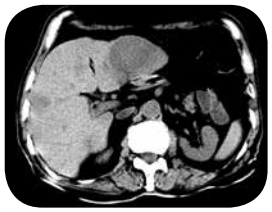

Transcatheter Embolization

Embolización transcatéter

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Summary

Embolotherapy, embolization or transcatheter embolization are names that today are assigned for the same procedure, known since the early twentieth century and that took force spreading from the beginning of the 1970s when its application was promoted through catheters. Since then the evolution of techniques and the continuous development of materials have made this technique an exceptional tool in the control of hemorrhage and treatment of different neoplasms.

Palabras clave (DeCS)
Embolización arterial, embolización, técnica de embolización, terapia de embolización
Embolización terapéutica
Catéteres
Angiografía

Resumen

Emboloterapia, embolización o *embolización transcatéter* son nombres que actualmente se le asignan al mismo procedimiento, conocido desde comienzos del siglo XX, que tomó fuerza y se difundió desde principios de 1970 cuando se impulsó su aplicación por medio de catéteres. Desde entonces, la evolución de las técnicas y el continuo desarrollo de materiales han convertido esta terapia en una herramienta de utilidad excepcional en el control de la hemorragia y el tratamiento de diferentes neoplasias.

Introduction

Embolization means: "obliteration of a vessel by introducing into the bloodstream an occlusive agent (foreign body, biological tissue, sclerosing fluid, etc.), which produces the deliberate interruption of vascular flow, mechanically or by producing an intense inflammatory reaction of the vessel wall". It has multiple applications, such as the treatment of active hemorrhages and, in many cases, embolization is the procedure that saves the patient's life; it is used as a treatment in different entities, such as vascular malformations, palliative or therapeutic treatment of neoplasms, redistribution of preoperative blood flow; as a procedure associated with surgery, devascularizing the area to reduce intraoperative bleeding (presurgical embolization), multiple therapies (portal embolization), ablation of transplants and tumor reestablishment, among others. Embolization is a therapeutic tool in continuous evolution, current and futuristic, which provides important help in the practice of medicine today and allows interaction and teamwork between practically all specialties.

The purpose of embolization is to occlude the vessel or territory of interest as selectively as possible. Hence, to minimize collateral damage to adjacent structures that are not the target of treatment, by releasing liquid or solid occlusive agents, to temporarily or permanently block arteries or veins. It is used both in the emergency department and in elective procedures (1,2).

Embolization requires a detailed knowledge of vascular anatomy, its indications, contraindications, careful selection of materials and radiology equipment. Experience has shown that it must be performed, in all cases, by appropriately trained interventional radiologists, given the potential for side effects and collateral damage that the procedure entails if it is not performed correctly.

Historical review

Since the beginning of the 20th century, various materials have been used in vascular embolization (table 1) (3).

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Table 1. Embolization agents used throughout history

Year	Author/Company	Material/advances
1904	Dawbain, Lussenhop and Spence	Paraffin
1930	Brooks	Muscle
1930	Bungenberg de Jong, et al.	They initiated studies of entrapment of substances within coacervates (base of the microspheres).
1950	Barrett K. Green	They developed the microencapsulation that uses the process of phase separation-coacervation (base of the microspheres).
1950-1960	Sidney Fox	Described the protocells, later called microspheres.
1960	Lussenhop	Methylmethacrylate
1972	Rösch, Dotter, Brown	Autologous clot
1972	Zanetti, Sherman	Acrilates
1974	Carey, Grace	Spongostan® /Gelfoam®
1974	Serbinenko	Balones desprendibles
1974, 1997+, 2000*	Portsman	PVA: Polyvinyl alcohol
1975	Gianturco	Metal coils
1981	Ellman	Alcohol
1982	Amplatz	Hot contrast medium
1990, 1997*	Alexander Laurent, at the Lariboisière Hospital, París	Embosphere gelatin microspheres Trisacryl gelatin microspheres (GMS) (Embosphere®)
1990, 2003+, 2004* 2004+ 2006*	Shinichi Hori, et al., at Osaka University, Japan. Biocompatibles Contour SE, Boston Scientific. Merit Medical Biocompatibles	Composite microspheres of PVA (DC® Beads in Europe, and LC® beads in the United States) or Super-absorbent polymer microspheres (SAP) (HepaSpheres® in Europe or QuadraSpheres® in the United States). Microspheres or pearls releasing drugs (DEB). Microspheres composed of PVA and modified by adding a group of sulphonic acid (negative) which can be loaded with doxorubicin (DEBDOX) and irinotecan (DEBIRI) which are chemotherapeutic agents with positive charge.
2001	Amplatz	Amplatz Vascular plugs Amplatzer®
2002*	Sirtex Medical Limited	Chargeable microspheres with yttrium-90 SIR-Spheres®
2007*	Celonova Biosciences, San Antonio, Texas, Estados Unidos	Microspheres coated with polymethyl methacrylate (Embozene®) or polyphosphazene (Polyzene-F)
2007*	Covidien	Onyx®

* Date of approval by the FDA (Food and Drugs Administration), United States.
+ Date of approval in Europe.

Materials

There are numerous catheters and embolizing agents to access the area of interest and perform the procedure. The knowledge to properly choose when and how the different elements are used is crucial for the success of the procedure and to avoid complications.

Before applying any embolizing agent it is mandatory to obtain a stable and safe position, which guarantees the correct release of the agents and helps to prevent their migration. This is achieved by approaching the release site with specific devices, whose function is to navigate the vessels until the point of interest is reached: catheters, microcatheters, guides and microguides.

Catheters

For each procedure, the catheter that offers the best approximation to the point of release should be chosen and provide sufficient stability and safety to embolize. You must move forward freely and navigate fluently.

Microcatheters

There are multiple available, their choice depends on the anatomy, tortuosity of the vessels, difficulty for catheterization, the preferences of the professional and, sometimes, some other aspects that must be considered, such as costs, availability in the environment, between others.

Some characteristics that must be taken into account

The length of the catheter is important to guarantee access to the area of interest, in turn the guide must allow the safe advance of the materials and the exchange of these according to the need of the procedure. The internal lighting must be sufficient to allow the passage of the guides and microcatheters and also of the embolization materials; however, it should not be excessive because it favors complications. There are catheters whose configuration facilitates access selectively. They can be shaped according to the case; this choice can make the difference between achieving or not the success of the procedure (4-6).

Embolizing agents

The choice of embolization material depends on clinical, anatomical and local flow factors in the area to be treated. The risks and benefits of this therapy, the diameter and length of the sector to be occluded, the time required for occlusion, the collateral circulation of the area, among others should always be evaluated. You should always know the expected effect of the treatment, to adjust the embolization and achieve the goal.

Embolization is a current therapeutic option, which requires knowing the normal and particular anatomy of each patient, and the physiopathological process that is expected from the treatment in order to reach the target without affecting the adjacent structures or other distant tissues. Hence, the procedure, the materials and the embolizing agent must be carefully planned (7, 8).

All that is needed is to look at the potential complications of embolization to convince yourself of the importance of all the above, so it is insisted that it should be performed by interventional radiologists properly trained in units, with the relevant learning curve.

Among the factors to plan an embolization and choose the materials, it is convenient to check previously:

1. What is the best way to get to the area of interest? Not always the shortest path is the best.
2. What are the alternatives? In case the anatomy at the time of the procedure by the chosen route is unfavorable and prevents reaching the target.
3. What territory irrigates the vessel to be occluded? Extension and importance of it. Is it terminal circulation?
4. What is the caliber of the vessel that is going to be embolized?
5. What is the length of the vascular segment to occlude?
6. If the tissue irrigated by the vessel must remain viable after embolization. Possibilities of ischemia or infarction.
7. What is the flow of the area of interest and its collateral?
8. Time that is required to keep the vessel occluded.
9. Purpose of embolization: Hemostatic, preoperative, etc.
    - » The occlusion of a proximal vessel is useful when a single inference irrigates the area of interest, when a rapid result is required or if distal collaterals are to be preserved. Metal coils or occlusion plugs can be used to preserve the viability of the tissue.
    - » Distal occlusion has an increased risk of tissue infarction (9).

The embolization materials that are used most frequently are:

Gelfoam® (Pfizer)

Absorbable embolizing agent, very widespread and versatile. It was used for the first time in 1945 for hemostatic purposes in surgeries; for endovascular purposes, in 1964, to occlude a cavernous carotid fistula, successfully. It is a gelatin hemostatic sponge of animal origin, which is processed in blocks, sheets or powder by friction, which once used is reabsorbed after days or weeks (between 15 to 17 days on average) (10-12). It is used in sheets, wedges, pieces, powder, or macerated, also called pasta, porridge, manufactured at the time of its use, by fragmentation and mixing of the sheets or blocks of sponge. These various forms are injected through a catheter, to release them into the bloodstream and shape the plunger.

This material causes vascular occlusion due to mechanical obstruction, that is, it accelerates the development and provides structural support for the thrombus, although, by itself, it has no hemostatic action (13). It is also used in cases of patients with scheduled surgeries within 48 hours after the application thereof; in addition, its use and adequate performance has been described in the embolization of uterine fibroids, in the treatment of digestive tract hemorrhage, and in the tract that remains after the removal of a biliary bypass catheter, among others (14-16).

The vessels embolized with Spongostan® are generally recanalized within 3 weeks to 3 months (5), which allows conservative embolization.

The use of this embolizing agent also involves some risks, among which infections are found first: the bubbles it contains can harbor anaerobic microorganisms (17,18) and, second, the significant risk of ischemia (19,20), generally related to selective embolization especially when the cut particles are small.

Metal coils

Widely known by their English name, coils, they have multiple applications in pediatric patients (21) and in adults, with numerous indications, such as the management of aneurysms (22), and hemostasis, among others. In general terms, they are the embolization material of choice for the occlusion of medium and large caliber vessels (23).

There are different types, among those of controlled release, which are recoverable and can be rearranged. They are manufactured with stainless steel, platinum or other alloys. They act mechanically, as permanent occluders, which induce local thrombosis, although some have thrombogenic elements in their construction, such as polyester, dacron or silk fibers, which promote platelet aggregation and thrombosis. They are available in a variety of sizes, lengths and shapes.

The metallic coils have the disadvantage of making it difficult to follow the embolized lesions since they produce metallic artifacts that diminish the image quality in scanography, so it is suggested to follow the patients with these elements by ultrasound, magnetic resonance or nuclear medicine (24-26). Some metallic spirals are made of platinum and nitinol that make them safe for magnetic resonance (27,28).

Autologous clot

Seldom used now, only in cases where temporary occlusion is desired for hours or days, since lysis occurs quickly. It was the first solid embolic agent used and today its validity remains in some applications, such as in the practice of biopsies.

PVA particles (polyvinylalcohol)

Approved for use in embolization in 1997, in Europe and in 2000, in the United States. This particulate embolization agent is injected through a catheter. In the past, there was no adequate calibration for the size of these particles, and their behavior during embolization was uncertain (29,30); however, nowadays they are available in sizes from 50 to 1,200 microns in diameter and their proper selection is essential to achieve a successful embolization. They physically obstruct the vessels, thus favoring the formation of thrombi, since they remain in the body longer, compared with Gelfoam®; however, thrombus can be metabolized before fibrosis occurs, resulting in recanalization after a few weeks or months (31,32).

Microspheres

They are perfectly round and slightly deformable embolic agents, they can be compressed approximately 20% of their diameter; this should be considered when choosing your size. They have the advantage of having a uniform size, which decreases the risk that smaller spheres may end up in distal vessels and cause ischemic complications. Its diameter varies between 50 and 1,200 microns. They are not radiopaque, so they must be mixed with contrast medium (33).

Some microspheres can be impregnated with agents or cytostatic drugs, for use in the management of chemoembolizations.

Polymers

The liquid embolizing materials can be injected with catheter or microcatheter, flow through the vascular structures and then solidify to occlude the light. They are especially useful in the treatment of arteriovenous malformations and fistulas (34-36). Within this group the most used at present are Onyx® and n-butyl-cyanoacrylate (NBCA).

- ***Onyx®:*** Widely used today. It is a liquid agent with low adhesive capacity, which has a slow polymerization. The drawback is its high cost. Onyx® is an alcohol-vinyl-ethylene copolymer (EVOH), contains as solvent dimethyl sulfoxide (DMSO) and tantalum powder. It is available in two presentations according to its viscosity: Onyx® 18 and Onyx® 34. Among its characteristics are that it is a controllable material, which produces complete filling, is cohesive and non-adhesive. Within its applications is the treatment of fistulas and cerebral arteriovenous malformations (37-39).
- ***N-butyl-cyanoacrylate (NBCA):*** It is one of the main liquid adhesive agents used mainly in the treatment of high-flow arteriovenous malformations, highly vascular tumors and lymphatic malformations. Although in principle it was used without radiopaque agents, it is currently used in combination with oils such as Ethiodol® in a ratio of 1: 4 (Ethiodol: NBCA). Due to the viscosity of this component, it occludes the vessels, and also generates an acute inflammatory process in the wall of these, which subsequently progresses to chronic in approximately four weeks (40-42).

Sclerosing agents

Tetradecyl sulphate of sodium

At 1-3%, it is a fluid that induces thrombosis, inflammation and obliteration of the vascular lumen. It is used to occlude superficial vein in the lower limbs, although it can also be used in arteries. It should not be used in high-flux lesions, and in some situations occlusion can be done by using a balloon to prevent reflux.

Absolute ethanol

The 95% alcohol is a potent sclerosing agent, which produces intravascular thrombosis, sclerosis of blood vessel walls or death of perfused tissues. The associated pain can be so severe that many patients require general anesthesia. The occlusion with balloons is useful to allow the alcohol to act on the target for several minutes, to avoid the reflux and the passage to the vein, which would produce acute pulmonary hypertension and the death of the patient.

Indications

Within the indications of arterial embolization there are several categories (table 2).

Table 2. Embolisation indications

Indications	Contraindications
• Pre-surgical (controlling intraoperative bleeding). • Trauma. • Acute or recurrent hemorrhage (any origin, neoplastic, iatrogenic, traumatic, etc.). • Occlusion of aneurysms, malformations and arteriovenous fistulas. • Suppression of the vascularization of neoplastic and non-neoplastic lesions. • Palliative management of tumors.	• Absolute: None. • Relative: In cases where the arterial irrigation is through terminal arterioles, with high risk of ischemia and possible necrosis.

Source: Haskal, Martin, Cardella, et al. (2).

1. Occlusion of aneurysms, pseudoaneurysms, congenital or acquired vascular malformations that have potentially serious effects on the patient's health (figure 1).
2. Treatment of acute or recurrent hemorrhages that may be gastrointestinal, post-traumatic, iatrogenic, of neoplastic origin or benign tumors that generate symptoms, such as myomas (figures 2 and 3) (43-45). In the case of hemoptysis, they usually originate from the bronchial arteries or their anatomical variants (figure 4). Embolization is also useful in the treatment and control of postoperative bleeding.

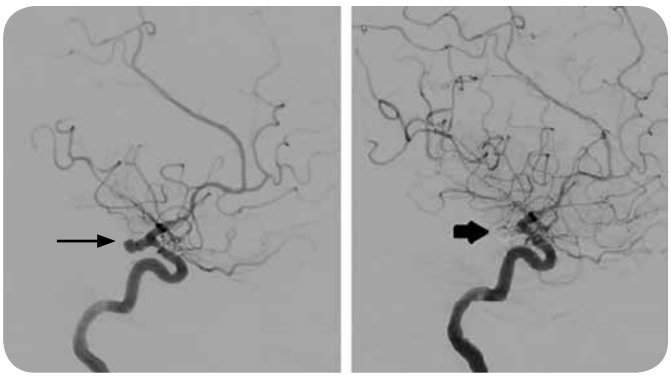

Figure 1. a) Aneurysm of the saccular type at the birth of the posterior communicating artery. b) Post-embossing result with Microsphere®, Hydroframe® and Hydrocoil® metallic coils. The complete exclusion of the aneurysm from the bloodstream is demonstrated.

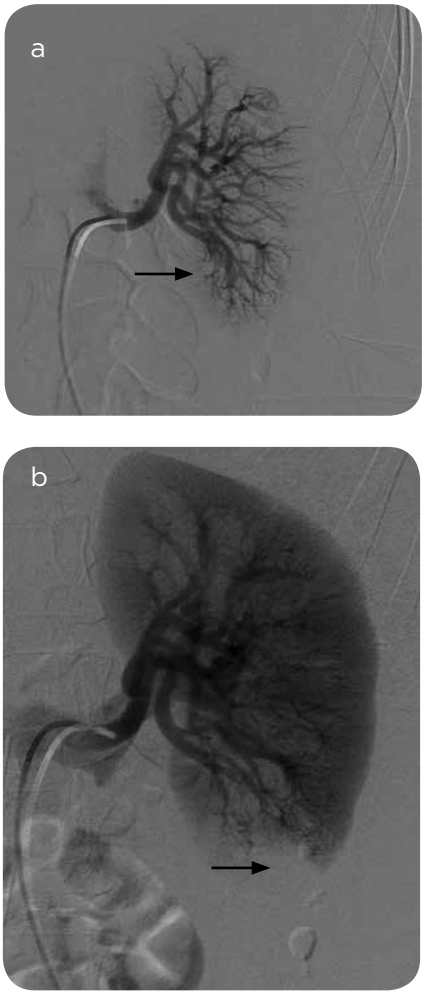

Figure 2. Bleeding and hemodynamic decompensation secondary to renal biopsy in a patient with systemic lupus erythematosus and marked thrombocytopenia. a) Through an approach through the left common femoral artery, the iliac-femoral axis and the left renal artery are catheterized. The diagnostic series show pseudoaneurysm in the lower pole of this kidney (arrow). b) After performing selective catheterization of the secondary and supraselective branches of the afferent artery of the pseudoaneurysm, it is embolized with resorbable material (Spongostan®) to achieve hemostasis and complete isolation of the pseudoaneurysm of the circulation (arrow).

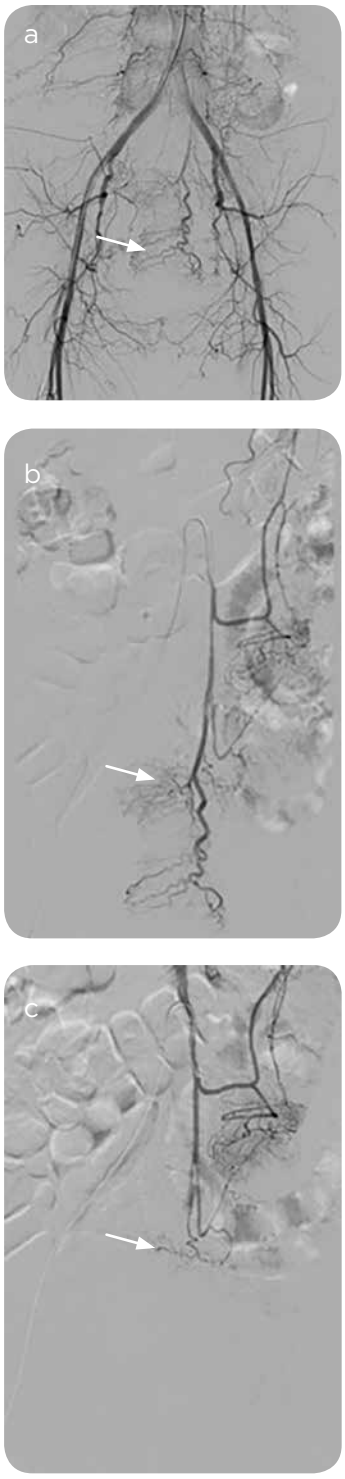

Figure 3. Patient in the seventh decade of life, with rectal bleeding of 1 year secondary to unresectable rectal neoplasia. a) Aortogram showing marked vascularization in the pelvis (arrow). b) Catheterization is performed with injection of non-ionic contrast medium. An area of increased caliber of the terminal portion of the inferior mesenteric artery is observed with localized hyperemia at the height of the rectum (arrow). c) Embolization was performed with polyvinyl alcohol particles, with a satisfactory morphological and functional result. The embolized territory was occluded conservatively to avoid possible areas of ischemia or necrosis, which is why other materials were not used in this embolization.

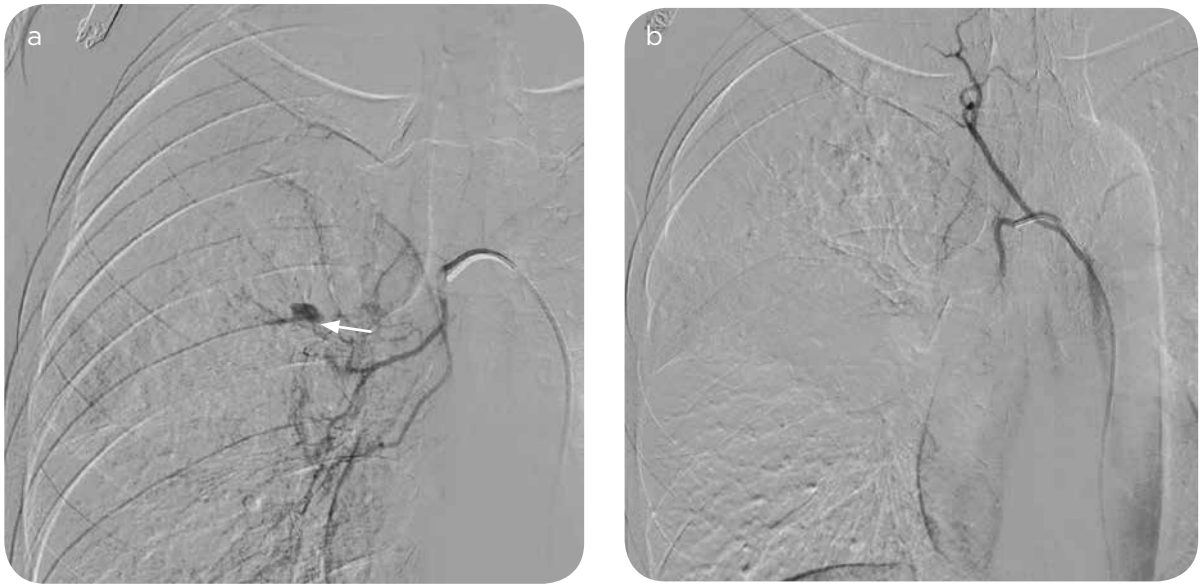

Figure 4. Patient with massive hemoptysis. a) Bronchial arteriography demonstrating site of active bleeding (arrow) through the artery to the anterior segment of the right upper lobe, which is embolized with alcohol-polyvinyl particles. b) Post-embolization control that shows complete occlusion of the vessel involved.

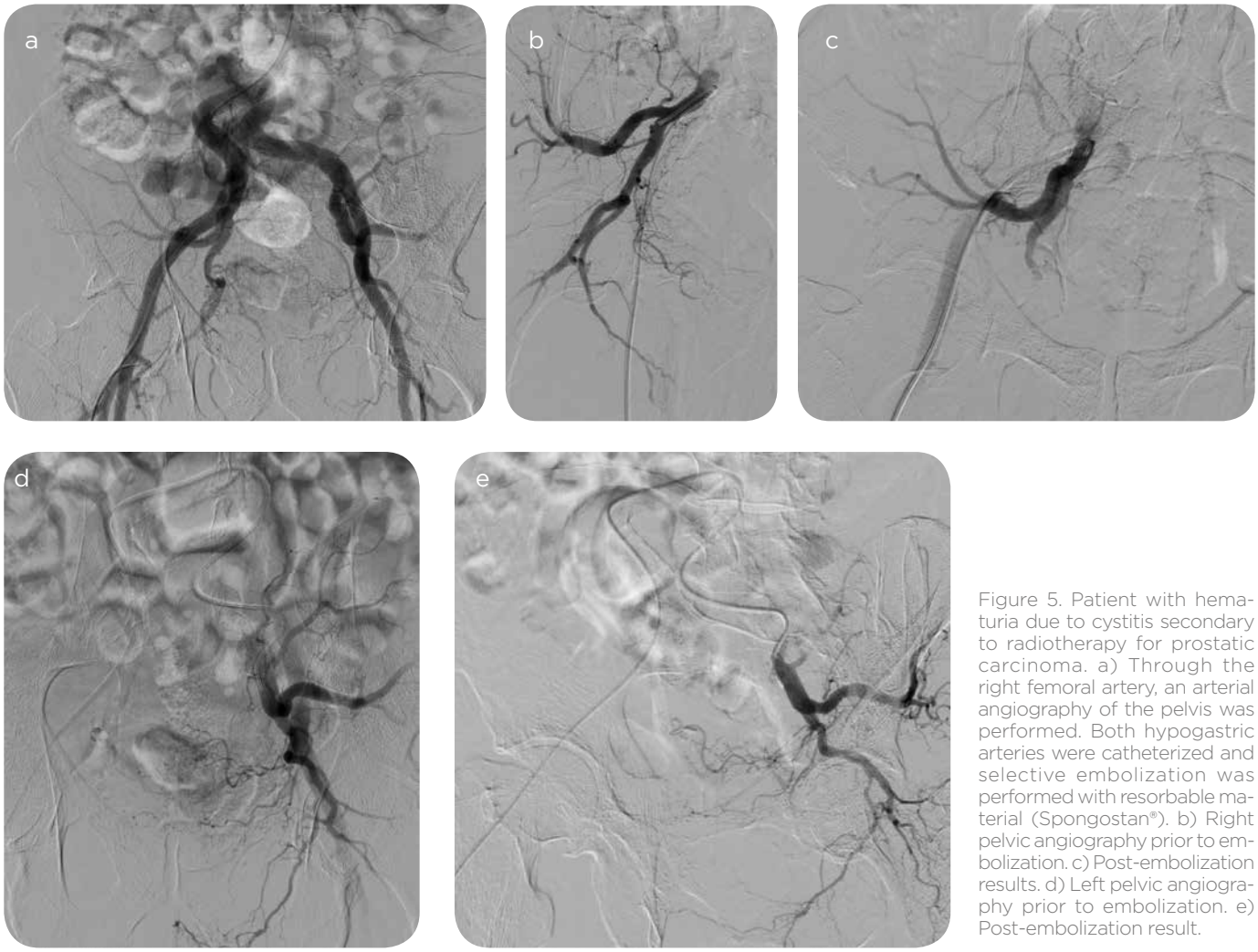

Figure 5. Patient with hematuria due to cystitis secondary to radiotherapy for prostatic carcinoma. a) Through the right femoral artery, an arterial angiography of the pelvis was performed. Both hypogastric arteries were catheterized and selective embolization was performed with resorbable material (Spongostan®). b) Right pelvic angiography prior to embolization. c) Post-embolization results. d) Left pelvic angiography prior to embolization. e) Post-embolization result.

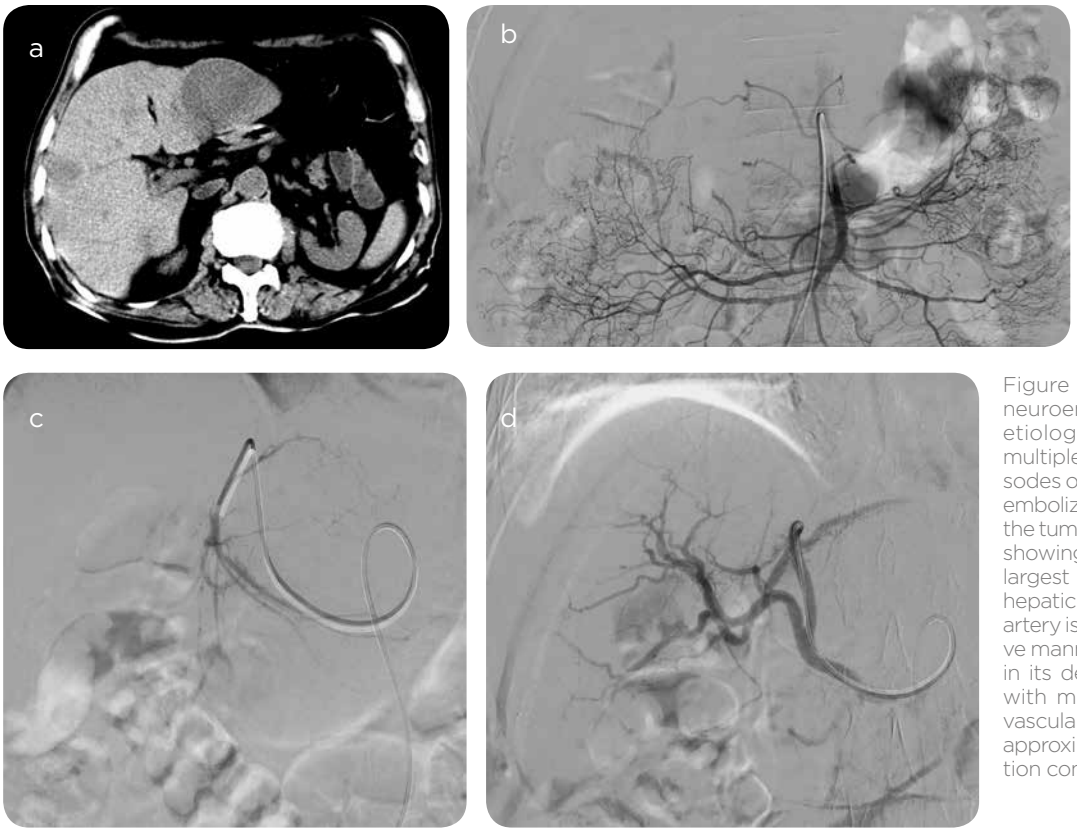

Figure 6. Patient with a history of neuroendocrine tumor of unknown etiology for 3 years, refractory to multiple treatments and several episodes of carcinoid syndrome; Hepatic embolization is performed to decrease the tumor burden. a) Abdominal scans showing two low density lesions, the largest of which is located in the left hepatic lobe. b and c) The left hepatic artery is catheterized in a supraselective manner and the catheter is located in its descending branch, embolized with microparticles, decreasing the vascular supply of this tumor mass by approximately 50%. d) Post-embolization control.

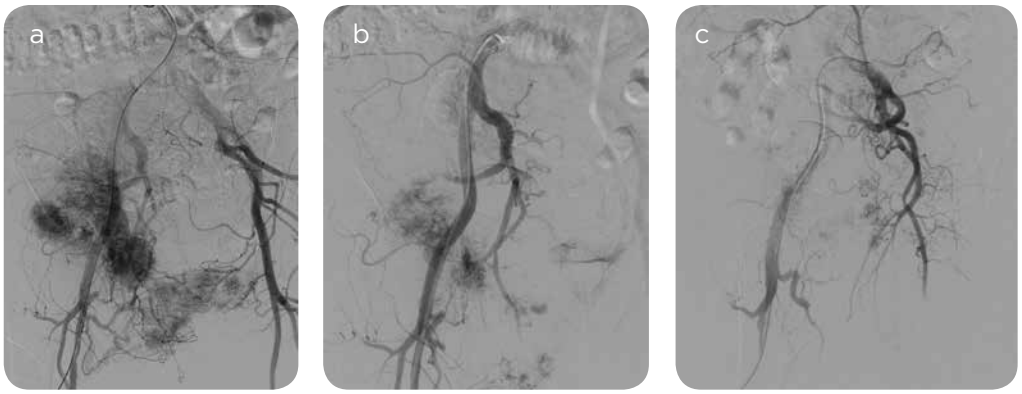

Figure 7. Patient of 80 years of age, with clear cell renal tumor and large metastatic hypervascularized mass in the pelvis that causes severe pain. a) By right femoral approach, aortogram showing a large hypervascularized tumor lesion is performed. b) By selective and supraselective catheterization, embolization of the tumor lesion is performed in the pelvis with microparticles. c) Post-treatment control.

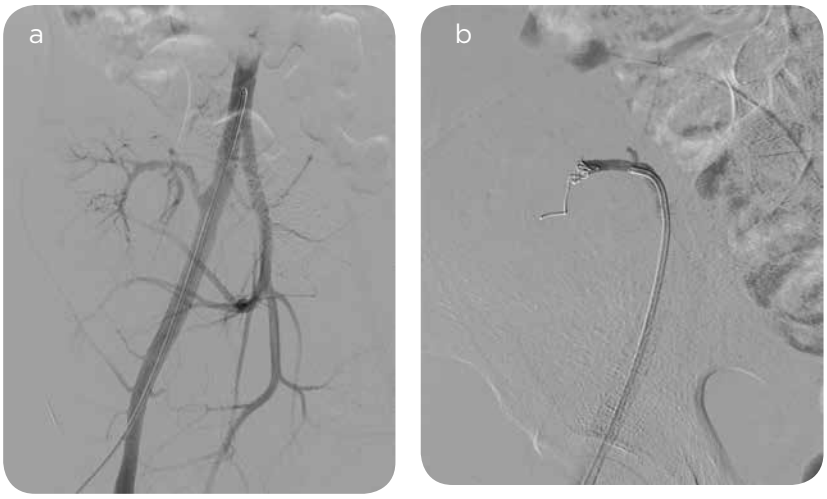

Figure 8. Patient with previous renal graft loss. The artery is embolized for the renal graft as an alternative to a nephrectomy. By approaching the right femoral artery, the artery of the renal graft is catheterized. a) Arteriography demonstrating localization of the renal graft. b) Selective graft catheterization and selective embolization with polyvinyl alcohol microparticles and metal coils.

3. Suppression of the vascularization of benign or malignant tumors for palliative purposes; for example, in the case of liver tumors, renal cell carcinoma, bone tumors, among others (figures 5, 6 and 7).
4. Devascularization of non-neoplastic lesions; for example, in cases of hypersplenism, pelvic congestion syndrome, ectopic pregnancy, aneurysms, among others.
5. Protect vascular flow and redistribution to neighboring tissues, and preserve vitality in cases where it is necessary to maintain active tissue, such as in chemoembolizations, right gastric and gastroduodenal artery embolizations, in hepatic embolizations, and radioembolization with Yttrium 99, to guarantee tissue viability and vascular flow to these, despite the previous procedure.
6. Avoid surgical procedures, as in the case of the exclusion of renal grafts that have failed (figure 8).
7. Facilitate surgical procedures, for which preoperative embolization is performed; for example, embolization of nasoangiofibromas, tumors of the musculoskeletal system, aneurysmal bone cysts, etc. It is applied in entities that due to their great vascularization show significant intraoperative bleeding and are technically difficult procedures if all vessels are intact at the time of resection. To do this, the afferent vascular bed is previously embolized, which provides a dry surgical field. It has been shown that embolization prior to surgery reduces intraoperative bleeding, the need for blood transfusion and morbidity and mortality in surgical treatment (46-48).
8. As part of a therapeutic treatment; for example, in the embolization of the right portal vein to produce the hypertrophy of the left hepatic lobe, in order to perform right posterior hepatectomy (49-51).
9. Manage persistence of flow out of the light of the endoprosthesis, when repairs of aortic aneurysms are made endovascularly (1).

Conclusion

There is a wide range of embolization elements and multiple indications, for which the realization of a procedure under a valid indication and an adequate selection of the work elements are fundamental to achieve the adequate result (51).

Over the years, the techniques and materials used have evolved and the use of this therapeutic modality has been extended as an alternative to more invasive procedures with greater comorbidities.

It should be noted that embolization is a method with low morbidity, because it is minimally invasive and is ideal for patients with contraindications for conventional or high-risk treatments and difficult surgical approaches. Similarly, it has been shown that blood transfusion requirements decrease, improves the patient's stabilization time (51), which allows rapid control of hemorrhage.

Additionally, embolization avoids the trauma implied by the surgical act per se, collateral trauma that is inevitable, since in surgery it is necessary to cut, expose tissues and vessels, separate ligations, etc. From the skin to the target to be treated, surgery must open the way affecting tissues, which does not occur in embolization, since in this procedure the approach and treatment are done inside the light of the same vessel that is going to be treated.

Embolization is a procedure that is performed frequently in our institution, and over the years they have increased both the number of patients treated by this method and the complexity of them.

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