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Microembolization Techniques of Vascular Occlusion: Radiologic, Pathologic, and Clinical Correlation

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Vascular occlusion is described using microemboli of a predetermined size for the treatment of neoplastic conditions with a "capillary barrier." Particulated microemboli of either 40–60 μm Gelfoam powder or 200–1,000 μm polyvinyl alcohol foam (PVA) are best. Fluid embolic agents such as silicone fluid are used in lesions without a capillary barrier. The radiographic, pathologic, and clinical results in three patients are described in detail. Microembolization is useful in the treatment of neoplastic conditions for it produces tumor necrosis in addition to hemostasis.

The intraarterial treatment of vascular lesions has been improved by the use of superselective catheter techniques [1–3], small embolic particles [4] and the development of a functional approach to a specific vascular territory [5]. A further refinement of embolization technique in cases where an "arteriolar capillary barrier" is present is the use of microemboli of a uniform *predetermined* size to produce distal arterial occlusion with preservation of the proximal uninvolved vessels. Where the integrity of the barrier is compromised by vascular dilatation, fluid embolic agents introduced during flow arrest can be used to occlude the distal feeding vessels [4, 6, 7]. We describe three patients in detail to illustrate important considerations in devascularization of neoplasms of the brain and facial soft tissues.

Materials and Methods

The catheters or delivery systems and embolic agents that we use have been described previously [3, 4]. For microembolization, we use two types of solid embolic particles: Gelfoam (Upjohn, Fort Lee, N.J.) and polyvinyl alcohol foam (PVA) (Unipoint Ind., High Point, N.C.). Gelfoam, a reabsorbable sponge, is used in powder form with particles 40–60 μm in diameter for the preoperative devascularization of hypervascular neoplasms, and is delivered by small diameter catheters placed superselectively in the feeding pedicle. The blood flow carries the powder into the vasculature into the depths of the tumor where collateralization cannot occur. Double-lumen balloon catheters are useful and should be used whenever possible to selectively control the blood flow and to prevent reflux.

Nonabsorbable polyvinyl alcohol foam (PVA) is made radiopaque with 60% tantalum oxide or 66% barium sulfate, and is cut into predetermined sizes of 200–980 μm diameter using conventional angiographic catheter hand punches. The particles, which are difficult to see fluoroscopically, are suspended in contrast material to allow one to monitor their injection. The fluid embolic agent that we use is a low viscosity silicone fluid mixture described by Hilal and Michelson [8]. It is injected under balloon catheter flow arrest and allowed to vulcanize in the vascular tree of the lesion.

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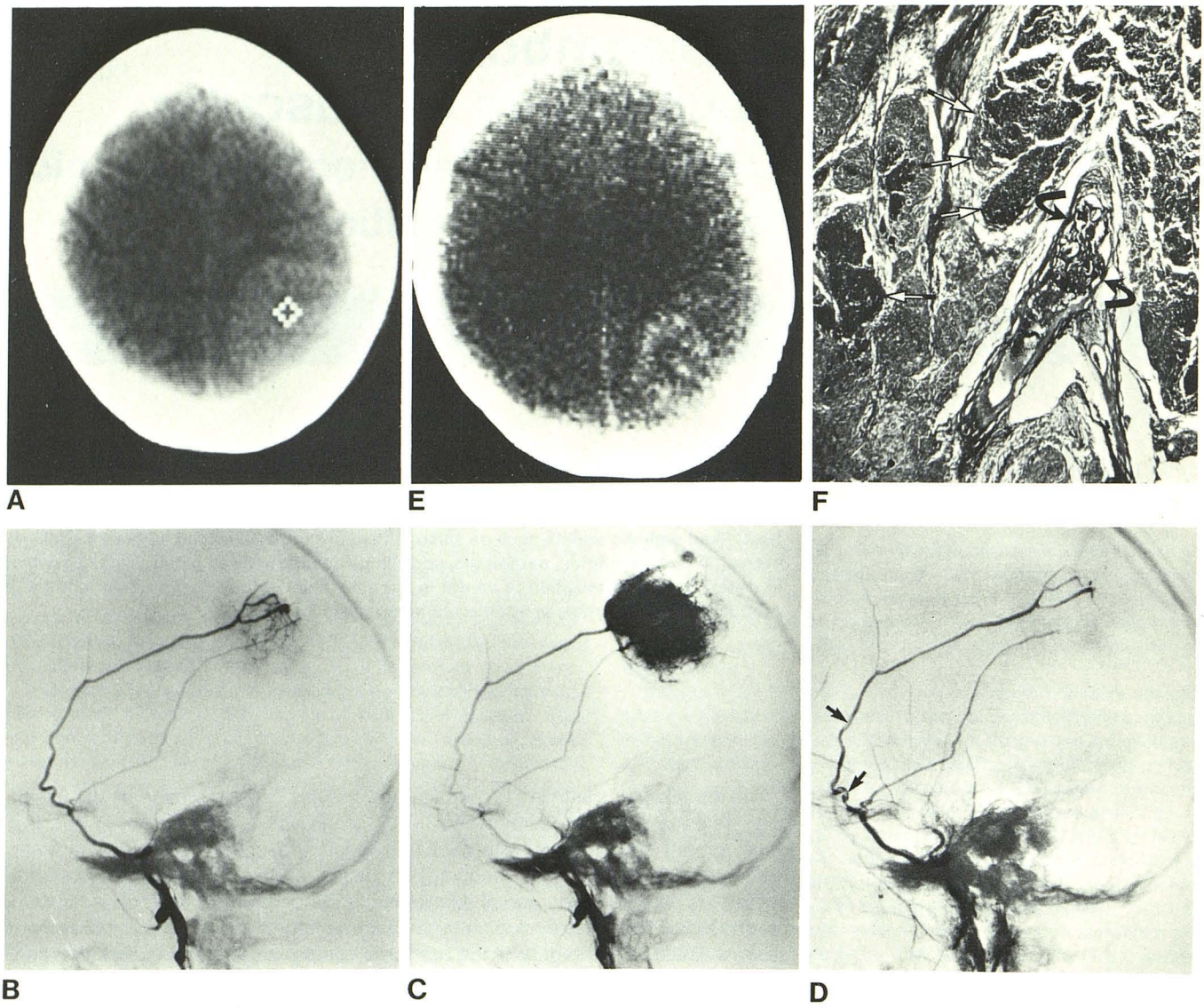


Fig. 1.—Case 1. **A**, Unenhanced scan. Homogeneous area of increased density in left parietal area. Lateral angiograms in early (**B**) and mid (**C**) arterial phases. Hypervascular meningioma supplied by parietal branch of left middle meningeal artery. There is preferential flow toward tumor and no visualization of meningolacrimal artery. **D**, Lateral subtraction angiogram after embolization with 50–60 μm Gelfoam powder, late arterial phase. Middle meningeal artery is preserved but shows filling defects representing emboli (*arrows*). Only tumor bed has been occluded with microemboli. **E**, Unenhanced scan 1 day after embolization. Central area of decreased density within tumor (cf. **A**). **F**, Photomicrograph of meningioma specimen (azocarmine stain). Multiple Gelfoam foreign bodies in small diameter vessels (*curved arrows*). Perivascular necrosis (*arrows*).

Representative Case Reports

Case 1

A 25-year-old woman was seen 1 month before admission with grand mal seizures. Computed tomography (CT) showed a left parietal high convexity meningioma (fig. 1A), which at angiography was shown to be supplied by the left middle meningeal artery (figs. 1B and 1C). No anastomoses between the middle meningeal artery and the ophthalmic or carotid systems were demonstrated during subselective angiography. Multiple microemboli of Gelfoam powder particles of 40–60 μm were injected into the tumor bed with preservation of the proximal middle meningeal trunk (fig. 1D).

Fluoroscopic control of the progressive occlusion was monitored by the washout, or clearance, of the microemboli suspended in angiographic contrast material. Microembolization was stopped when the tumor bed was occluded (fig. 1D). A repeat CT scan without contrast material 1 day after embolization showed a central area of decreased density within the tumor (fig. 1E) that had not been present on the preembolization scan (fig. 1A). The tumor was completely excised 2 days after embolization without significant bleeding. Gelfoam foreign bodies were present in vessels of 40–300 μm diameter and multiple areas of perivascular necrosis were seen (fig. 1F).

Case 2

A 28-year-old woman with a congenital facial hemangioma had received radiation therapy 26 years before without apparent benefit.

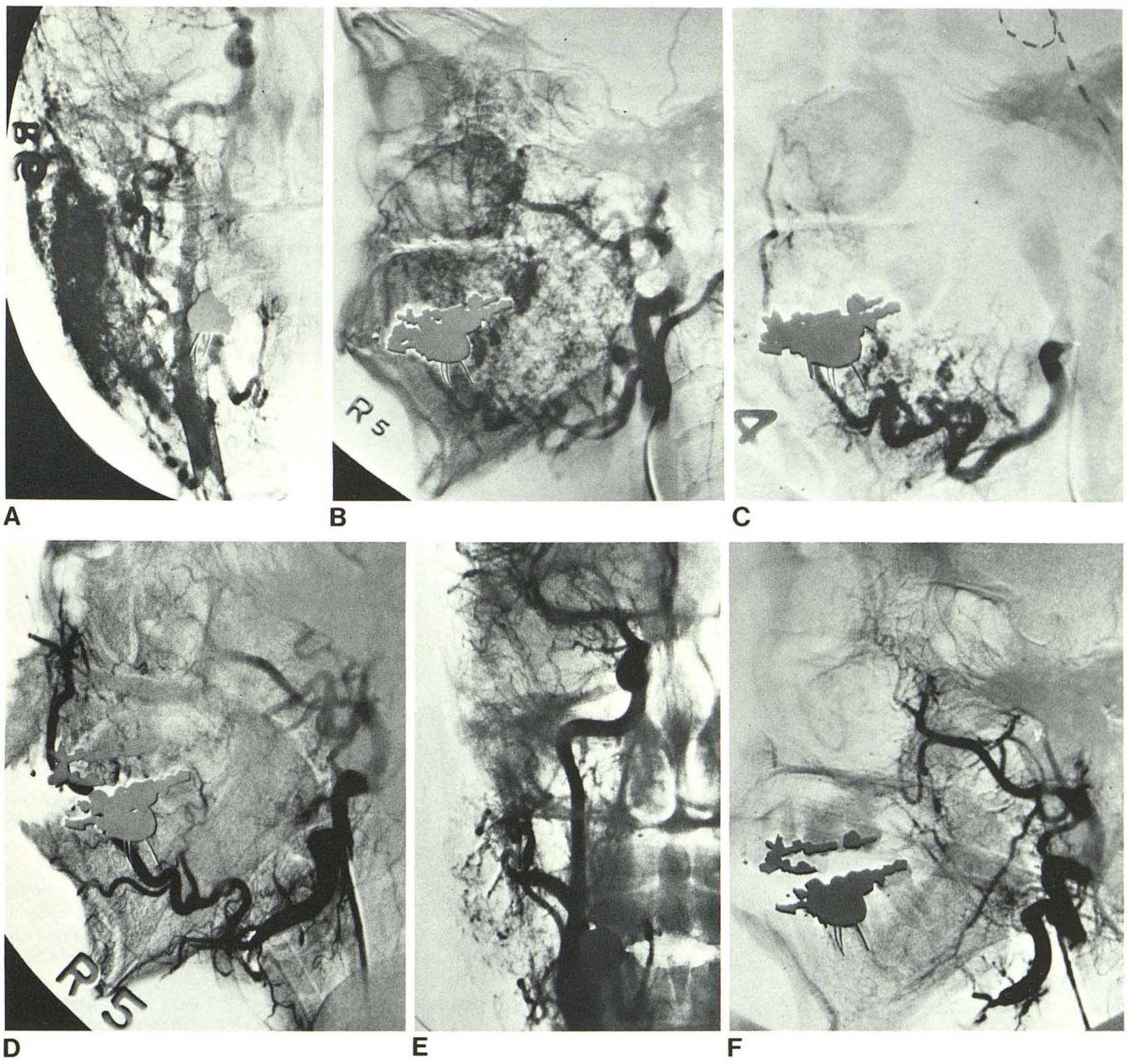


Fig. 2.—Case 2. **A**, Frontal, right common carotid artery angiogram. Note numerous abnormal capillary vessels and thickness of lesion. **B**, Lateral right external carotid angiogram. Right facial, right transverse facial, and right internal maxillary arteries are involved. **C**, Lateral subtraction, right facial artery angiogram. Note capillary network arising from main facial trunk. **D**, Facial artery angiogram after injection of multiple 400 μm particles of PVA. Facial artery is preserved and tumor vessels are occluded. (Reprinted from [4]). **E**, Postembolization frontal subtraction angiogram of right common carotid artery in midarterial phase (cf. **A**). **F**, Postembolization lateral subtraction angiogram of right external carotid artery after embolization (cf. **B**).

At 1½ years before admission an attempted resection of the hemangioma was aborted because of profuse bleeding. Subsequently the lesion increased in size and became "bumpy" due to multiple dilated vascular channels (fig. 6A). A dense rubbery mass was palpable and a loud bruit was audible to the patient and the examiners. Angiography revealed an extensive capillary hemangioma supplied by the right facial artery, the right internal maxillary artery, and the right transverse facial artery (figs. 2A and 2B). The lesion was 3 cm thick and extended from the zygoma to the lower border of the right cheek. The embolization was staged and four procedures were performed at intervals of 2–3 weeks. The first procedure was a subselective catheterization of the right facial artery (fig. 2C) with injection of 400–560 μm PVA particles, resulting in occlusion of small vessels with preservation of the main facial trunk (fig. 2D). At a second stage procedure 3 weeks later, we noted new vessels to the hemangioma from the main facial artery; therefore, the more proximal facial trunk was occluded with larger PVA particles.

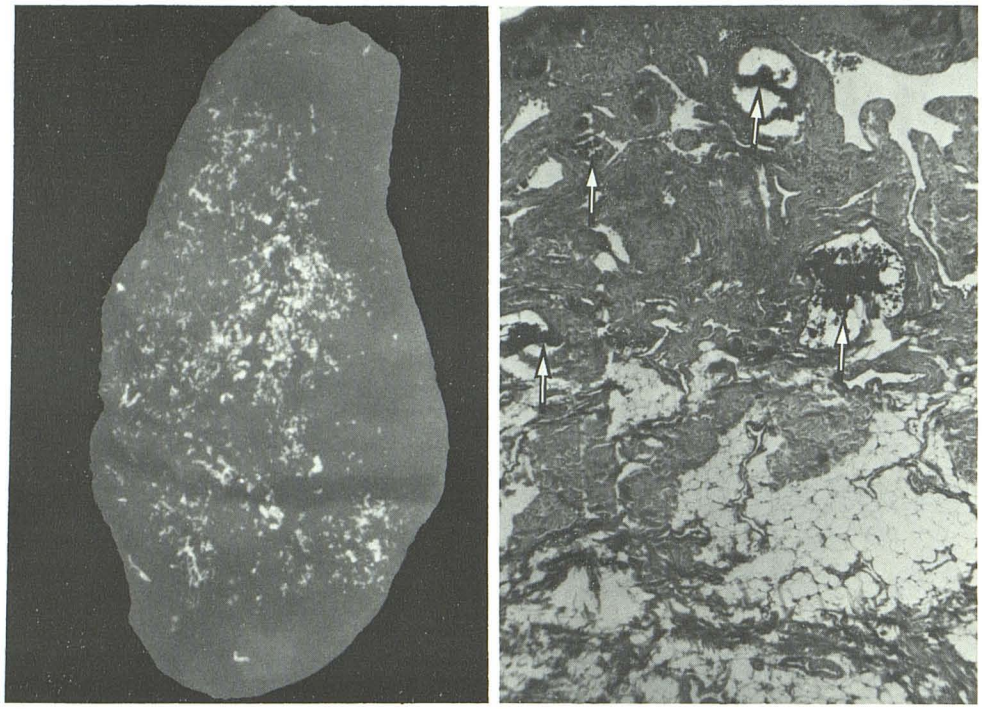


Fig. 3.—Case 2. **A**, Radiograph of skin specimen. Multiple radiopaque microemboli. **B**, Photomicrograph of skin specimen. Microemboli in vessels of 300–400 μm diameter (*arrows*).

The same technique was used in the internal maxillary artery at a third session. Microembolization of the transverse facial artery was carried out at a fourth session, and that artery was occluded proximally. The last angiogram showed no supply to the lesion (figs. 2E and 2F). There was a considerable decrease in the bulk of the mass and the bruit was no longer present. Surgical removal of the lesion was accomplished with a total blood loss of 250 ml and a split thickness skin graft was performed 2 days later. A film of the skin specimen showed multiple radiopaque microemboli (fig. 3A), which on microscopic examination were seen to be in vessels 400–1,000 μm in diameter (fig. 3B). At 1½ years later there had been no recurrence; some involution was seen at the edges of the skin graft (fig. 6B).

Case 3

A 4½-year-old girl had massive bleeding from her left gingiva. A selective external carotid angiogram showed an extensive vascular hemangioma of the left maxillary area extending to the roof of the mouth and gingiva with prominent arteriovenous shunts (fig 4A). In January 1977, before other materials became available, the left internal maxillary artery was embolized with Gelfoam macroparticles and Pantopaque with a good angiographic result (fig. 4B). Rebleeding occurred 3 months later. A repeat angiogram showed recanalization of the left internal maxillary artery, which was then embolized with 560 μm particles of dry compressed expansile PVA [4]. Relatively distal complete occlusion of the internal maxillary artery was obtained. The remaining hemangioma still filled through the left transverse facial artery, ascending palatine artery, and proximal branches of the left internal maxillary artery. At this time we estimated that more than 60% of the lesion had been occluded.

The patient remained asymptomatic for 5 months when gingival bleeding once again recurred. Repeat angiography showed a blood supply through the nonembolized vessels visualized previously. The transverse facial and ascending palatine arteries were selectively catheterized and low viscosity radiopaque silicone fluid was injected using a double-lumen balloon catheter to arrest the blood flow while the silicone vulcanized (fig. 4C) [6]. This embolization accomplished occlusion of the gingival part of the hemangioma (fig. 4D) so that a biopsy could be carried out without bleeding. The biopsy demonstrated an angiomatous hemangioma [9] with silicone occluding 40 μm vessels (fig. 4E). Skin discoloration occurred during the embolization of the transverse facial artery due to the black tantalum powder used to radiopacify the silicone fluid (fig. 7) (we now use white tantalum oxide for skin surfaces of white patients and black tantalum for black patients).

The patient remained asymptomatic for 1½ years before bleeding recurred. Angiography showed the previouly embolized vessels to be occluded, but the lesion was now supplied by the proximal branches of the internal maxillary artery. The feeding branches were successfully catheterized and embolized with low viscosity silicone fluid and tantalum oxide, obtaining 95% occlusion of the hemangiomatous nidus (fig 5) with considerable reduction of the patient's facial asymmetry. No surgery was performed: the extensive involvement would require a radical disfiguring operation without guarantee of preventing recurrence (fig. 7). The patient was still asymptomatic after 1½ years.

Discussion

The first two cases demonstrate the application of microembolization of the external carotid artery in lesions that have an "arteriolar-capillary barrier" where the emboli will lodge. In such cases microembolization offers a considerable advantage over surgical ligation or large particle em-

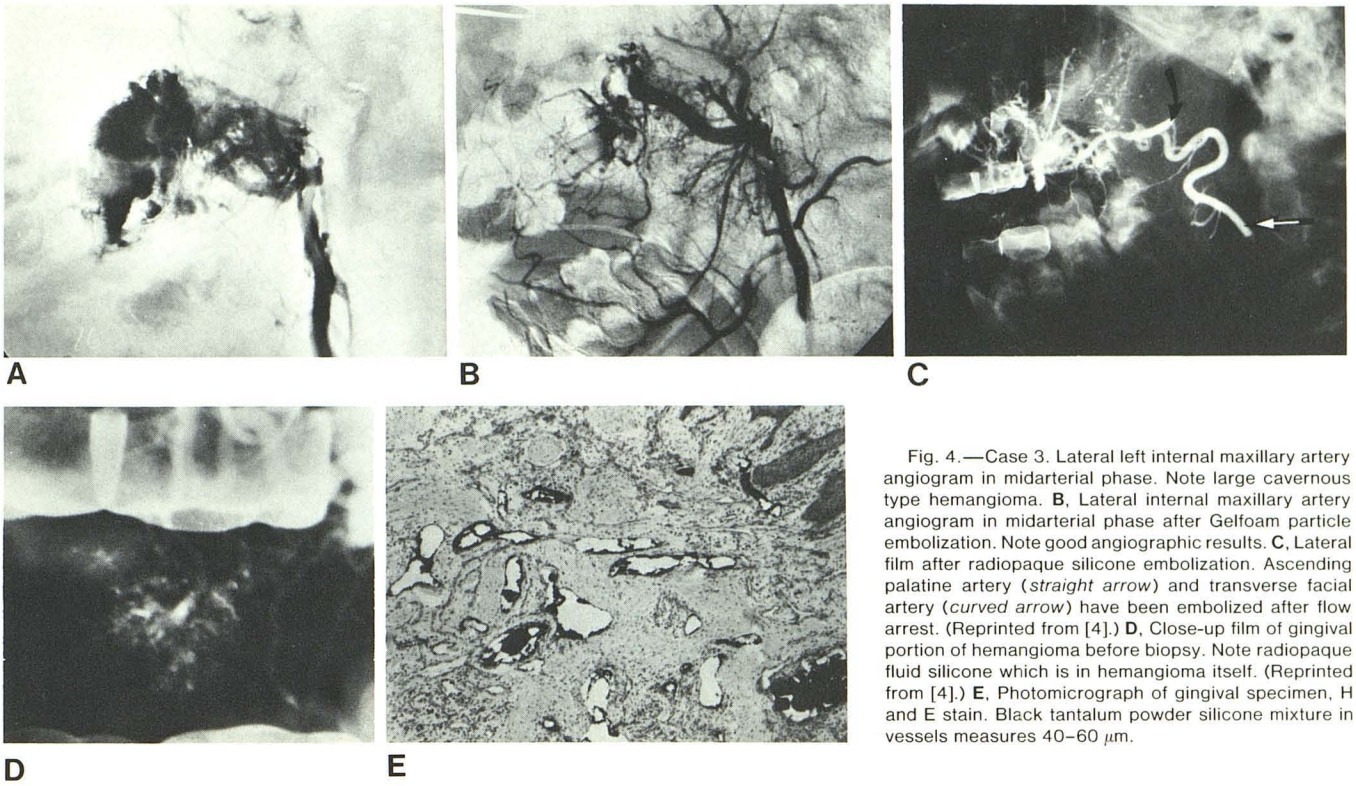


Fig. 4.—Case 3. Lateral left internal maxillary artery angiogram in midarterial phase. Note large cavernous type hemangioma. **B**, Lateral internal maxillary artery angiogram in midarterial phase after Gelfoam particle embolization. Note good angiographic results. **C**, Lateral film after radiopaque silicone embolization. Ascending palatine artery (*straight arrow*) and transverse facial artery (*curved arrow*) have been embolized after flow arrest. (Reprinted from [4].) **D**, Close-up film of gingival portion of hemangioma before biopsy. Note radiopaque fluid silicone which is in hemangioma itself. (Reprinted from [4].) **E**, Photomicrograph of gingival specimen, H and E stain. Black tantalum powder silicone mixture in vessels measures 40–60 μm.

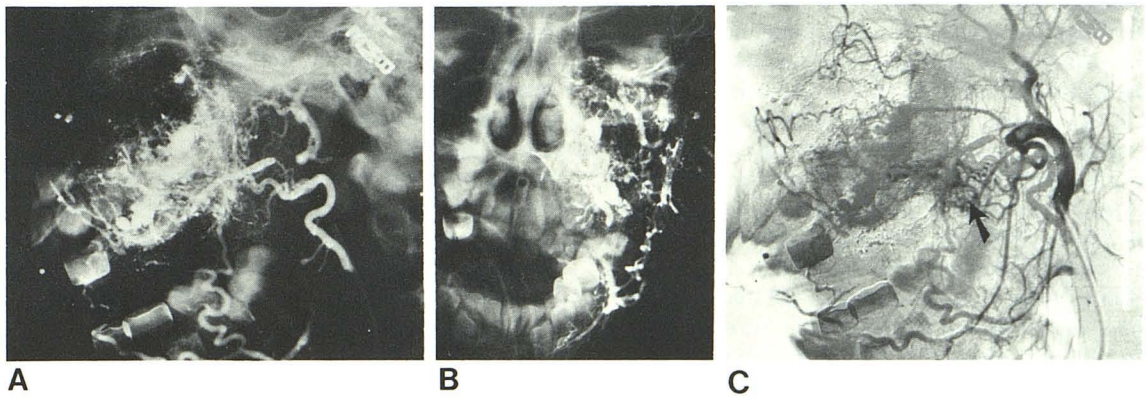
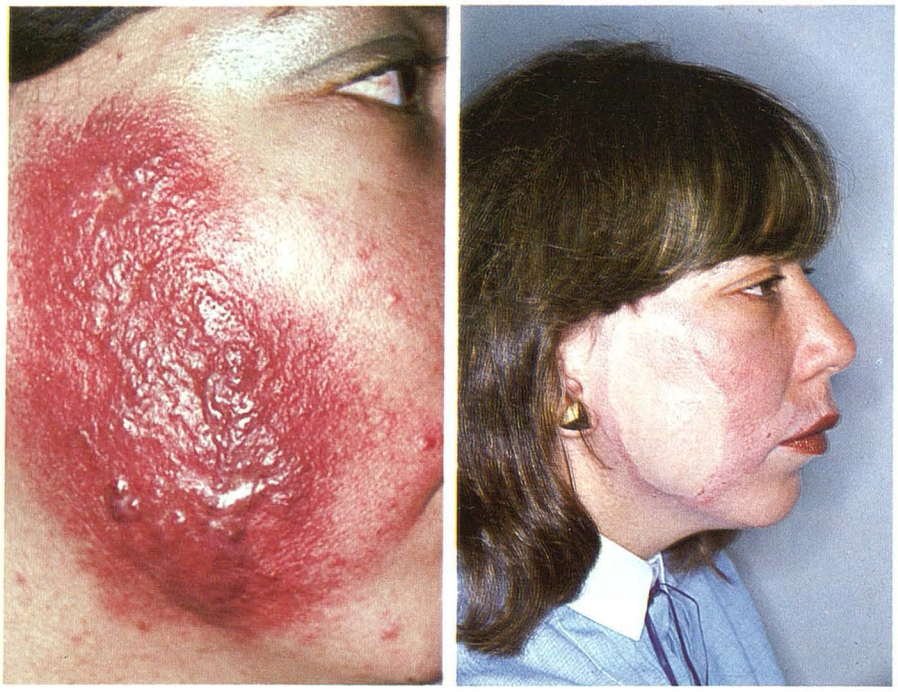


Fig. 5.—Case 3. Frontal (**A**) and lateral (**B**) films after the last embolization. Hemangioma has radiopaque cast. **C**, Lateral subtraction angiogram, late arterial phase. There is 95% occlusion of lesion with filling of only a very small part (*arrow*).

bolization by accomplishing occlusion of the capillaries or precapillary vessels.

Preoperative microembolization of the dural blood supply of meningiomas simplifies surgery by decreasing bleeding and it may also decrease tumor recurrences by specifically producing necrosis at the site of dural attachment. In case 1, we elected to preserve the proximal middle meningeal artery to avoid occluding its petrosal branch, which arises near the foramen spinosum so as to preserve its blood supply to the seventh nerve [10]. This branch is the main arterial supply to the peripheral facial nerve in 25% of cases [11]. Placement of the catheter tip 15 mm beyond the foramen spinosum should be attempted. Technically this is difficult to accomplish, and frequently preferential flow must be used to carry the emboli beyond the origin of the petrosal artery. Since the origin of the petrosal branch is about at right angles from the middle meningeal artery, geometric linearity causes the emboli to bypass the branch. If the meningolacrimal artery is visualized before embolization, 40–60 μm embolic particles should not be used because of the danger of ophthalmic or internal carotid artery embolization. If necessary, it is simple to occlude the proximal



A B

Fig. 6.—Case 2. **A**, "Red" hemangioma before treatment. Venous channels are dilated. **B**, 1½ years later. Some involution at graft edges.

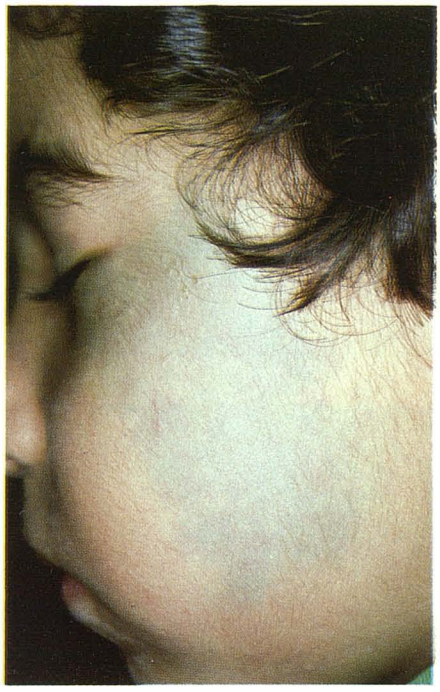


Fig. 7.—Case 3. Dark discoloration of skin secondary to black tantalum powder.

middle meningeal artery at the end of the procedure with large (1 × 3 mm) particles; however, the surgeon can occlude this vessel at the time of surgery, knowing that the tumor nidus is already occluded by the microemboli.

In case 2, at the second stage embolization, a repeat angiogram demonstrated new small feeding vessels from the facial trunk, which prompted repeat microembolization, followed by occlusion of the facial trunk itself with larger particles of dry compressed PVA in order to prevent the development of neovascularity. During surgery the plan was to remove the hemangioma and attach a full thickness skin graft from the ipsilateral shoulder and back; however, there was no hemangioma deeper than the dermis. Therefore, the normal tissue below the dermis was allowed to granulate for 2 days and a split thickness skin graft from the buttock was then applied.

Case 3 represents an extensive high blood flow hemangioma without a capillary barrier. Here, a different technique of microembolization using a fluid embolic agent was needed to better penetrate the lesion and still not pass into the veins. The silicone was injected under balloon flow arrest, so that it could vulcanize in the vascular bed of the lesion. If flow arrest cannot be accomplished, a more viscous silicone fluid may be used that cannot pass beyond 200–400 μm vessels.

In our experience, particulate microemboli frequently have been the material of choice for microembolization of neoplastic conditions. Gelfoam microparticles are easy to inject, are readily available, and their long-term biocompatibility is well known [4]. Recanalization is not a problem, as in more proximal occlusion, for the particles lodge in very small vessels in the depth of the neoplasm, where collateralization cannot occur, and produce irreversible tissue necrosis. Were PVA to be available in powdered form, it would probably be equally useful. Gelfoam should not be used for the occlusion of larger vessels, unless recanalization is desirable. PVA, because of its permanent occlusive properties [12], is probably the material of choice when attempting permanent occlusion of vessels with a diameter of 200 μm or larger. Very small particles (40–60 μm) are probably contraindicated in the external carotid artery, particularly the maxillary, ascending pharyngeal, and occipital branches, except under specific conditions, for the particles may escape into the internal carotid and vertebral arteries through normal anastomotic channels [2, 13–15], which may enlarge during embolization. Larger particles (400 μm) usually will not traverse these small collateral communications and may be used without fear of antegrade brain embolization.

Particles of 40–60 μm may be used in the middle meningeal artery if the meningolacrimal artery is not visualized prior to embolization; if visualized, particles with a diameter larger than the anastomosis should be used to prevent emboli from passing into the cerebral circulation.

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