

Polyvinyl Alcohol Sponge for Embolotherapy: Particle Size and Morphology

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The size and morphology of particulate polyvinyl alcohol (PVA) sponge prepared by a blender technique for embolotherapy were analyzed by light and scanning electron microscopy. Techniques for preparation and sizing of PVA sponge particles are described. Two types of particulate material, differing in both size and morphology, were found. Large particles ($>50\ \mu\text{m}$) had irregular shapes and sharp, jagged edges. Smaller particles ($2\text{--}50\ \mu\text{m}$) were more numerous. Attempts to characterize the smaller particles were unsuccessful. Preparation of PVA sponge particles using the blender technique is a viable choice in external carotid neuroembolization procedures. However, the potential effects of small particles possibly causing cranial nerve palsies does need consideration.

In recent years, particulate polyvinyl alcohol (PVA) sponge (Ivalon) has been widely used for embolization procedures [1–4]. At our institution, PVA sponge particles are prepared via a blender technique [5]. Little is known about the size, consistency, or morphology of particles prepared in this fashion. We investigated these parameters of particulate PVA by light and scanning electron microscopy.

Materials and Methods

Particulate PVA sponge used in this study was prepared by a blender technique [5]. Large, nonuniform PVA particles ($590\text{--}1000\ \mu\text{m}$) were purchased in dry form from the manufacturer (Unipoint Industries, High Point, NC). One package of particles and 1000 ml of sterile water were placed in a high-shear blender (Fisher Scientific, Pittsburgh, PA). The particles were blended at maximum speed for 15 min. The resulting slurry was filtered through a series of three sieves of decreasing sizes (2.0, 1.0, and 0.5 mm; USA Standard Testing Sieve, Fisher Scientific, Pittsburgh, PA). The wet particles were stirred manually and, to some extent, forced through the sieve pores. The particles were repeatedly washed with sterile water during sieving, and the supernatant was discarded. Particles that passed through all three sieves were collected, dried by evaporation, packaged, and gas-sterilized.

The largest diameter of 100 consecutive PVA sponge particles suspended in saline was measured by light microscopy. These measurements were performed on two different preparations of particulate PVA sponge. Fifty mg of this material was suspended in 5 ml of saline and stained with 0.5 ml of Wright stain for better visualization under the light microscope (Lietz Optical Instruments, West Germany). Particle size was measured on a $50\text{-}\mu\text{m}$ hemacytometer grid (American Optics, McGaw Park, IL) at $\times 125$ magnification. Wright stain and saline were examined independently with the light microscope to ensure that each was free of contaminants. Dry particles were examined on a scanning electron microscope (ETEC Autoscan V-2) operated at 20 kV. The particles were mounted with copper tape on aluminum stubs. The specimens were sputter-coated with gold-palladium alloy for routine scanning electron microscopy with a vacuum evaporator (Denton DV-502). Exposures were made on film (Polaroid Pn-55) at various magnifications [6].

Two distinct groups of particles, based on size and morphology, were apparent. We attempted to physically separate these two groups by centrifugation (Sorvall RC-3 centrifuge). Ficoll/Hypaque gradients of 1.12 and 1.077 at various centrifugation speeds were used. Magnetic resonance (MR) spectroscopy (IVM NR 80 spectrometer) was evaluated as a

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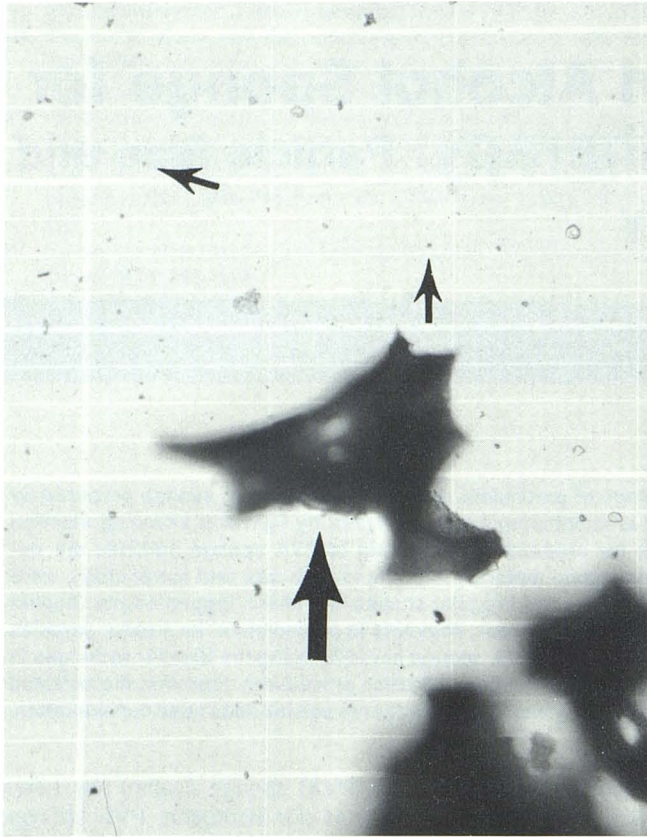


Fig. 1.—Field of PVA sponge particles under light microscope ($\times 100$). Single large particle (*large arrow*) in center (only part of it can be focused). Grid lines are $50\ \mu\text{m}$ apart. Many small ($<50\ \mu\text{m}$) particles (*small arrows*) in this field. Note the differences in size, shape, and number between large and small particles.

possible means of chemically categorizing these particles using several organic and inorganic solvent materials.

Results

The distribution of particles by size and morphology fell into two distinct groups: large ($>50\ \mu\text{m}$) and small ($<50\ \mu\text{m}$) particles (fig. 1). The large particles had irregular shapes and sharp, jagged edges (fig. 2). Measurements of the greatest diameter of these large particles are listed in table 1. The frequency distributions of the large particle size in batches 1 and 2 were both bell-shaped.

A second group of particles were smaller and more numerous, ranging in size from 2 to $50\ \mu\text{m}$. These particles were visible with the light microscope but were too small to be accurately sized by this technique. Numerically, the ratio of small-to-large particles was 15:1 over 20 light microscopic fields (figs. 1 and 3).

Attempts to separate these smaller particles by gradient centrifugation were unsuccessful. Attempts to characterize these particles via MR spectroscopy were equally unrewarding, because the MR spectrum of PVA sponge was heavily overlapped by the spectra of all solvent solutions.

Discussion

PVA sponge is a commonly used particulate embolization material [1-4]. Various preparation techniques have been

TABLE 1: Sizes of Largest PVA Sponge Particle Using Blender Technique

	Batch 1	Batch 2
Total no. of particles counted	100	100
Average particle diameter (μm)*	488.5	455.5
Mode (μm)	400	350 and 500
Range (μm)	50-900	50-850

Note.—PVA = polyvinyl alcohol.
* Overall average particle diameter of both batches was $472.0\ \mu\text{m}$.

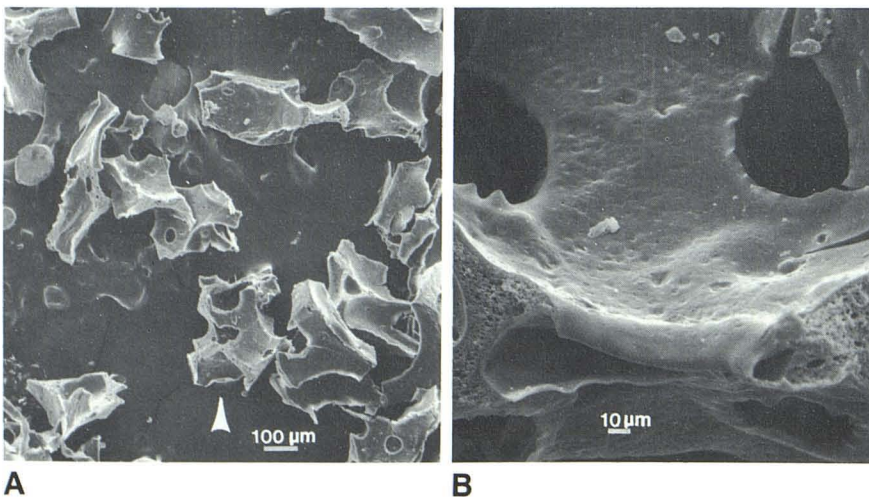


Fig. 2.—Scanning electron micrographs of PVA sponge particles. **A**, Single particle, $400\ \mu\text{m}$ in diameter (*arrowhead*) ($\times 60$). Use of scanning electron microscopy, rather than light microscopy, augments appreciation of three-dimensional quality of particles. **B**, Single PVA sponge particle ($\times 400$). In foreground, cut edge of particle reveals spongelike nature of its interior.

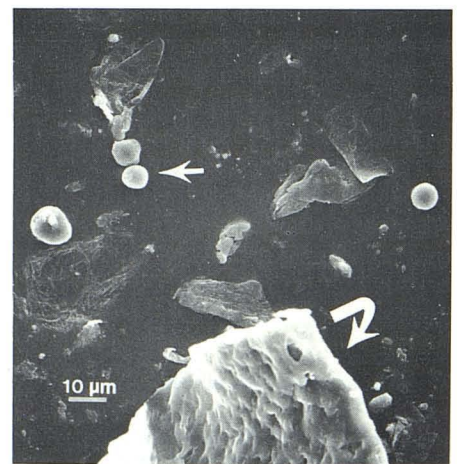


Fig. 3.—Scanning electron micrograph of large (*curved arrow*) and small (*straight arrow*) particles ($\times 700$).

described, including dry block shavings and precut particles [7-9]. Another alternative and the method used at our institution is to use particles obtained by a blender technique [5].

The average overall diameter of large PVA sponge particles (472.0 μm) correlates well with the smallest sieve size used for filtration (500 μm). The fact that particles larger (up to 950 μm) than the smallest sieve size have been filtered through a 500- μm sieve was at first puzzling. However, when the pliable nature of these particles is considered, the manual spreading of the particles during the sieving may be expected to mechanically force larger particles through the smaller-diameter sieve pores [3, 10].

The irregular appearance of the large PVA sponge particles is probably due to the shearing and chopping action of the blender. Particle morphology may account for the observation that PVA sponge particles in embolized vessels appear to serve as a "scaffolding" for the ingrowth of fibroblasts [7, 10, 11]. This in turn accounts for the relative permanence of PVA sponge-induced vessel occlusion [10, 11].

The presence of the small particles was unexpected. As attempts at separation and characterization of these particles were unsuccessful, the nature of these particles remains unknown. These small particles are not present in packages of 590- to 1000- μm particles purchased from the manufacturer. We suspect, therefore, that the small particles may represent a contaminant acquired during the blending process. This hypothesis is unproved, however. They also may represent small pieces of the larger PVA sponge particles. Reports of facial nerve palsies after external carotid embolization using particulate material smaller than 50 μm warrant concern for the potential presence of such particles in standard embolization preparations [12, 13]. However, our own experience has not suggested a significant clinical risk that can be directly attributed to this aspect of the material, and we consider PVA sponge preparations as described to be a viable choice in external carotid neuroembolization procedures. Nevertheless, this subject should warrant further inter-

est in understanding the composition of PVA sponge preparations and the potential effects of small particles relating to cranial nerve palsies after embolization.

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