Injection-Corrosion Casts of the Central Nervous System*

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Advances in neuroradiological techniques in recent years have resulted in improved visualization of small arteries and veins on cerebral angiograms. Knowledge of the normal anatomy of these fine vessels is of great importance, if one is to recognize abnormalities in the number, position and configuration of these vessels. Many so called "negative cerebral angiograms" actually do show discrete signs of a space-occupying lesion as evidenced for example by displacement of arteries of the basal ganglia.2

In order to recognize these small vessels, the vascular tree of brains removed at autopsy were filled with a barium gelatin solution and both the whole intact brain and brain slices were radiographed. These were then compared with pre-mortem angiography. To obtain a three-dimensional picture of the vascular tree, plastics were injected into the cerebral arteries and veins, and the cerebral tissue was corroded away leaving the vascular anatomy intact. The plastic was also rendered radiopaque and radiographs were taken. The model of the arterial tree was radiographed in various projections and the films obtained were compared with the models.

Since July, 1960, we have been studying the cerebral arteries by means of post-mortem arterial injections using a modified Schlesinger mixture consisting of barium, gelatin, buffered salts and preservatives, to which formalin is added prior to use.6 The protein mixture is denatured by the formalin and hardens in the arteries. X-rays of the whole brain injected with the barium suspension produce a good demonstration of the larger vessels. However, the finer arteries could only be identified on roentgenograms of the brain slices, i.e. after the brain had been cut by the neuropathologist. The confluence of the shadows of the opacified small arteries on roentgenograms of the whole brain made it impossible to identify the fine arterial anatomy. Reconstruction techniques from brain sections were unsatisfactory, and it was the desire to study the smaller arteries in three dimensions that led to our injection-corrosion study. While the barium injections do not interfere with brain slicing, the plastic injected specimens cannot be cut. A small biopsy can be made, however, in the area of a known lesion such as glioblastoma, following the injection. The cast obtained facilitates a three-dimensional study of the tumor vessels and shunts, such as that employed by Nyström.5 We have also undertaken this type of study.

If a plastic which is resistant to acid and alkali is injected into cerebral vessels, sub-arachnoid cisterns, or the ventricular system and is permitted to harden, the brain may be corroded or digested away leaving a cast of the hollow structures. This injection-corrosion cast permits a leisurely study of the most detailed vascular anatomy shown by x-ray.

Although a simple process, the injection of a solution of polyvinyl acetate, dissolved in acetone, proved unsatisfactory for a number of reasons. The solvent, which represented a considerable portion of the resin mass, is freely miscible with water, while the vinylite is insoluble in this medium. Because the acetone was lost into the formalin in which the specimen was stored, the plastic cast was irregularly shrunken (Fig. 1) and was both brittle and thermolabile.

Encouraged by Tompsett's work7,8 we then tried a liquid monomer which could be injected into the cerebral vessels and made to solidify or polymerize at room temperature. Tompsett injects his cerebral vessels in the cadaver and permits the resin to harden in situ over a number of days. With few excep-
tions, the brains which have been made available to us were offered on the condition that the organ be removed in about 5 to 10 minutes so that the injection would not interfere with the remainder of the autopsy. Consequently, we were faced with a greater likelihood of deformity of the vascular cast prior to hardening.

Thanks to recent research in plastics chemistry\textsuperscript{1,2} a number of amine accelerators such as dimethyl-p-toluidine (DMT) or dimethylaniline (DMA) have been found to permit rapid polymerization of methyl methacrylate with benzoyl peroxide at room temperatures. We have used a number of different acrylics, polyesters, polystyrenes, epoxy resins, and metal alloys with a low melting point. Each of these has advantages and disadvantages. The epoxy resins, while shrinking less than 1\% and capable of great hardness, are inhibited by small quantities of blood or water and may not harden satisfactorily. Metal alloys in our experience have proved too brittle for arterial casts, although they have been satisfactory for obtaining casts of the ventricular system both in our studies and in those of others.\textsuperscript{4}

Pure methyl methacrylate casts tend to be quite brittle and thermolabile. A less brittle and thermostable resin was obtained by the admixture of the longer chain ethyl or butyl methacrylate dissolving a small amount of methyl methacrylate polyester, and adding a phthalate plasticizer and a cross-linking agent such as triethylene glycol dimethacrylate. These resulted in a material with good elastic memory and improved physical strength. Since these materials have proved satisfactory, we have discontinued use of other resins.\textsuperscript{†}

A commercial preparation of a composition similar to that noted above is Batson’s Corrosion Solution #17. We have found this material equally satisfactory for all injection-corrosion purposes. It also offers the convenience of liquid stock solutions without the need to weigh out, mix or dissolve reagents. We have found satisfactory and faster curing times possible with higher concentrations of catalyst and accelerator in the following proportions: base 50 cc., catalyst 12 cc. and promoter 12 drops. If repairs should be necessary, small amounts of base with larger proportions of catalyst and promoter can be used as a glue.

Careful in vitro tests should be performed to determine polymerization times regardless of the plastic chosen. The limiting factor for hand injection has been the time it takes for the monomer to polymerize to a stringy or viscous state. In about twice this time the plastic mass tends to become a gel and this generally hardens to a hard rubber state in twice the gel time (Fig. 2). In addition to the monomer, catalyst and accelerator, we have used assorted pigments (each of which may alter the polymerization time), acetone (for cleaning instruments and syringes), pediatric feeding tubes (for cannulating the vessels), an assortment of syringes, dissection instruments and trays, and plastic pails for storage and corrosion.

Whenever possible the injection should be

\textsuperscript{†}The various plastics and reagents may be obtained from the sources listed below:

- Benzoyl Peroxide: Lucidol Division, Wallace & Tiernan Inc., 1740 Military Road, Buffalo 4, N.Y.
- Dimethyl-p-toluidine (DMT) and other accelerators: Wallace A. Erickson & Co., E. 43rd North Wales St., Chicago 10, Illinois.
- Dioctyl Phthalate (DOP) and other plasticizers: Pittsburgh Chemical Co., Grant Building, Pittsburgh 10, Pa.