved, given the heterogeneity and subjective nature of reporting on this adverse event. The threshold reported for bronchial artery embolization was thought to be at the higher end of spectrum, given the authors' experience. There is substantial variance in the severity of postembolization syndrome and consequently, in the need for ameliorative therapy.

to alter the thresholds as needed to higher or lower values to meet its own QI program needs. Furthermore, determining these thresholds in the pediatric population is even more challenging, primarily due to the relative lack of peer-reviewed publications on various areas in pediatric interventional radiology in which embolization is performed. Therefore, given the limited pediatric data, it is the consensus of the Guidelines and Statements Committee that the specific technical success rates [**Table 2** (18,36,44–68)] and specific adverse events for percutaneous transcatheter embolization [**Table 3** (5,16–18,32,36,39,44–47,55,57,59,62–68,71,92,100–105)] apply to both adult and pediatric populations. The technical success rates for percutaneous transcatheter embolization are listed in **Table 2** along with the recommended threshold values. Ranges and 95% confidence intervals are reported where available.

ADVERSE EVENTS

The published rates for the individual types of adverse events (**Appendix D**) (11) are highly dependent on patient selection and may be based on series comprising several 100 patients, which is a volume larger than most individual practitioners are likely to treat. Generally, the adverse event-specific thresholds should, therefore, be set higher than those of the adverse event-specific reported rates listed above. It is also recognized that a single adverse event can cause a rate to cross above an adverse event-specific

threshold when the adverse event occurs within a small patient volume (eg, early in a QI program). In this situation, the overall procedure threshold is more appropriate for use in a QI program. In **Table 3**, all the values were supported by the weight of literature evidence and panel consensus. An access site hematoma is considered a general complication for all embolization procedures, with a low complication rate, and is addressed in more detail in SIR's QI guidelines for vascular access and closure device use (106).

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APPENDIX A. SIR STANDARDS DIVISION PREAMBLE AND METHODOLOGY FOR QI STANDARDS

Preamble

The mission of the Society of Interventional Radiology (SIR) is to improve patient care through image guided therapy. The Society was founded in 1973, and is recognized today as the primary specialty society for physicians who provide minimally invasive image guided therapies. The Standards Division of the SIR provides evidence-based clinical practice documents to ensure patient safety and enhance the delivery of patient care. Standards Division members are leaders in the field of interventional radiology from both the private and academic sectors of medicine who dedicate the vast majority of their professional time to performing interventional procedures and as such, they represent a broad expert constituency of the subject matter under consideration for standards development. The Standards Division currently produces the following types of documents:

Clinical Practice Guidelines/Practice Parameters:

Statements that include recommendations intended to optimize patient care and assist physicians in clinical decision making. They are developed using a rigorous methodology involving a systematic review of the literature and assessment of the evidence.

Competence and Training Statements:

Statements that make recommendations on training and competencies required for a given clinical topic, procedure or therapy. Recommendations are supported by evidence when available and/or expert consensus.

Quality Improvement Standards:

Statements that combine the recommendations of clinical practice guidelines (where available) and performance measures to provide guidance on clinical quality improvement in IR practice.

Position Statements:

Statements that reflect the opinion of the SIR concerning areas of evolving clinical practice and/or technologies. Position statements are evidence-based whenever possible but since the scope usually involves a developing clinical practice or technology, the body of evidence may not be robust and an independent panel of experts, usually multidisciplinary, may be convened for document development.

Reporting Standards:

Statements that define a set of standardized data elements to be used in data collection efforts for describing processes and outcomes of interventional radiology procedures. The purpose of reporting standards is to facilitate professional agreement on common vocabulary/definitions and to permit comparison of data across studies or combination of data from studies for further analysis.

METHODOLOGY FOR QI STANDARDS

Topics for Standards document development are solicited through an annual survey that allows SIR members the opportunity to submit topics for consideration. The proposed QI topics are approved and prioritized by the Executive Council. A recognized expert or group of experts are identified to serve as the principal author or writing group for the document. Additional authors or societies may be sought to increase the scope, depth, and quality of the document dependent upon the magnitude of the project.

An in-depth literature search is performed using electronic medical literature databases, such as Medline (via PubMed) and The Cochrane Library. A critical review of peer-reviewed articles is performed with regards to the study methodology, results, and conclusions. All documents have adopted an updated methodology for evidence grading and assessment of strength of recommendation (Appendix A) [1, 2] in order to fulfill IOM standards for guidelines development. Accepted definitions of the hierarchical classification of evidence, commonly used by systems such as Oxford and GRADE, are included and an assessment of the strength of recommendation is defined to assist in clinical decision making [1, 2]. Similar classification systems are used by other specialty practice societies such as the ACC/AHA [3]. The level of evidence assessment will be used to create the evidence tables that inform the Standards documents. For documents that incorporate clinical recommendations, the strength of recommendation will be used to denote how well the recommendation is supported by systematic evidence. The qualitative weight of these articles is assembled into an evidence table, which is used to write the document such that it contains evidence-based data with respect to content, rates, and thresholds. Threshold values are determined by calculating the standard deviation of the weighted mean success and adverse events reported in all relevant trials with a sample size of approximately 50 patients or greater. Calculated threshold values represent two standard deviations above or below the mean for adverse event and success rates respectively.

When the evidence of literature is weak, conflicting, or contradictory, a modified Delphi technique may be utilized to enhance effective decision making [4, 5] and consensus for the threshold value is reached when 80% of panelists are in agreement. Reported adverse event-specific rates in some cases reflect the aggregate of adverse events of varying severities. Thresholds are derived from the National Benchmarks from the National Quality Registry for IR, when available, a critical evaluation of the literature, and evaluation of empirical data from the members of the Standards Division.

The draft document is critically reviewed by the writing group and members of the Standards Division, either by telephone conference calling or face-to-face meeting. Comments are discussed by the members of the Standards Division, and appropriate revisions made to create the final document prior to peer-review, approval by the SIR Operations Committee, and publication.

SIR standards documents are developed to improve quality of care for patients however, there are other ongoing national quality improvement efforts such as the Centers for Medicare & Medicaid Services (CMS) Quality Payment Program (https://qpp.cms.gov). Reportable measures for the CMS Quality Payment Program will change from year to year. To see if there are reportable measures that pertain to this QI standard, please refer to the current CMS measures. CMS measures and access tools to help with reporting of performance measures can be found through the American College of Radiology (ACR) at https://www.acr.org/Quality-Safety/National-Radiology-Data-Registry/Qualified-Clinical-Data-Registry and the SIR at https://www.sirweb.org/practice-resources/quality-improvement2/ir-quality-registry/. The IR Quality Registry permits the collection of performance measures for image-guided interventional procedures, and participating facilities and physicians will receive reports based on aggregated benchmarks to facilitate patient safety and quality improvement efforts. The IR registry also provides participants opportunities to fulfill CMS Physician Quality Reporting System reporting requirements, and gain maintenance of certification credit from the American Board of Radiology (ABR).

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APPENDIX B. SOCIETY OF INTERVENTIONAL RADIOLOGY QUALITY IMPROVEMENT STANDARDS FOR PERCUTANEOUS TRANSCATHETER EMBOLIZATION

Sean R. Dariushnia, et al.

Reference	Ref. type	N	Objective	Results and Comments	Strength
1. Angle, et al 2010	CPG	n/a	Previous QI document for embolization		n/a
2. Brown, et al 2012	CPG	n/a	Current QI document for TAE, chemoembolization		n/a
3. Dariushnia, et al 2016	CPG	n/a	Current QI document for TIPS		n/a
4. Lang 1992	retrospective	57	To evaluate success rates of embolization in bleeding duodenal ulcers	Terminal vessel embolization was more effective in attaining long-term control of bleeding (15 of 28 patients) than was gastroduodenal artery embolization (eight of 29) (P =.084). Occlusion of terminal vessels with 6-cyanoacrylate resulted in long-term control of bleeding in nine of 10 patients. With selective embolization of terminal vessels, late complications of duodenal stenosis occurred in seven of 28 patients; when occlusion was at the level of the gastroduodenal artery (P =.131), this developed in only two of 29.	D
5. Cox, et al 1992	Case series	2	Reported two cases of infarction of the left colon following ethanol oblation renal cell carcinoma	Hypothesized that the refluxed alcohol from kidneys flow directly into the inferior mesenteric artery, the first artery to rise from the anterior wall the order below the level of the renal arteries.	E
6. Gang, et al 1977	Case series	1	Reported case of spinal cord infarction after gelfoam embolization of renal arteries to reverse her dialysis cachexia	Hypothesized that the source of emboli was from reflux of the gelatin sponge. Patients with narrowed renal arteries and ostia may be at greater risk from tx renal embolization	E
7. Andrews, et al 2003	Animal study	10 pigs	To determine whether two commonly used embolic agents have differing rates of blood flow reduction during transcatheter embolization of the renal arteries in an animal model.	Renal arteries of pigs embolized with microspheres and PVA Tris-acryl gelatin microspheres reduced renal blood flow more quickly and reliably than did PVA.	E
8. Siskin, et al 2003	Animal study	11 pigs	To evaluate the effects of a spherical embolic agent consisting of polyvinyl alcohol (PVA)	Spherical, PVA-based embolization agent resulted in target organ infarction and temporary arterial occlusion. The	E

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
			and to compare this agent with commercially available embolization agents.	inflammatory response to PVA spheres was significantly less aggressive than the response to other agents tested	
9. Stampfl, et al 2008	Animal study	40 pigs	To evaluate the pattern of recanalization and specific inflammatory reaction after superselective embolization with four commercially available spherical embolic agents of different sizes in the mini pig kidney model	Evaluated embozene, embosphere, bead block, and contour SE paricles After embolization with Embozene microspheres, larger Embosphere particles, and Bead Block and Contour SE particles, the absence of inflammation or a low inflammation score was observed. Low inflamm changes in all; Recanalization more pronounced with Contour SE	E
10. Lewis, et al 2006	Comparative study	n/a	Describes the comparative performance of four commercially available microspherical embolisation products: Embosphere, Embogold, Contour SE and Bead Block	Contour significantly more compressible. All embolics reached equilibrium with contrast agent. Bead Block through Progreat catheter was best deliverable	n/a
11. Laurent, et al 1996	Technique	n/a	To develop a precisely calibrated, perfectly spherical, stainable, soft, and implantable but nonresorbable particulate embolization material.	The resulting embolization material consisted of spherical, stainable microspheres of medical grade with diameters ranging from 130 microns to 1200 microns.	n/a
12. Vaidya, et al 2008	Review	n/a	Gives a give a brief description of available embolic agents		n/a
13. Guirola, et al 2018	RCT	100	To compare safety and efficacy of vascular plugs (VPs) and fibered platinum coils (FPCs) for embolization in pelvic congestion syndrome (PCS).	Clinical success and subjective improvement were not significantly different at 1-year follow-up (89.7% for FPCs vs 90.6% for VPs; P =.760). Mean number of devices per case was 18.2 +/- 1.33 for FPCs and 4.1 +/- 0.31 for VPs (P <.001). Three FPCs and 1 VP migrated to pulmonary vasculature approximately 3-6 months after the embolization procedure.	B
14. Letourneau, et al 2010	Retrospective	35	To evaluate the safety and effectiveness of Amplatzer vascular plugs (AVPs) for percutaneous closure of arteries feeding pulmonary arteriovenous malformations (PAVMs).	Technical success was achieved in 35 feeding arteries (97%).	D
15. Pellerin, et al 2014	Prospective single-center	16	Reported use of microvascular plug (MVP) for occlusion of 1-3 mm vessels	MVP can be deployed with microcatheter into challenging anatomy. Stable occlusion seen in all placements	D
16. Huang, e al 2014	Retrospective	49	To assess the safety, efficacy, clinical outcomes, and prognostic factors associated with transcatheter arterial embolization (TAE) with N-butyl cyanoacrylate (NBCA) for nonvariceal upper gastrointestinal (GI) hemorrhage in hemodynamically unstable patients.	The technical and clinical success rates were 98% and 71%, respectively. incidence of rebleeding within 30 days was 39%	D

continued

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Reference	Ref. type	N	Objective	Results and Comments	Strength
17. Kim, et al 2017	Meta-analysis	440 patients	To evaluate the safety and efficacy of transcatheter arterial embolization with N-butyl cyanoacrylate (NBCA) for the treatment of gastrointestinal (GI) bleeding via a meta-analysis of published studies.	Technical success was achieved in 99.2% of patients with UGIB (259 of 261) and 97.8% of those with LGIB (175 of 179).	C
18. Krueger, et al 2005	Prospective single center	204	To prospectively evaluate ultrasonographically (US) guided percutaneous thrombin injection for treatment of femoral artery and brachial artery pseudoaneurysms.	Primary success 95.8% for simple PSA, 89% for complex PSA	C
19. Sheiman, et al 2001	Retrospective	54	To assess the clinical success of ultrasonography (US)-guided thrombin injection for the treatment of iatrogenic femoral pseudoaneurysms and to identify criteria that may predispose to treatment failure.	9 simple, 45 complex. 1000-1500 U thrombin used per PSA.	D
20. Valesano, et al 2017	Retrospective	39	To evaluate success and complication rates of percutaneous ultrasound-guided thrombin injection of nongroin pseudoaneurysms (PSAs).	Brachial a. most commonly treated; avg size was 2.4 cm Technical success 100:; treatment success 84.8%	D
21. Do, et al 2005	retrospective	40 pts 175 embolizations	To assess results and complications of EtOH for AVMs	Ethanol embolization was considered effective (cure, 16 patients; partial remission, 11 patients) in 27 patients (68%).	D
22. Vogelzang, et al 2014	retrospective	46	To evaluate the results of endovascular therapy of vascular malformations principally treated with ethanol embolization at a single center.	Twenty-four patients (52.2%) were considered cured, 12 (26.1%) showed improvement, and 10 (21.7%) had no change or showed worsening. Similar rates of cure or improvement were seen for AVMs and venous malformations ($P = 0.67$).	D
23. Takebayashi, et al 2009	retrospective	10	Evaluated the efficacy and side effects of transarterial ethanol ablation in sporadic and non-hemorrhaging angiomyolipomas (AMLs) in the kidney.	Nontarget occlusion did not occur by ethanol reflux in any cases but occurred causing spasms provoked by repeated inflation and deflation of the balloon in one case. Total occlusion of tumor vessels was observed in 7 patients and 92-95% occlusion in 3.	D
24. Maeda, et al 2013	Comparative study	8 pigs	To report on polyethylene glycol hydrogel-based resorbable embolization microspheres (REM) that were synthesized to resorb in < 24 hours	REM of 300-500 microm occluded more distal vessels than REM of 500-700 microm and 700-900 microm. REM of different sizes targeted different occlusion levels in kidney arteries. Gelfoam sponge provided an extended occlusion level without actual targeting.	E
25. Soyer, et al 2015	Review	n/a	Reports current indication for TAE in post-partum hemorrhage	Uterine atony represents up to 80 % of all causes of PPH TAE is successful in 90% of PPH	n/a
	CPG	n/a			n/a

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
26. Khalilzadeh, et al 2017			Proposed adverse events reporting system for SIR		
27. Patel, et al 2012	retrospective	50	To review a single-center experience with elective coil embolization of splenic artery aneurysm (SAA) and analyze efficacy of the technique at midterm follow-up.	98% treated with coils alone. 98% technical success	D
28. Xin, et al, 2011	retrospectve	12	to evaluate outcomes of the endovascular treatment of splenic artery aneurysms (SAAs) and pseudoaneurysms (SAPAs).	Endovascular procedures included embolization by sac packing (n = 5), sandwich occlusion of the splenic artery (n = 4) or stent graft deployment (n = 3) Technical success 100%	D
29. Kim et al, 2014	retrospective	20	To evaluate the technical feasibility and clinical outcome of bilateral uterine artery embolization (UAE) as a first-line therapeutic option for bleeding uterine arteriovenous malformation (AVM).	Used gelfoam and/or PVA. Technical success 90%, clinical success 89.5%	D
30. Rabkin, et al 1987	retrospective	306	A group of 306 patients with acute pulmonary hemorrhage were evaluated by means of bronchial arteriography and treated with transcatheter embolization.	Effective hemostasis was obtained initially in 278 patients (90.8%), including 87.5% of those treated during peak hemorrhage.	D
31. Hur, et al 2017	retrospective	152	To evaluate 30-day safety and efficacy of superselective embolization for arterial upper gastrointestinal bleeding (UGIB) using N-butyl cyanoacrylate (NBCA)	Technical success 100% Clinical success, 1-month mortality, and major complication rates were 70.4%, 22.4%, and 0.7%.	D
32. Velmahos, et al 2002	Prospective single-center	65	Safety and efficacy of AE for control of intraperitoneal and retroperitoneal bleeding.	AE was effective and safe in 95% and 94%, respectively, of 80 patients who were embolized.	C
33. Loffroy, et al, 2008	Retrospective	12	To evaluate the outcomes after transcatheter embolization of percutaneous biopsy-related arteriovenous fistulas in renal allografts.	Superselective, used 35 or 18 coils Technical success 100%	D
34. Haochen, 2019	Retrospective	43	to determine if superselective renal artery embolization is a safe and effective method of treating bleeding complications after percutaneous renal biopsy.	Successful embolization in all patients. Microcoil or microcoil + gelfoam	D
35. Moris, et al 2018	Sys rev	67 studies 4941 patients	Reviewed management of studies reporting ruptured HCC with regard to short-term and long-term outcomes	Overall aggregate in-hospital, 1- and 6-month survival were 57.0%, 66.9%, and 53.6%, respectively. patients treated with TACE or TAE, reported in-hospital and 1-month survival ranged from 30.3% to 66.7% and from 44.4% to 87.5%, respectively.	C
36. Bakal, et al, 1993	retrospective	93	Evaluated effectiveness of preoperative etoh renal artery embolization in reducing transfusion requirements for rcc	79% of embolizations were angiographically eomplete Complete RAE was associated with significantly decreased transfusion requirements	**D**

continued

Sean R. Dariushnia, et al *(continued)*

Reference	Ref. type	N	Objective	Results and Comments	Strength
37. He, et al 2017	Sys Rev	9 studies 44 patients	To review effects of arterial embolization for unresectable/recurrent pelvic/sacral GCT	radiographic response rate was 81.8%, with a local control and overall survival rate of 75% and 81.8%, respectively.	C
38. Yamashita, et al 1994	Retrospective	32	To report efficacy of OB/GYN bleeding related to post-partum hemorrhage and neoplasms	Postpartum hemorrhage, n=15 Malignant neoplasms, n=17 All controlled	D
39. Hocquelet, et al 2014	retrospective	39	To evaluate the efficacy of selective arterial embolization (SAE) of angiomyolipomas	92% primary technical success	D
40. He, et al 2012	Prospective single center	61	To evaluate whether total splenic artery embolization (TSAE) for patients with hypersplenism delivers better long-term outcomes than partial splenic embolization (PSE	Better post procedure WBC and PLT in Total Splenic embo vs. partial	C
41. Bhatia, et al 2015	Retrospective	13	To determine if proximal splenic artery embolization (PSAE) provides a safe and effective alternative to alleviate chemotherapy-induced thrombocytopenia (CIT), allowing patients with cancer to resume chemotherapy regimens.	Post proximal splenic embo platelet count improved significantly and all patients became eligible to resume chemotherapy	D
42. De Bruijn, et al 2016	RCT	177 81 UAE 75 hysterectomy	10 year follow up to compare clnical outcome and QOL after UAE and hysterectomy	84% response at 10 years Of total UFE 28/81 went on to hysterectomy QOL remained stable among hysterectomy vs UAE	B
43. Mao, et al 2009	RCT	16 Unilateral embo 8 Bilateral embo 8	evaluated the efficacy and safety of unilateral renal embolization (URE) for the treatment of severe refractory hypertension in hemodialysis patients.	Unilateral embo was as effective as bilateral embo in treating severe refractory HTN in HD patients	B
44. Solak, et al 2016	retrospective	8	evaluated role of RAE in the setting of severe symptomatic nephrotic syndrome	7/8 bilateral. All saw significant improvement of serum albumin and c reactive protein	D
45. Vanlangenhove, et al 2012	RCT	83	comparative study of the efficacy and safety of two different n-butyl-2-cyanoacrylates (NBCAs) for embolization of varicoceles.	Tech success NBCA 54/54, NBCA-MS 54/57. No glue related complications	B
46. Chick, et al 2018	retrospective	20	To report long term outcomes of selective arterial embolization for nonischemic priapism on erectile function utilizing validated outcome questionnaires after selective arterial embolization.	After selective arterial embolization, nonischemic priapism resolved in 18 (90%) patients. No patients with successful treatment of their nonischemic priapism developed a recurrence of nonischemic priapism during the study period following the initial treatment.	D
47. Gao, et al, 2018	RCT	100	To compare the efficiency and safety of uterine artery embolization (UAE) combined with local infusion of methotrexate (MTX) or MTX and 5-fluorouracil (5-FU) in the treatment of ectopic pregnancy (EP).	Technically successful in 100% Clinical success in 88% Time to successful B-HCG resolution was 26.74 UAE and MTX showed comparable efficiency to AUE combined with MTX + 5FU	B
48. Spreafico, et al 2015	retrospective		to demonstrate that tumors can be treated via one main feeding artery achieving flow	Compared to those patients who did not undergo coil embolization dosimetric and	D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
		90 patients without 17 patients with 19 lesions	redistribution by embolizing accessory vessels.	toxicity were comparable to those who were coil embolized Confirmed that intratumoral flow redistribution after accessory artery embolization was possible to treat tumor through single main feeding artery	
49. Yamashita, et al 2017	Prospective single center	319	To report outcomes of PVE among diseases, including hepatocellular carcinoma (HCC), biliary tract cancer (BTC), and colorectal liver metastases (CLM	degree of hypertrophy did not significantly differ by cancer types (median 10, 9.6, and 10%, respectively). 256/319) of patients completed subsequent hepatectomy after a median waiting interval of 24 days (range 5-90). 10% did not have adequate hypertrophy for resection. dropout after PVE was more common in BTC or CLM (odds ratio 2.75, p = 0.018), mainly because of disease progression.	C
50. Kasirajan, et al 2003	retrospective	104 8 Type 2	To describe the technique of transfemoral superselective coil embolization of type II endoleak and its influence on abdominal aortic aneurysm diameter.	In 6 of 8 patients superselective coil embolization embolization resulted in a mean decrease in aneurysm diameter of 1.3 +/- 1.2 cm over 9 +/- 3.2 months.	D
51. Lagios, et al 2018	Retrospective	25	To evaluate long-term efficacy of translumbar embolization of type II endoleaks exclusively supplied by the lumbar arteries in patients with growing abdominal aortic aneurysm sacs using N-butyl cyanoacrylate (NBCA) instilled via percutaneous needle access.	Translumbar embolization was achieved in all 25 patients. The endoleak resolved in 22 patients (88%) on duplex US performed 1 day after the embolization procedure.	D
52. Ward, et al 2013	retrospective	51	To review the effect of preoperative embolization of the inferior mesenteric artery (IMA) before endovascular aneurysm repair (EVAR) on subsequent endoleaks and aneurysm growth.	The incidence of secondary intervention for type II endoleak embolization was also significantly higher in those who did not undergo embolization (7.6% [12 of 158] vs 0.9% [one of 108]; P 1⁄4.013). At 24 months, an increase in aneurysm sac volume was observed in 47% of patients in the nonembolized cohort (21 of 45), compared with 26% of patients in the embolized cohort (13 of 51; P 1⁄4.03).	D
53. Piazza, et al 2016	RCT	55 EVAR 52 EVAR + sac embo	to evaluate outcomes of intraoperative aneurysm sac embolization during endovascular aneurysm repair (EVAR) in patients considered at risk for type II endoleak (EII), using a sac volume-dependent dose of fibrin glue and coils.	Patients in group B showed a significantly overall mean difference in aneurysm sac volume shrinkage compared with group A at 6 months (-11 +/- 17 cm(3) vs -2 +/- 14 cm(3); P <.01), 12 months (-18 +/- 26 cm(3) vs -3 +/- 32 cm(3); P =.02), and 24 months (-27 +/- 25 cm(3) vs -5 +/- 26 cm(3); P <.01).	B
54. Nevala, et al, 2010	retrospective	40	To evaluate the value of preoperative embolization of the inferior	Fewer endoleaks in the IMA embo group but failed to show any influence on late postoperative shrinkage	D

continued

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Reference	Ref. type	N	Objective	Results and Comments	Strength
			mesenteric artery (IMA) before endovascular repair of an abdominal aortic aneurysm.		
55. Carnevale, et al 2010	Case series		preliminary results for two patients with acute urinary retention due to BPH, successfully treated by prostate artery embolization (PAE)	At 6-month follow-up, US and MRI revealed a prostate reduction of 39.7% and 47.8%, respectively, for the bilateral PAE and 25.5 and 27.8%, respectively, for the patient submitted to unilateral PAE.	E
56. Shim, et al 2017	Systematic review	16 studies 297 patients	To determine overall treatment efficacy and safety of PAE compared to standard therapy	Overall weighted mean differences for all outcomes except prostate specific antigen were significantly improved from baseline by embolization treatment in noncomparative studies.	D
57. Uflacker, et al 2016	Meta-analysis	19 studies/268 6 included	Meta-analysis on available date on PAE	At 12 months, PV decreased by 31.31 cm(3) (P <.001), PSA remained unchanged (P =.248), PVR decreased by 85.54 mL (P <.001), Qmax increased by 5.39 mL/s (P <.001), IPSS improved by 20.39 points (P <.001), QOL score improved by -2.49 points (P <.001), and IIEF was unchanged (P = 1.0). PAE improved Qmax, PVR, IPSS, and QOL significantly with low incidence of adverse events	C
58. Salem, et al 2018	Prospective, single center	45	To evaluate safety and efficacy of PAE for LUTS	At 1 month, there were improvements in IPSS (23.6 +/- 6.1 to 12.0 +/- 5.9, P <.0001), QoL (4.8 +/- 0.9 to 2.6 +/- 1.6, P <.0001), Qmax (5.8 +/- 1.0 to 12.4 +/- 6.8,P <.0001). At 3 months, there were improvements in IPSS (10.2 +/- 6.0, P <.0001), QoL (2.4 +/- 1.6, P <.0001) and Qmax (15.3 +/- 12.3, P <.0001). At 6 months, there were improvements in IPSS (11.0 +/- 7.6, P <.0001) and QoL (2.3 +/- 1.7, P <.0001). At 1 year, there were improvements in IPSS (12.4 +/- 8.4,P <.0001) and QoL (2.6 +/- 1.6, P <.0001). There were reductions in postvoid volume residues: baseline 157 +/- 45, 1 month 123 +/- 47, P=.057, 3 months 127 +/- 114, P=.34, 6 months 112+/-116, P=.002 and 1 year 109+/-116 P=.025. Median decreases in TV and CG were 18% (CI: 13-27) (P=0.0001)	C

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
				and 27% (CI: 20-36)(P=0.0001), respectively. Self-limited adverse events included dysuria (n=13), hematuria (n=6), hematospermia (n=2), urinary frequency (n=3) and retention (n=2). No severe adverse events, nontarget embolization, or adverse effects on erectile function or sexual health.	
59. de Assis, et al 2015	Prospective single center	35	To describe the safety and efficacy of prostatic artery embolization (PAE) with spherical microparticles to treat lower urinary tract symptoms associated with benign prostatic hyperplasia in patients with prostate volume > 90 g.	Mean prostate size decreased significantly from 135.1 g before PAE to 91.9 g at 3 months of follow-up (P <.0001). Mean IPSS and quality-of-life index improved from 18.3 to 2.7 and 4.8 to 0.9 (P <.0001 for both), respectively. A significant negative correlation was observed between prostate-specific antigen at 24 hours after PAE and IPSS 3 months after PAE (P =.0057).	C
60. Gao, et al 2014	RCT	57 TURP 57 PAE	Compared PAE to TURP including technical success, clinical success	TURP had greater improvement immediately IPSS, QOL, Qmax. PAE had more adverse events and treatment failures. Both showed clinical improvements at all follow up time points and PAE, and degree of PAE clinical improvement approached that of TURP at 6, 12 and 24 months. Clinical success PAE was 90.6% at 2 years	B
61. Carnevale, et al 2016	RCT	45 15 TURP 15 oPAE 15 PERFECTED	To compare clinical and urodynamic results of transurethral resection of the prostate (TURP) to original and PErFecTED prostate artery embolization (PAE) methods for benign prostatic hyperplasia.	Technical success: TURP; bilateral embolization oPAE 86.7%, PERFECTED 100% Clinical success PAE was 93% at 12 months	B
62. Abt et al, 2018	RCT	48 PAE 51 TURP	To compare prostatic artery embolisation (PAE) with transurethral resection of the prostate (TURP) in the treatment of lower urinary tract symptoms secondary to benign prostatic hyperplasia in terms of patient reported and functional outcomes.	Mean reduction in IPSS from baseline to 12 weeks was -9.23 points after PAE and -10.77 points after TURP. Although the difference was less than 3 points (1.54 points in favour of TURP (95% confidence interval -1.45 to 4.52)), non-inferiority of PAE could not be shown (P=0.17).	B
63. Pisco, et al 2019	RCT	80 40 PAE 40 sham; sham went on to PAE	To assess safety and efficacy of PAE compared with a sham procedure	Superior efficacy of PAE compared to sham procedure	B
64. McWilliams, et al 2019	Position statement	n/a	Multisociety IR position statement on PAE for BPH		n/a
65. Foster, et al 2019	CPG	N/A	AUA evidence-based surgical management of LUTS/BPH.	Guideline statement 22: PAE 22. PAE is not recommended for the treatment	n/a

continued

Sean R. Dariushnia, et al. *(continued)*

Reference	Ref. type	N	Objective	Results and Comments	Strength
				of LUTS attributed to BPH outside the context of a clinical trial. (Expert Opinion)	
66. Pisco, et al 2016	Retrospective	630	To confirm that prostatic artery embolization (PAE) has a positive medium- and long-term effect in symptomatic benign prostatic hyperplasia (BPH).	PAE had a positive effect on IPSS, QOL, and all objective outcomes in symptomatic BPH. The medium- (1-3 y) and long-term (> 3-6.5 y) clinical success rates were 81.9% and 76.3%, with no urinary incontinence or sexual dysfunction reported.	C
67. Syed, et al 2016	Prospective multi center	4	To report 6-month safety and efficacy results of a pilot study of left gastric artery (LGA) embolization for the treatment of morbid obesity	Average excess body weight loss at 6 months was -17.2% (range, -4.2% to -38.5%). Patient 4, who had diabetes, showed an improvement in hemoglobin A1c level (7.4% to 6.3%) at 6 months. QOL measures showed a general trend toward improvement, with the average physical component score improving by 9.5 points (range, 3.2-17.2) and mental component score improving by 9.6 points	D
68. Weiss, et al 2017	Prospective single center	5	to evaluate the feasibility, safety, and short-term efficacy of bariatric embolization, a recently developed endovascular procedure for the treatment of obesity,	Mean excess weight loss of 5.9% ± 2.4 and 9.0% ± 4.1 was noted at 1 month and at 3 months, respectively. Mean change in serum ghrelin was 8.7% ± 34.7 and −17.5% ± 29 at 1 month and 3 months, respectively. Mean changes in serum glucagon-like peptide 1 and peptide YY were 106.6% ± 208.5 and 17.8% ± 54.8 at 1 month. There was a trend toward improvement in QOL parameters.	D
69. Bai, et al 2018	Prospective single center	5	To investigate the safety and 9-month effectiveness of transcatheter left gastric artery embolization (LGAE) for treating patients with obesity.	The level of serum ghrelin decreased by 40.83% ($p = 0.009$), 31.94% ($p = 0.107$), and 24.82% ($p = 0.151$) at 3, 6, and 9 months after LGAE, respectively. There was minimal reduction of leptin levels at 3 and 6 months following LGAE (decreased by 0.26%, $p = 0.929$, and 4.33%, $p = 0.427$, respectively), but it declined obviously 9 months after LGAE (decreased by 11.22%, $p = 0.295$). Both waist circumference and waist-to-height ratio decreased after LGAE.	D
70. Okuno, et al 2017	Prospective single center	72 patients	To describe the safety and efficacy of transcatheter arterial embolization for mild to moderate radiographic knee osteoarthritis (OA) that is resistant to conservative treatment.	Osteoarthritis Index pain scores significantly decreased from baseline to 1, 4, 6, 12, and 24 months after treatment (12.1 vs 6.2, 4.4, 3.7, 3.0, and 2.6; all $P < .001$). The cumulative clinical success rates at 6 months and 3 years after embolization were 86.3% (95%	D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
				confidence interval [CI], 78%-92%) and 79.8% (95% CI, 69%-87%), respectively. WORMS scores at 2 years after embolization in 35 knees showed significant improvement of synovitis vs baseline (P =.0016) and no osteonecrosis or other evidence indicating aggressive progression of degenerative changes.	
71. Lee, et al 2019	Retrospective	41	To compare the clinical outcomes of transcatheter arterial embolisation for chronic knee pain in patients with mild-to-moderate versus severe knee osteoarthritis.	Used imipenem/cilastatin for embolic The mean visual analogue scale scores in the mild-to-moderate osteoarthritis group were significantly decreased at 1 day, 1 week, 1 month, 3 months, and 6-months (5.5 at baseline vs. 3.2, 3.1, 2.9, 2.2, and 1.9, after treatment; all P =.00). These improvements were maintained at a mean of 10 +/- 3 months (range 6-19 months) post-treatment. The visual analogue scale scores were significantly decreased in the severe osteoarthritis group for 1 month post-treatment (6.3 at baseline vs. 4.1, 4.1, and 4.4 at 1 day, 1 week, and 1 month; all P <.01).	**D**
72. Bagla, et al 2019	retrospective	20	To evaluate the efficacy and safety of embolization of hyperemic synovial tissue for the treatment of knee pain secondary to osteoarthritis (OA).	Used sPVA Embolization of at least 1 genicular artery was achieved in 20/20 (100%) patients. Mean VAS improved from 76 mm +/- 14 at baseline to 29 mm +/- 27 at 6-month follow-up (P <.01). Mean WOMAC score improved from 61 +/- 12 at baseline to 29 +/- 27 at 6-month follow-up (P <.01). Self-limiting skin discoloration occurred in 13/20 (65%) patients. Two of 20 (10%) patients developed plantar sensory paresthesia that resolved within 14 days.	D
73. Ganguli, et al 2008	Retrospective	78	To review the management postembolization syndrome and the management of leukocytosis after UFR	Increase in white blood cell (WBC) counts within 24 hours after the procedure in 86% of patients, with clinically defined leukocytosis (WBC count >11,000/microL) present in 21% of patients. Interventional radiologists and other clinicians involved in the care of these patients should expect such changes and not be alarmed regarding early infectious complications.	**D**

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Reference	Ref. type	N	Objective	Results and Comments	Strength
74. Blackburn, et al 2016	Sys Review	15 studies	To identify effective management strategies for PES or one of its characterizing symptoms (fever, pain, and nausea and/or vomiting).	A number of interventions have shown potential benefit in the management of PES. A systemic approach using combination therapy is necessary to effectively manage characterizing symptoms. Further research is needed to determine the impact of primary disease site, TACE technique, and chemotherapeutic agent on PES.	**D**
75. Yinglu, et al 2009	RCT	120	To seek for a systematic approach to prevent and treat the syndrome, we carried out this study to observe the effect of ginsenosides (GS) and dexamethasone (Dex) in alleviating the postembolization syndrome following TACE.	Dex combined with GS not only markedly decreased the occurrence ratio and duration of such symptoms as nausea, vomiting, and fever, but also significantly reduced levels of total bilirubin, glutamic oxaloacetic transaminase, and glutamic-pyruvic transaminase (AST) and improved the Child-Pugh stage of liver function as compared with single use of GS or Dex.	**C**
76. Chehab, et al 2018	CPG	n/a	SIR practice parameter on antibiotic prophylaxis		n/a
77. Yamamoto, et al 2008	Retrospective	16	to evaluate clinical results and technical problems of transcatheter coil embolization for splenic artery aneurysm.	Overall, the primary technical success rate was 88% (14 of 16 patients). In the remaining 2 patients (12.5%), partial recanalization occurred, and re-embolization was performed. The secondary technical success rate was 100%. Seven (44%) of the 16 study patients suffered partial splenic infarction.	D
78. Oesterling, et al 1986	retrospective	602	Developed a systematic management scheme for renal AML	253 lesions $<$ 4 cm; 178 lesion $>$ 4 cm 2 cm or less sized lesion low risk for hemorrhage	D
79. Davidson, et al 2019	CPG	n/a	SIR guidelines on review of AC agents		n/a
80. Patel, et al 2019	CPG	n/a	SIR Guidelines on recommendations for AC periprocedural management		n/a
81. Hayakawa, et al 1992	retrospective	63	to evaluate the immediate and long-term results in 63 patients who underwent transarterial embolization for control of hemoptysis.	Overall immediate success rate was 86.1%. Visualization of anterior spinal artery was a contraindication to embolization	D
82. Ivanick, et al 1983	Case report	1	Reported major complication of bronchial artery embolization with alcohol	Authors reported unstable catheter position and they thought particle embo would be dangerous. Used alcohol instead. Not aware of risk of bronchial necrosis	E
83. Miller, et al 1983	Review	n/a	Reivews major complications of embolization procedures	Describes complications in thorax, abdomen, pelvis, retroperitoneum	n/a
	Retrospective	104			D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
84. Remy, et al 1977			Reported treatment of hemoptysis with bronchial embolization	Technical success 84% Anterior spinal artery was AC	
85. Uflacker, et al 1983	Retrospective	33	Reported experience of bronchial aa. Embolization in massive hemoptysis	Technical success 100%; Clinical success 82% Presence of spinal artery was not considered a contraindication—in these cases larger gelfoam pledgets were used	D
86. Uflacker, et al 1985	Retrospective	64	Reported long-term results of BAE for hemoptysis	Immediate control successful in 77%; long-term control 82% Anterior spinal artery not visualized	D
87. Thiex, et al 2010	Retrospective	15 patients 36 embolizations	presents experience with Onyx in the treatment of CNS AV lesions in pediatric patients.	Embolization was complete in 2 patients, nearly complete in 9 patients, and partial (and ongoing) in 4 patients. Following staged embolization, 7 patients underwent surgical resection without significant blood loss and with good functional outcome in all cases. Clinically silent non-target embolization was encountered in 2 of 36 procedures. After 3 of the 36 embolizations, patients developed transient neurologic symptoms, all of which resolved to baseline within 24 hours. There were no non-neurologic adverse events. There was no imaging evidence of infarct or hemorrhage.	D
88. Saeed Kilani, et al 2015	Review	n/a	Reviews advantages of Onyx and to identify its main indications		E
89. Heran, et al 2010	CPG	n/a	Current QI guidelines for pediatric arterial access and arteriography		n/a
90. Swan, et al 2016	ACR practice parameter	n/a	Current ACR-SIR-SPR practice parameter for informed consent for image guided procedure		n/a
91. White, et al 1988	Retrospective	276	Describes experience and techniques for tx of PAVM	After embolotherapy, symptomatic hypoxemia was corrected, and serial values have remained constant for 5 years. Complications were minimal, and no patient required surgery. Balloon embolotherapy is effective long-term therapy for PAVMs, and family screening should be pursued because of the possibility of a higher frequency of paradoxical embolization (stroke) than previously recognized.	D
92. Tau, et al 2016	retrospective	16 110 AVMs	reports the experience of a referral medical center with the use of coils and Amplatzer plugs for treating PAVMs in patients with hereditary hemorrhagic telangiectasia.	16 patients met the study criteria. Imaging scans were available for 63 of the total 110 PAVMs treated in 41 procedures. Coils were used for embolization in 37 PAVMs, Amplatzer plugs in 21, and both in five. Median follow-up time was 7.7 years (range 1.4-18.9). Re-canalization	D

continued

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Reference	Ref. type	N	Objective	Results and Comments	Strength
				was detected in seven vessels, all treated with coils; there were no cases of re-canalization in plug-occluded vessels	
93. Mohsen, et al 2008	Retrospective	81	To assess the long-term morphological and functional outcome of superselective transarterial embolization (TAE) for treating traumatic renal vascular injury	Technical success 88%	**D**
94. Sam, et al 2008	Retrospective	50	To evaluate safety and efficacy of renal artery embo in iatrogenic injuries	Technical success 48/50	**D**
95. Zeng, et al 2013	Systematic review	17619 reviewed 117	Reported risk factors for failed superselective renal artery embolization after nephrolithotomy hemorrhage	Technical success in 90%	**C**
96. Matalon, et al 1979	prospective	28	To determine angio effectiveness in identifying bleeding sites and controlling massive hemorrhage in pelvic fractures	Angio and embolization reduces hemorrhage and facilitate patient management	C
97. Velmahos, et al 2000	Retrospective	137 patients 97 were pelvic fractures	To report technical and clinical outcomes of TAE for traumatic bleeding in abdomen and pelvis	Angiographic control of bleeding in 91%	D
98. Hagiwara, et al 2004	Prospective single-center	269 19	to determine whether nonsurgical management using transcatheter arterial embolization (TAE) is safe for patients with blunt multiple trauma who transiently respond to the initial fluid resuscitation	For all these patients, TAE was successfully performed. Before TAE, the systolic blood pressure was 79.9 +/- 8.4 mm Hg, and the shock index was 1.45 +/- 0.25 mm Hg. After TAE, the corresponding values were 120.6 +/- 19.3 mm Hg and 0.87 +/- 0.16 mm Hg, respectively ($p < 0.001$). The rate of fluid administration required after TAE (214.2 +/- 139.3 mL/hour) was significantly less than that required before TAE (1244.2 +/- 347.1 mL/hour; range, 632-1,728 mL/hour) ($p < 0.001$).	C
99. Haulon, et al 2001	prospective	60	Report procedural details and immediate results of type II endoleaks after aortic stent graft implantation	Technical success 94% Clinical success 72%	C
100. Giles, et al 2015	retrospective	29	reports experience with transcaval coil embolization (TCCE) of the aneurysm sac.	90% technical success	D
101. Lee, et al 2015	retrospective	66	to assess the efficacy and clinical outcomes of TAE for acute non-variceal upper GI bleeding and to identify predictors of recurrent bleeding within 30 days.	The technical success rate was 98%. Rebleeding within 30 days was observed in 47% after an initial TAE and was managed with re-embolization in 8, by endoscopic intervention in 5, by surgery in 2, and by conservative care in 12 patients.	D
102. Urbano, et al 2014	Retrospective	31	To evaluate the efficacy, safety, and clinical outcomes of superselective embolization using ethylene-vinyl alcohol copolymer (Onyx	The technical success rate was 93.5%. The embolic material refluxed in one patient,	D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
			Liquid Embolic System; ev3 Neurovascular, Irvine, California) as the primary treatment for acute and massive lower gastrointestinal bleeding (LGIB).	causing an undesired embolization, without any clinical consequences.	
103. Bua-ngam, et al 2017	Retrospective	38	To assess the safety and efficacy of transcatheter arterial embolization (TAE) in the treatment of acute lower gastrointestinal bleeding (LGIB) and to determine the potential factors that influence treatment outcome.	Technical success of TAE was obtained in 35/38 patients Bowel ischemia occurred in 5/38 patients (13%)	D
104. Hur, et al 2014	retrospective	112	To assess the safety and efficacy of transcatheter arterial embolization for lower gastrointestinal bleeding (LGIB) and to determine the prognostic factors that affect clinical outcome.	The technical success rate was 96.4%. For the entire group, the rates of early recurrent bleeding, major complications, clinical success, and in-hospital mortality were 17.4%, 4.6%, 74.5%, and 25.0%, respectively. These were 15.2%, 4.8%, 75.3%, and 26.2%, respectively, in the NBCA group.	D
105. Funaki, et al 2001 AJR	retrospective	27	evaluated therapeutic microcoil embolization in a group of patients with severe colonic hemorrhage	Technical success was achieved in 93% (25/27) of the procedures.	D
106. Waugh, et al 2004	retrospective	27	Presented 5 year experience of peripheral mesenteric embolization for LGIB	Technical success was achieved in 96% of cases. The clinical symptoms of mesenteric ischaemia developed in four patients after embolization and were managed conservatively in two. The procedure-related mortality was low when compared with the published complication rates for emergency surgery, in this clinical setting.	D
107. Chan, et al 2016	retrospective	26	To evaluate the efficacy of mesenteric embolization for LGIB and to identify predictors for re-bleeding after the procedure.	Technical success rate was 100%, with no occurrence of post-embolization ischaemia. Clinical success rate was 65.4%, with nine patients re-bleeding within 30 days post-embolization.	D
108. Spigos, et al 1980	Retrospective	41	Described techniques and results of partial splenic embolization	Indications included azathioprine intolerance after renal transplant, hypersplenism, PSE prior to renal transplant, thalassemia major, and Splenic v thrombosis Success in 38/41	D
109. Sclafani, et al 1995	retrospective	172	To determine if angiographic findings can be used to predict successful nonoperative therapy of splenic injury and to determine if	56 of 60 patients treated by splenic artery occlusion and bed rest had a successful outcome.	D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
			coil embolization of the proximal splenic artery provides effective hemostasis.		
110. Schnuriger, et al 2011	Meta-analysis	275 proximal 120 distal	To assess the outcomes after angioembolization in blunt trauma patients with splenic injuries and to examine specifically the impact of the technique used.	Proximal: recurrent bleeding 2.2%, infarction 5.8%; Distal recurrent bleeding 4.2%, infarction 18.3%, infection 0.8% Technical success 90%	D
111. Haan, et al 2005	Retrospective	132	To examine the success rate of nonoperative management of blunt splenic injury in an institution using splenic embolization.	132 patients underwent embolization, with a nonoperative salvage rate of 90%	D
112. Brillantino, et al 2015	Prospective single center	24	To evaluate the safety and effectiveness of NOM in the treatment of minor (grade I-II according with the American Association for the Surgery of Trauma; AAST) and severe (AAST grade III-V) blunt splenic trauma, following a standardized treatment protocol.	Of 24 patients that had undergone angioembolization, 22 (91.6 %) showed high splenic injury grade. The success rate of embolization was 91.6 % (22/24). No major complications were observed. The minor complications (2 pleural effusions, 1 pancreatic fistula and 2 splenic abscesses) were successfully treated by EAUS or CT guided drainage.	C
113. Abulkhir, et al 2008	Meta-analysis	37 studies 1088 patients	Examined the impact of portal vein embolization on liver resection	A total of 75 publications met the search criteria but only 37 provided data sufficiently enough for analysis involving 1088 patients. The overall morbidity rate for PVE was 2.2% without mortality. Four weeks following PVE, 85% patients underwent the planned hepatectomy (n = 930).	C
114. Di Stefano, et al 2005	retrospective	188	To assess the frequency of adverse events related to percutaneous preoperative portal vein embolization (PPVE).	Tech success 98%; clinical success 86% Complications included thrombosis of the portal vein feeding the future remnant liver (n = 1); migration of emboli in the portal vein feeding the future remnant liver, which necessitated angioplasty (n = 2); hemoperitoneum (n = 1); rupture of a metastasis in the gallbladder (n = 1); transitory hemobilia (n = 1); and transient liver failure (n = 6). Incidental findings were migration of small emboli in nontargeted portal branches (n = 10) and subcapsular hematoma (n = 2).	D
115. Madoff, et al 2005	retrospective	44	To analyze outcomes after right portal vein embolization extended to segment IV (right PVE + IV) before extended right hepatectomy	After right PVE + IV with PVA particles, FLR volume increased 45.5% +/- 40.9% and FLR/TELV ratio increased 6.9% +/- 5.6%. After right PVE + IV with tris-acryl microspheres, FLR volume increased 69.0% +/- 30.7% and FLR/TELV ratio increased 9.7% +/- 3.3%. Differences in FLR volume (P =.0011), FLR/TELV ratio (P =.027), and resection rates (P =.02) were statistically significant. Seventy-	D

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
				one percent of patients underwent extended right hepatectomy (86% after receiving tris-acryl microspheres, 57% after receiving PVA).	
116. Morag, et al 1984	Retrospective	146	To report results of gonadal vein embolization for varicoceles	Main indicatios were subfertility and abnormal spermatogenesis Jugular vein approach is stressed, especially if right sided. 128/146 success	D
117. Porst, et al 1984	Retrospective	259	To report outcomes if varicocele embolization with varicocid	Varicocid-benzyl alcohol and sodium morrhuate Success in 217/259	D
118. Zuckerman, et al 1994	Retrospective	182	Summarizes 11-year experience with percutaneous varicocele occlusion	Technical success rate was 95.7%. Patients followed to mean 59 months.	D
119. Kim, et al 2006	Retrospective	127	To evaluate the long-term clinical outcome of transcatheter embolotherapy in women with chronic pelvic pain caused by ovarian and pelvic varices.	Overall, 83% of the patients exhibited clinical improvement at long-term follow-up, 13% had no significant change, and 4% exhibited worsened condition.	D
120. Kwon, et al 2007	Retrospective	67	To evaluate the therapeutic effectiveness of ovarian vein embolization using coils for pelvic congestion syndrome	Tech success 100%, clinical success 82%	D
121. Eckstein, et al 1984	Retrospective	222 194 ADH; 17 gelfoam/PVA	To report experience of embolization in patients with UGIB	initial rate of bleeding control in all patients angiographically treated was 73%.	D
122. Reyes, et al 1994	retrospective	59	Evaluated technical success and immediate and long-term results of percutaneous varicocele embolotherapy in the adolescent population.	Technical success 90%	D
123. Manunga, et al 2017	retrospective	6 studies 620 patients reviewed 12 patients embolized	To demonstrate the impact of IMA embolization using a meta-analysis of currently available studies combined with our own experience	Cumulative success rate 99.2%. Preoperative embolization of the IMA protects against the development of type II endoleaks and secondary interventions and may potentially lead to a rapid aneurysm sac regression	D
124. Koo, et al 2015	retrospective	20	To evaluate the efficacy and clinical outcomes of transcatheter arterial embolization (TAE) for gastrointestinal (GI) bleeding from gastrointestinal stromal tumor (GIST).	Technical success 95%, clinical success 90%	D
125. Bhatia, et al 2015	Retrospective	13	To determine if proximal splenic artery embolization (PSAE) provides a safe and effective alternative to alleviate chemotherapy-induced thrombocytopenia (CIT),	post-PSAE peak platelet count improved significantly (to 209 x 10(9)/L; range, 83-363 x 10(9)/L) compared with the nadir counts and the pre-PSAE counts ($P < .01$) at a mean short-term follow-up of 35 days (range, 7-91 d).	D
126. Brown, et al. 2018	Sys review / meta-analysis	14 studies (828 pts)	To describe the risk factors and role of endovascular treatment for pelvic congestion syndrome.	Technical success of 99.8% (96.2-100%) and clinical success of 84% (68.3-100%). Few procedural complications.	B
127. Kim et al., 2017	Sys review / meta-analysis	15 studies (n=440	To evaluate the safety and efficacy of transcatheter arterial embolization for the treatment of gastrointestinal bleeding.	261 (59.3%) of patients had upper GI bleeding (UGIB) and 179 (40.7%) had lower GI bleeding (LGIB). Technical success of 99.2% with UGIB (259 of 261) and 97.8% with LGIB (175 of 179). Clinical success of 82.1% with UGIB and 86.1%	B

continued

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Reference	Ref. type	N	Objective	Results and Comments	Strength
				with LGIB. Low complication rates at 5.4% UGIB and 6.1% LGIB.	
128. Lienden et al., 2013	Sys review / meta-analysis	44 studies (1791 pts)	To review the indications, technique, and outcome of portal vein embolization.	Technical success of 99.3% and clinical success of 96.1%. Major complications rate of 2.5%, with mortality rate of 0.1%. Use of n-butyl cyanoacrylate had a greater hypertrophy response compared with other embolization materials.	B
129. Makris et al., 2018	Sys review / meta-analysis	30 studies (3505 pts)	To assess the safety and effectiveness different embolic materials used in varicocele embolization.	Technical success >92% for all embolic materials. Low complication rate and similar safety profile for all embolic agents. Recurrence rates from 4.2 (glue)-11.03% (sclerosants).	B
130. Malling et al., 2019	Sys review / meta-analysis	13 studies (1046 pts)	to review the efficacy and safety of PAE in the treatment of BPH with LUTS.	Technical success rates of 76.7 to 100% and clinical success rates of 76.3 to 100%. Major complication rate of 0.3%. Statistically significant improvements of all outcomes and low complication rates at 12-month follow-up.	B
131. Muller et al., 2015	Review	14 studies (642 pts)	To review the use of renal artery embolization in the management of renal disease.	Technical success rates range from 83.5% (65-100%). Clinical success rates range from 87.3% (78-100%). Efficient, safe, and low rate of serious complications. Renal artery embolization the first-line option in penetrating or iatrogenic trauma when conservative treatment fails.	B
132. Panda et al., 2017	Sys review / meta-analysis	13 studies (n=2,137)	To analyze the indications, technique, short-term and long-term efficacy, outcomes, and complications of bronchial artery embolization.	Technical success rates from 81-100%. Clinical success rates 82-98.5%. Rate of major complications 0%–6.6%. High hemoptysis recurrence rates.	B
133. Rong et al., 2017	Sys review / meta-analysis	15 studies (876 pts)	To analyze the roles of different embolization locations and embolic materials in splenic artery embolization.	Technical success rate 90.1%. High incidence of life-threatening complications 20.4%. Proximal embolization led to lower complications than distal or a combination. Coils had fewer life-threatening complications than gelfoam.	B
134. Sidloff et al., 2013	Sys review / meta-analysis	7 studies (120 procedures)	To assess the risk of rupture, and determine the benefits of intervention for the treatment of type II endoleak after endovascular abdominal aortic aneurysm repai.r	Clinical success rate of 62.5%. Translumbar embolization had higher clinical success rate, lower recurrence rate, and lower complication rate than transarterial embolization (0% vs. 9.2% complications, respectively).	B
135. Talwar et al., 2020	Sys review / meta-analysis	30 studies (976 pts)	To review the adverse event profile of partial splenic embolization.	Technical success rate 99%. Adverse events: 73.4% postembolization syndrome, 9.4% pleural effusion, 8.1% ascites, 2.4% thrombosis, 1.3% bacterial peritonitis, 1.3%	B

continued

Reference	Ref. type	N	Objective	Results and Comments	Strength
				splenic abscesses, 0.6% gastrointestinal bleeding, 1.0% mortality. Patients with liver disease at high risk for major complications.	
136. Ultee et al., 2018	Sys review / meta-analysis	50 studies (1073 pts)	To investigate clinical outcomes of different type II endoleak treatments in patients with a persistent type II endoleak after EVAR.	Technical success rate 84% (95% CI 77.2-89.8%). Clinical success rate 68.4% (95% CI 61.2-75.1). Peri-operative complications 3.8% and mortality 1.8%.	B
137. Griessenauer 2015	Sys review / meta-analysis	28 studies (956 cases)	To review data on embolization technique, efficacy, and complications.	Technical success rate of 68.3%. Overall complication rate of 3.1%. Polyvinyl alcohol and Onyx had comparable rates of complete embolization and blood loss. More recent studies show decrease in operative blood loss.	B
138. Cinquantini et al., 2018	Retrospective	49	To compare the outcomes of non-operative management with splenic artery embolization for the management of hemodynamically stable patients with splenic injuries.	Clinical success rate similar for both groups: 87.8% for embolization, 95% for non-operative management. Largest causes of failure were inappropriate patient selection and technical or procedural embolization failures.	D
139. Olthof et al., 2018	Retrospective	57	To investigate whether splenic artery embolization improves success rate compared to observation alone in contemporaneous patients with blunt splenic injury.	No significant difference between embolization and non-operative management. Clinical success rate for embolization 84% and for non-operative management 92%.	D
140. Andersen et al., 2019	Registry-based observational	322	To investigate the frequency of re-embolizations and the clinical outcome after embolization with the use of different embolization materials further, to define which PAVM morphology and size of feeding arteries that most often were re-embolized, and to estimate the clinical outcome of the patients including those that were re-embolized.	Technical success rate of 90.6%. 9.3% required re-embolization. Standard coils are not recommended as the first choice treatment for PAVMs, with vascular plugs recommended.	C
141. Frood et al., 2020	Retrospective	96	To evaluate the impact of bronchial artery embolization on outcomes and long-term survival in patients with massive haemoptysis.	Technical success of 90% and clinical success of 86.5%. Three major complications were reported (cardio-pulmonary arrest, paraparesis and stroke). Long-term survival (56% at 5 years) was dependent on underlying pulmonary pathology.	D
142. Woo et al., 2013	Retrospective	406	To compare the safety and effectiveness of the embolic agents polyvinyl alcohol particles versus n-butyl-2-cyanoacrylate for bronchial artery embolization for control of hemoptysis.	PVA had technical success of 93.9% and clinical success of 92.2%. n-butyl-2-cyanoacrylate had technical success of 96.5% and clinical success of 96.5%. No statistically significant difference in major complication rate (0.3% for PVA, 0% for NBCA) or overall complication rate (34.1% for PVA, 31.0% for NBCA) between groups.	
	Retrospective	341			D

continued

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Reference	Ref. type	N	Objective	Results and Comments	Strength
143. Agmy et al., 2013			To report outcomes for bronchial artery embolization in the management of moderate recurrent and/or life-threatening hemoptysis.	Technical success rate of 95%. Recurrence of hemoptysis in 9.6% of patients. Complications included pain, dysphagia, and post-embolization syndrome.	
144. Shao et al., 2015	Retrospective	344	To discuss clinical analysis, embolization approach, outcomes, and complications of bronchial artery embolization for the treatment of hemoptysis.	17.7% of patients experienced recurrent hemoptysis within 1 month, and 21.5% >1 month. Complications included pain and post-embolization syndrome.	D
145. Kauffman et al., 2007	Retrospective	27	To review partial splenic embolization for cancer patients with thrombocytopenia because of splenic sequestration precluding the administration of systemic therapy	Clinical success rate 96.3%. Most common complications were abdominal pain, fever, and pulmonary consolidation/atelectasis or effusion. Embolization was effective in managing thrombocytopenia secondary to hypersplenism.	D
146. Hill et al., 2020	Retrospective	98	To identify response predictors and to longitudinally evaluate partial splenic artery embolization efficacy and durability in cancer patients with hypersplenism-related thrombocytopenia.	Clinical success rate of 58%. Major complication rate of 8%. Most common complication was post-embolization syndrome. 41% of patients did not experience recurrence of thrombocytopenia.	D
147. Luz et al., 2016	Prospective	33	To evaluate partial splenic embolization in patients with thrombocytopenia that impeded systemic chemotherapy continuation.	Clinical success rate of 94%. No major adverse events occurred; minor adverse events such as upper GI bleeding and pain, fever, and nausea attributed to post-embolization syndrome.	C

APPENDIX D. ADVERSE EVENT CLASSIFICATION

Part A: Adverse Event (AE) Description

Descriptive narrative of adverse event (including sedation and anesthesia) and severity characterization. This part is suitable for scientific use (presentations, publications etc.) as well as for adverse event reviews within a practice, practice group, facility or specialty.

1. **Mild adverse event**: No therapy or nominal (non-substantial) therapy (post-procedural imaging performed and fails to show manifestation of adverse event); near miss (e.g., wrong site of patient prepped, recognized and corrected prior to procedure, wrong patient information entered for procedure, etc.);
2. **Moderate adverse event**: moderate escalation of care, requiring substantial treatment, e.g., intervention (description of intervention and result of intervention) under conscious sedation, blood product administration, extremely prolonged outpatient observation or overnight admission post outpatient procedure not typical for the procedure (excludes admission or hospital days unrelated to adverse event);
3. **Severe adverse event**: marked escalation of care, i.e. hospital admission or prolongation of existing hospital admission for $>$ 24 h hospital admission that is atypical for the procedure, inpatient transfer from regular floor/telemetry to ICU or complex intervention performed requiring general anesthesia in previously non-intubated patient (generally excludes pediatrics or in circumstances where GA would primarily be used in lieu of conscious sedation, e.g., in mentally challenged or severely uncooperative patients);
4. **Life-threatening or disabling event**, e.g. cardiopulmonary arrest, shock, organ failure, unanticipated dialysis, paralysis, loss of limb or organ;
5. **Patient death or unexpected pregnancy abortion**

* The SIR Adverse Event Severity Scale is intended to approximate the surgical Clavien-Dindo scale and the NCI CTCAE scale. The SIR scale is tailored towards the procedures and adverse events encountered in IR practices. The grading of interventional oncology adverse events can selectively incorporate relevant adverse event grading definitions published in the current CTCAE for oncological interventions, which may be particularly relevant in the context of research publications. All adverse events occurring within 30 days of a procedure should be included in the adverse event description and analysis, regardless of causality, in the interest of objectivity. The adverse event scale itself does not assess operator performance.

Modifier:

M = multiple adverse events, each of which is counted and evaluated separately if possible;

Part B: Adverse Event Analysis

The following part pertains to adverse event analysis. It is designed to enable a confidential and constructive review of any adverse event within an IR practice or practice group. Applicability for scientific publications is limited and there is none for other public use. The following content is meant to provide a strictly confidential, legally non-discoverable, non-punitive, objective, consistent and clinically constructive analytic guide that may result in quality improvement measures to advance the quality of patient care in interventional radiology.

Causality

Category 1. Adverse event not caused by the procedure

Category 2. Unknown whether adverse event was caused by the procedure

Category 3. Adverse event caused by the procedure

Patient and Procedural Risk Modifier:

Category 1. High risk patient AND technically challenging procedure

Category 2. High risk patient (e.g. ASA 4, uncorrectable coagulopathy, poor functional status (ECOG 3 & 4), polypharmacy/polyintravenous therapy and transfusion, septicemia, hemodynamic instability, recent catastrophic event/ICU admission/major surgery or interventions) etc. OR low risk patient and technically challenging procedure (e.g. TIPS with occluded portal vein, percutaneous biliary drain placement in non-dilated biliary system, etc.)

Category 3. No modifier

Adverse Event Preventability

Category 1: Rarely preventable: i.e. well described and "typical" for the procedure and occurring despite adequate precautionary and preventive measures

Category 2: Potentially preventable

Category 3: Consistently preventable: e.g. inappropriateness of procedural indication (may use checklist see below)

Adverse Event Management

Category 1: Most operators would have handled the adverse event similarly;

Category 2: Some operators would have handled the adverse event differently;

Category 3: Most operators would have handled the adverse event differently;

Examples of Consistently Preventable Event

- Wrong patient
- Absolute contraindication for procedure

- Wrong side for procedure
- Wrong procedure
- Wrong medication/contrast agent/blood product (dose/administration route)
- Exposure to known allergens
- Intra-arterial placement of catheter meant to be intravenous or non-venous placement of IVC filter
- Ferromagnetic devices contraindicating performance of MRI
- Failure to follow up or communicate laboratory, pathology, or radiology results
- Use of known malfunctioning equipment or patient monitor system
- Lack or inappropriate use of monitoring equipment during sedation