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ORIGINAL ARTICLE

Materials in embolotherapy of high-flow priapism: results and long-term follow-up

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PURPOSE
To review our experience with embolic materials used in the selective arterial embolization of high-flow priapism and present the results of long-term follow-up.

MATERIALS AND METHODS
Eight patients with traumatic high-flow priapism were reviewed. The patients were evaluated with clinical findings, laboratory examinations, and imaging findings including color Doppler ultrasonography and angiography. Diagnostic angiography demonstrated a connection between the cavernosal artery and the corpus cavernosum. Fistulas were embolized using autologous blood clot, polyvinyl alcohol particles, detachable coils, or acrylic glue. One or more procedures per patient were needed to achieve success.

RESULTS
Eleven embolization procedures were performed in eight patients. Immediate resolution of priapism was obtained after the procedures. Three patients (37.5%) had recurrence of priapism in the subsequent 1–3 weeks and required a repeat procedure. After the final procedures, all patients had complete resolution of priapism. Normal recurrence of erectile function was obtained in six of the patients (75%) after the final embolization.

CONCLUSION
Selective arterial embolization is a useful therapeutic option in the management of patients with high-flow priapism. Various materials can be used successfully as embolizing agents in the procedures according to the patient's status.

Key words: • *priapism* • *embolotherapy* • *radiology, interventional* • *erectile dysfunction*

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Priapism is defined as a persistent erection that is not associated with sexual desire and which does not subside after sexual intercourse or masturbation (1). Three types of priapism are described: low-flow (ischemic), high-flow (non-ischemic), and recurrent (2). Low-flow or veno-occlusive priapism is the most common type. The underlying mechanism is obstructed venous outflow, leading to a painful, engorged penis. Owing to the resulting anoxia, the condition necessitates early intervention and treatment, as lack of treatment results in necrosis and fibrosis with subsequent erectile dysfunction (3).

In contrast, high-flow priapism is a rare condition; it differs from low-flow priapism in that there is a direct arterial connection to the corpus cavernosum, frequently following perineal or penile trauma. It is not a medical emergency since venous outflow remains intact and there is no ischemia to the corporal tissue (4). However, the same patients may have ischemic or non-ischemic episodes (2).

Selective transcatheter arterial embolization is the current treatment of choice in cases of high-flow priapism. Herein, we present our experience with different embolic materials used in the selective arterial embolization of eight patients with high-flow priapism.

Materials and methods

From 2002 to 2007, eight patients with high-flow priapism were treated at four institutions. Patients ranged from 2 to 65 years of age, with a mean age of 29 years. All patients had a history of perineal or penile trauma, followed by persistent erection >6 hours. One patient (patient 5) had a history remarkable for self-injection of papaverine. Table summarizes the patients' age, duration of priapism, imaging findings, location of lesions, number of embolizations, embolic materials, and post-procedure erectile function.

The diagnosis of priapism was established by history and physical examination performed in urology clinics. Except for the 2-year-old patient (patient 7), cavernous body blood gases were investigated, revealing arterial blood. The finding of arterial blood in the clinical setting of priapism supported a diagnosis of non-ischemic high-flow priapism.

After clinical and laboratory examinations, color Doppler ultrasonography (US) was performed in all patients. In seven of the patients, US examinations showed a focal hypoechoic area indicating pseudoaneurysm with high velocity flow in the injured corpora cavernosa. The 65-year-old patient (patient 5) had increased cavernous blood flow without a focal hypoechoic area.

The diagnosis was confirmed by arteriography, including flush angiography of the pelvis followed by selective catheterization of the internal iliac and/or pudendal vessels in all patients. Angiograms revealed pseudoaneurysms originating from deep cavernosal and/or bulbourethral ar-

teries with fistulas to the corpora cavernosa in 7 of the patients (Fig. 1). In one patient (patient 5), there were several small fistulas of the left deep cavernosal artery at the base of the penis resulting in early venous return, without pseudoaneurysm (Fig. 2a). The lesions were bilateral in 3 patients, right-sided in 2 patients, and left-sided in 3 patients. In one of the patients with a left sided-lesion, there was only one cavernosal artery ending in a pseudoaneurysm with a fistula, and the right side was hypoplastic (patient 2).

After demonstrating the arteriocavernosal fistulas, a decision to use selective transcatheter embolization of the lesions was made in each case. After informed consents were obtained, the embolization procedures were performed; these were done under local anesthesia with deep sedation in adult patients and under general anesthesia in the 2-year-old patient (patient 7). After catheterization of the internal iliac and/or pudendal vessels at the lesion sides with a selective diagnostic catheters (Cobra or Simmons 1, Terumo Medical Corporation, Tokyo, Japan), a coaxial system using a microcatheter (Rapid Transit, Cordis, Miami, Florida, USA) with a micro-guide wire (Terumo Medical Corporation, Tokyo, Japan) was used to reach as close as possible to the lesions under roadmap. An agent to prevent vasospasm (glyceryl trinitrate 0.1–0.2 mg) was applied intra-arterially when necessary. A test injection through the microcatheter was then performed to demonstrate free flow without vasospasm or occlusion. Thereafter, embolizations were performed. Embolizing agents used included autologous blood clot, polyvinyl alcohol (PVA) particles (Contour-PVA Embolization Particles, Target Therapeutics, Boston Scientific Corporation, USA), detachable coils (Micrus Endovascular, San Jose, California, USA), and acrylic glue (Histoacryl, B. Braun, Melsungen, Germany). After the embolizations, repeat selective angiography was performed to demonstrate occlusion of the lesions.

One patient (patient 5) with several small fistulas of the left cavernosal artery to the corpora cavernosa was treated with 150–250 µm PVA particles (Fig. 2b). Embolic material was prepared as a suspension in a solution of nonionic contrast medium diluted to half concentration with saline.

One of the patients (patient 4) was mentally retarded. The pseudoaneurysm originating from his right cavernosal artery was occluded with acrylic glue. A mixture of 0.5 mL n-butyl-2 cyanoacrylate (NBCA) diluted with 0.5 mL ethiodized oil (Lipiodol; Guebert Laboratories, Aulney-sous-Bois, France) was prepared (50% diluted glue). The mixture was injected through a microcatheter prefilled with 5% dextrose with gentle pressure to avoid backflow.

Autologous blood clots were used as the first embolic material in the three patients with bilateral lesions (patients 1, 3, 7) and in three patients with unilateral lesions (patients 2, 6, 8), including the patient with a single left cavernosal artery (Fig. 1c, d). The blood clot was prepared by removing 15–20 mL of the patient's blood, and leaving it to stand in a Petri dish for 4 to 5 min to allow partial coagulation. The clot was then pierced into smaller parts with a lancet, increasing the ease of injecting it through the microcatheter. Pierced parts of the clot were mixed with nonionic contrast medium to observe any unintended backflow during the injections. The mixture was then aspirated into a syringe and injected through the microcatheter. Three to 4 mL of the mixture was usually a sufficient amount to produce embolization.

Two patients with bilateral lesions (patients 3, 7) and one patient with unilateral right sided lesion (patient 8) were cured using autologous blood clot alone. The remaining three patients showed recurrences of priapism in the following 1–4 weeks (patients 1, 2, 6). Control angiograms of the patient with bilateral lesions (patient 1) showed

Table. Parameters of the patients in the study

	Age (y)	Priapism duration (days)	Color Doppler findings	Angiography findings	Side of lesion	Number of procedures	First embolic material	Second embolic material	Post-procedure erectile function	Follow-up period (months)
Patient 1	25	15	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Bilateral	2	Autologous blood clot	Detachable coil	Preserved	60
Patient 2	23	45	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Left[a]	2	Autologous blood clot	Detachable coil	Lost	40
Patient 3	29	5	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Bilateral	1	Autologous blood clot	-	Preserved	24
Patient 4	42	5	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Right	1	NBCA	-	Lost	42
Patient 5	65	2	Increased cavernous blood flow	Fistula	Left	1	PVA	-	Preserved	60
Patient 6	23	20	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Left	2	Autologous blood clot	NBCA	Preserved	52
Patient 7	2	2	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Bilateral	1	Autologous blood clot	-	Preserved	20
Patient 8	25	10	Focal hypoechoic area + high velocity flow	Pseudoaneurysm + fistula	Right	1	Autologous blood clot	-	Preserved	38

[a]single left cavernosal artery, hypoplastic right cavernosal artery
PVA, polyvinyl alcohol; NBCA, n-butyl-2 cyanoacrylate.

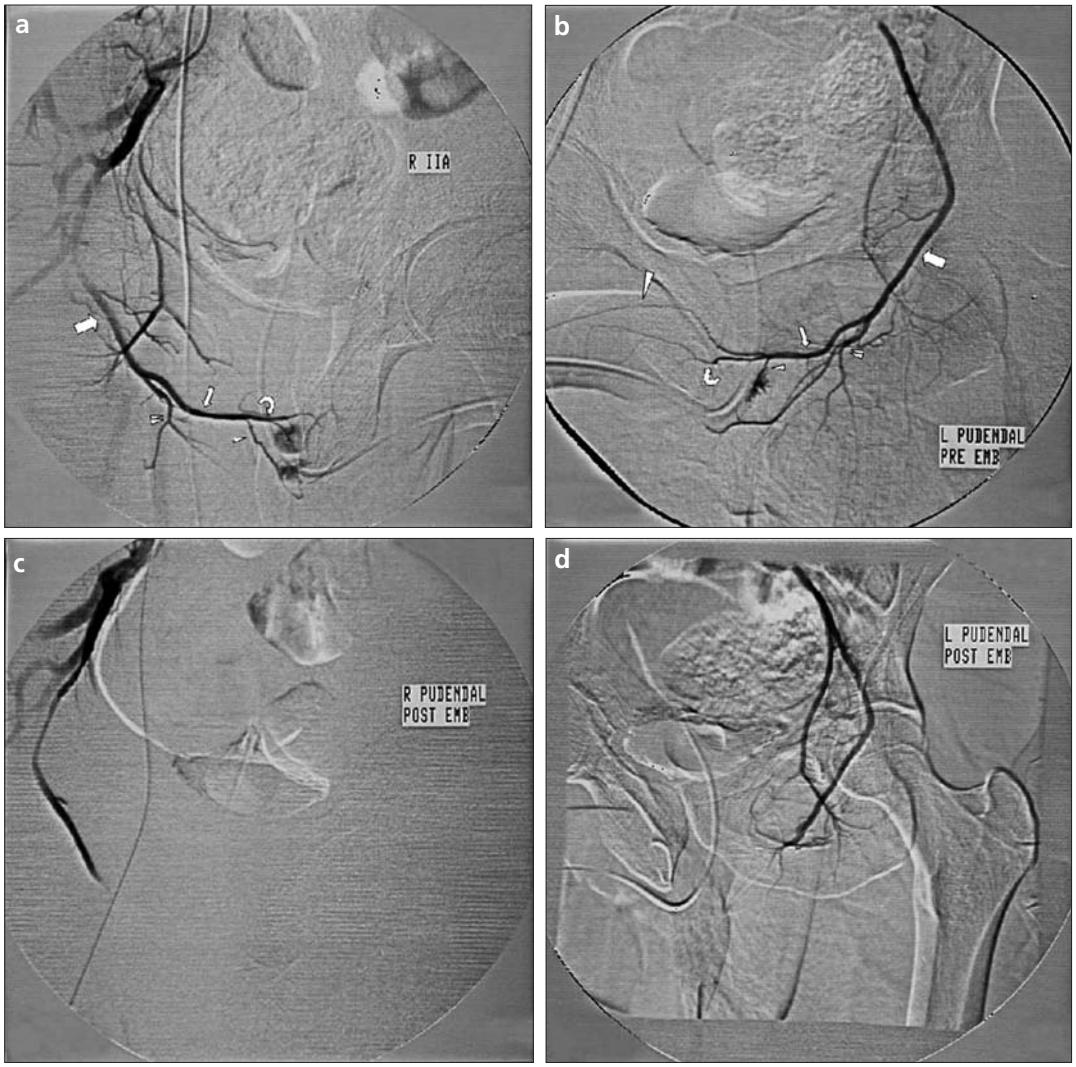

Figure 1. a–d. Angiograms of the right internal iliac artery **(a)** and the left pudendal artery **(b)** show internal pudendal arteries *(large arrows)* dividing into the perineal-scrotal arteries *(double arrowheads)* and penile arteries *(small arrows)* further dividing into the bulbourethral arteries *(small arrowheads)* and deep cavernosal arteries *(curved arrows)* on both sides. The dorsal penile artery is not seen on the right side while observed on the left side *(large arrowhead)*. Two pseudoaneurysms originating from both the bulbourethral artery and the deep cavernosal artery on the right side **(a)** and one pseudoaneurysm originating from the bulbourethral artery on the left side **(b)** were noticed. Control angiograms of the right **(c)** and left **(d)** internal pudendal arteries after embolization with autologous blood clot display nonfilling of pseudoaneurysms as well as the perineal, penile, deep cavernosal, and bulbourethral arteries.

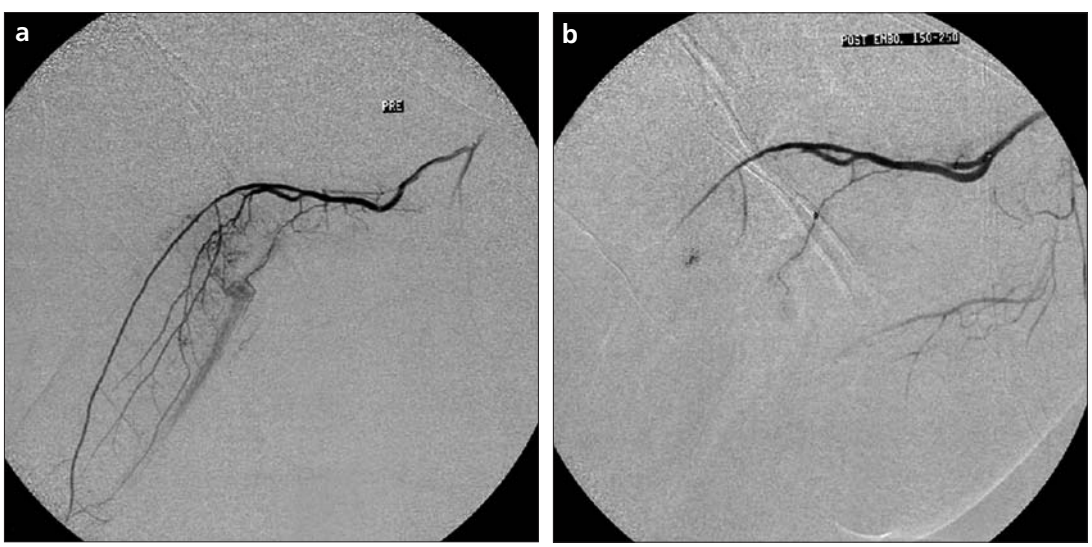

Figure 2. a, b. Superselective angiogram of the left penile artery **(a)** shows several small fistulas filling from the left deep cavernosal artery at the base of the penis with early venous return. There is no pseudoaneurysm observed. Control angiogram **(b)** after embolization with polyvinyl alcohol particles reveals disappearance of the fistulas.

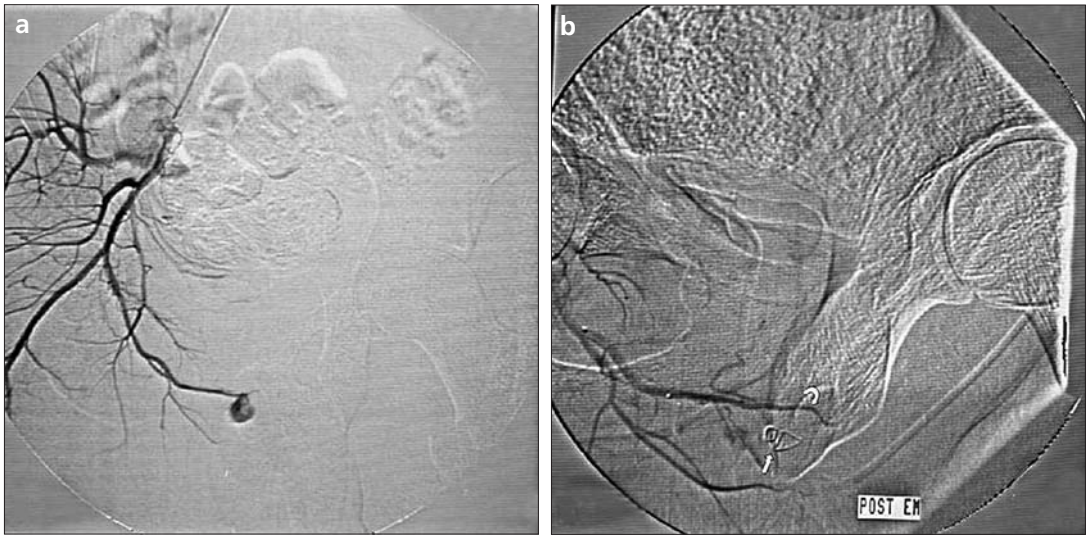

Figure 3. a, b. Second angiogram of the right internal iliac artery of the same patient as in Figure 1 that was obtained due to the recurrence of priapism **(a)** shows the recanalization of the right penile, perineal and deep cavernosal arteries with pseudoaneurysm of the cavernosal artery. The pseudoaneurysm of the right bulbourethral artery in the previous angiogram is no longer seen. Control angiogram **(b)** of the right internal pudendal artery after superselective embolization with two detachable microcoils *(arrow)* shows that the pseudoaneurysm was completely occluded with restoration of the distal filling of the right deep cavernosal artery *(curved arrow)*.

that one side was occluded, while the other side was recanalized. Pseudoaneurysm in the recanalized side was superselectively filled with detachable coils while preserving the deep cavernosal artery patent in this patient (Fig. 3). Angiograms of the two patients with unilateral lesions (patients 2, 6) revealed recanalization. In the patient with a single left cavernosal artery (patient 2), repeat embolization of the pseudoaneurysm with detachable coils was performed. Because of complete transection of the artery, restoration of the deep cavernosal artery was not achieved. In the last patient (patient 6) with a unilateral lesion, repeat embolization was performed with acrylic glue as described for patient 4.

The patients were followed up at 6 weeks and 6 months with both clinical findings and penile color Doppler US examinations. After one year, they were followed up annually with clinical assessment only. The average follow-up was 40 months (range, 20–60 months), and two patients were followed up for 5 years.

Results

A total of eleven embolization procedures were performed in eight patients. There was initially complete resolution of priapism after all procedures. However, three patients (patients 1, 2, 6) experienced recurrent priapism and required repeat embolizations in the subsequent 1–4 weeks. No further recurrence of priapism was observed after the final embolizations.

All patients had uneventful recovery without complications such as leg numbness, claudication, bleeding, embolic symptoms, or infection. Upon discharge, all patients (except for the 2-year-old patient) were instructed to avoid sexual intercourse for a period of 6 weeks following embolization.

Follow-up revealed normal recurrence of early morning erections in six of eight (75%) patients within a 6-week period after the final embolizations. Two patients in our series (25%) lost their erectile capabilities (patients 2 and 4). The mentally retarded patient was the one of two (patient 4). It was noted, however, that he sometimes had ejaculations without erections. The other patient with difficulty maintaining an erection was the patient who had a single left cavernosal artery (patient 2).

Discussion

The aim of therapy in the non-ischemic high-flow priapism is to close the arterial fistula without jeopardizing erectile function (5). Treatment options are mechanical (sustained perineal compression), pharmacological (intracavernous administration of α-adrenergic agonists or methylene blue), surgical (shunt surgery, ligation of the internal pudendal artery), and radiological (selective transcatheter embolization) (6–11).

The American Urological Association (AUA) guidelines include a management algorithm for priapism (12). They recommend "observation" as initial management of non-ischemic (high-flow) priapism. If conservative management fails, invasive treatment options (embolization or surgery) are indicated. Immediate invasive procedures are carried out if requested by the patient. Selective arterial embolotherapy is recommended as the first-line invasive procedure. Surgical management (shunt surgery, ligation of the internal pudendal artery) is the last option for longstanding cases.

Conservative treatment includes compressive perineal dressing with or without ice packs, in hope of leading to vasospasm and thrombosis of the ruptured artery in days to weeks. This approach may achieve detumescence only if used early in the course of priapism. A spontaneous resolution rate of up to 60% can be obtained with conservative treatment according to the published series (2). However, using conservative treatment with a strategy of watchful waiting has the theoretical disadvantage of possible structural alteration resulting from excessive arterial inflow, as well as social and psychological difficulties related to the condition (6). Although there is no risk of ischemic damage, because there is no decrease of oxygen saturation in the cavernous bodies, excessive arterial inflow with high

oxygen levels and chronic erection may be deleterious to the cavernosal smooth muscle and connective tissue matrix (13, 14). It may cause corporal fibrosis leading to a secondary erectile dysfunction in the long term (5).

Selective arterial embolization for the high-flow priapism, first described by Wear et al. in 1977, is the current therapy of choice in experienced hands (15). Higher detumescence and lower postprocedure erectile dysfunction rates associated with the procedure have been reported (16). It can be performed with the following embolizing materials: autologous blood clot, gel-foam, PVA, coils, and NBCA (17–21). In our patients, all of these materials except gelfoam were used.

Autologous blood clot is a temporary occlusive agent, thus permitting cicatricial closure of the arterio-cavernosal fistula and subsequent re-channeling of the embolized artery (17). Due to the temporary interruption of the blood flow feeding the fistula, it seems to represent an ideal embolic material. However, the recurrence of priapism is frequent because of premature lysis of the clots (22). Therefore, multiple sessions of arterial embolization may be necessary within a month of the first arterial embolization (5, 20).

Gel-foam produces temporary interruption of the arterial blood flow like the autologous clot because of its absorbable property. Its occlusive effect lasts 5 to 6 weeks after being injected. Thus, it shares the same advantages and disadvantages of the autologous clot (18, 23). We did not use gel-foam in any of our cases, because of practical reasons of using the autologous clot as compared to the gel-foam.

Non-resorbable particles such as PVA lead to more durable occlusions, although late recanalizations are reported (24). They have been used successfully in embolotherapy of high-flow priapism (11, 19). Use of PVA particles carries a danger of unintentional peripheral embolization if care is not taken to avoid the proximal reflux. In our series, only one patient was treated with PVA particles. Multiple small fistulas in the cavernosal artery were successfully treated with PVA particles, which have excellent ability to penetrate microvascular structures.

Microcoils are permanent filling materials. The use of microcoils in the treatment of priapism was first described by Callewaert et al. (25). They embolized common penile arteries with microcoils bilaterally without erectile dysfunction. Detachable (and therefore retrievable) microcoils are deposited very accurately, allowing either embolization of the feeding arteries or selective occlusion of the pseudoaneurysm (20). There is a theoretical risk of erectile dysfunction if the treatment has been performed via occlusion of the cavernosal arteries with the coils, especially in bilateral lesions. However, using selective occlusion of the pseudoaneurysm with detachable microcoils, no additional risk of erectile dysfunction is present. In unilateral lesions, occlusion of the cavernosal arteries does not seem to have an increased risk of erectile dysfunction (20). Therefore, we did not use coils as bilateral embolic agents. We postulated that using microcoils in unilateral lesions provided the advantage of embolizing only the fistula site by preserving the distal and parenchymal vasculature and collateral vessels.

NBCA is a permanent embolizing agent that quickly polymerizes when in contact with an ionic medium such as blood, resulting in immediate vascular occlusion (21). There is a risk of gluing of the microcatheter tip to the artery during the procedure if it is not withdrawn in a timely fashion. When using NBCA, the occlusion site and extent cannot be adjusted as accurately as it can be when using microcoils. Hence, its use needs experience and extreme care. Because it is a permanent material, it has the same theoretical risk of erectile dysfunction as microcoils.

Absorbable embolic materials are preferred in embolotherapy of bilateral high-flow priapism, since no collateral blood flow is available from the contralateral side. Also, dissolution of the embolic material was thought to be essential for restoring arterial flow and decreasing the risk of erectile dysfunction. This is especially important in patients with bilateral fistulas (26). Therefore, we decided to use the autologous blood clot as an initial embolization agent for both all bilateral lesions and 3 of 5 unilateral lesions. However, as was shown in our series, premature thrombolysis and recurrent priapism requiring reintervention occurred on occasion.

In unilateral lesions, the choice of temporary versus permanent occlusive agents is controversial. Although the literature suggests the use of permanent embolic materials be reserved for patients with recurrent priapism after an initial procedure with temporary embolic agents, permanent materials can be used for primary embolizations by experienced physicians in selected cases with unilateral lesions, since higher priapism resolution rates can be achieved with permanent occlusive agents (21, 27). We used NBCA, a permanent embolic material, for primary embolization in one patient (patient 4, mentally retarded) with a unilateral large fistulous lesion. Advantages and disadvantages of temporary and permanent occlusive agents in the procedures were explained to the patient's family. Because of the probability of recurrence with temporary occlusive agents was particularly high with a large fistulous lesion, the family requested definitive treatment despite the potential risk of erectile dysfunction. Although erectile function of the patient was lost after the procedure, it may not have been related to the use of permanent agent because of the unilateral nature of the condition. Considering the complex mechanisms of erection, there may be several factors causing loss of erection.

Although surgery is the traditional treatment method in high-flow priapism, it is more invasive, less efficacious, and associated with higher rate of erectile dysfunction than is arterial embolotherapy (16, 28, 29). A wide range of surgical procedures is described for this type of treatment, including proximal ligation of the internal pudendal artery; shunting procedures; penile exploration including incision, irrigation, and drainage of corporeal sinuses; and percutaneous aspiration of the corpus cavernosum (3). Possible postoperative complications include infection with abscess formation, urethral injury, and penile hematoma (3). The success rate of these procedures ranges from 20% to 65%, depending on the definition of success (16, 29). The major problem with these surgical procedures is the high rate of erectile dysfunction (50%) (28, 29). Therefore they should only be used after failed treatment with selective arterial embolization, as recommended in the AUA guidelines (12).

Radiologic arterial embolizations are superior to surgery in rates of both detumescence and potency (100% and 86% to 91%, respectively) (4, 17). A comprehensive review about the diagnostic and therapeutic concepts in high-flow

priapism evaluated 202 patients collected since 1960, treated with either surgery or embolization (16). The investigators defined the procedural success as restored erectile function without recurrent priapism. By these criteria, success rates of 20% for surgery and 89% for arterial embolization were reported.

Our results are similar to those of other reports in literature regarding the rate of resolution of priapism (100%). However, in restoration of erectile capacity, our success rate (75%) was lower than that reported by others. Bilateral lesions also occurred more frequently (37.5%) in our data than in the reports of others. If the patient with a variational single cavernosal artery is included in this ratio, it reaches 50%. This ratio was 27% in the series of Numan et al. (17). It is possible that the high rate of bilateral lesions in our data may be the cause of the relatively lower rate of restoration of erectile capacity.

Recurrence rates of 30–40% have been reported after treatment by selective embolization in high-flow priapism (5, 17, 18). Considering all of the patients, our recurrence rate was 37.5%, (3 of 8 patients), within the limits in the literature. However, in the group embolized with the temporary embolic material (autologous blood clot), our recurrence rate was 50%, (3 of 6 patients), which is a little higher than reported in the literature. It may be due to differences in the tear size of the injured vessel or in the clot lysis time between our patients and others. In our patients who had recurrence of priapism, a second procedure with another embolizing material provided definitive detumescence.

There are few reports in the literature concerning long term follow-up results for high-flow priapism after embolotherapy (4, 5, 30). The recurrence rate of priapism varies from 0% to 40% after 6 months and 0% to 20% after one year. In our series, minimum and average follow-up periods were 20 and 40 months, respectively. After 6 months or more of follow-up, none of our patients had new recurrence of priapism or erectile function loss.

In conclusion, selective arterial embolization is the current therapy of choice in the treatment of high-flow priapism. It can be performed with different embolizing agents that are either temporary (absorbable) or permanent. Temporary embolizing materials, such as autologous blood clots, are preferred in bilateral lesions. In patients with multiple small fistulas in the cavernosal artery, PVA particles can be successfully used, as they have excellent ability to penetrate the microvascular structures. Permanent embolizing materials such as NBCA or microcoils should be reserved for recurrent priapism after an initial procedure with absorbable materials. However, in selected cases with unilateral lesions, permanent occlusive materials can be used for primary embolizations in experienced hands.

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