

hydrogel to be visualized under fluoroscopy and a therapeutic agent such as one or more human growth factors. As used in this application, the term "hydrogel" refers to a broad class of polymeric materials that have an affinity for water and typically swell in water, but which do not necessarily dissolve in water. In general, hydrogels are formed by polymerization and crosslinking of a hydrophilic monomer in an aqueous solution to cause the solution to gel. In a presently preferred embodiment, the hydrogel can be constituted to be liquid at a temperature below body temperature and to gel at body temperature so that the gel can be easily introduced into the aneurysm, but rapidly gels in the space to occlude at least a portion of the aneurysm.

The hydrogel of the present invention can be one or more hydrogels selected from organic gels and inorganic gels. Organic gels from which the hydrogel of the invention can be selected include, by way of example and not by way of limitation, gels formed from polysaccharides and mucopolysaccharides including, but not limited to hyaluronic acid, dextran, heparin sulfate, chondroitin sulfate, heparin, agar, starch, and alginate; polyaminoacids; proteins that support cell growth and healing, including but not limited to fibronectin, gelatin, collagen, fibrin, pectins, albumin, ovalbumin, and polyamino acids; collagen-hydroxyethyl-methacrylate (HEMA); polyphosphazines; polyphosphoesters; polyethylene glycol; polyethylene oxide; polyvinyl alcohol; polyvinylpyrrolidone; polyethylloxazoline; polyethylene oxide-co-polypropyleneoxide block copolymers; PGA-PEG-PGA block copolymers; PGA-PEG diblock copolymers; acrylates, including but not limited to diacrylates, oligoacrylates, methacrylates, dimethacrylates and oligomethoacrylates; PEG-oligoglycolylacrylates, such as described in U.S. Pat. No. 5,626,863, which is incorporated by reference herein; carboxy alkyl celluloses, including but not limited to carboxymethyl cellulose; partially oxidized cellulose; biodegradable polymers including but not limited to polymers and oligomers of glycolide, lactide, polylactic acid, polyesters of α -hydroxy acids, including lactic acid and glycolic acid, such as the poly(α -hydroxy) acids including polyglycolic acid, poly-DL-lactic, poly-L-lactic acid, and terpolymers of DL-lactide and glycolide; ϵ -caprolactone and ϵ -caprolactone copolymerized with polyesters; polyalactones and polycaprolactones including poly(ϵ -caprolactone), poly(δ -valerolactone) and poly(γ -butyrolactone); polyanhydrides; polyorthoesters; other hydroxy acids; polydioxanone; and other biologically degradable polymers that are non-toxic or are present as metabolites in the body; as well as non-degradable polymers such as styrene and acrolein.

Collagen-hydroxyethyl-methacrylate (EMA) hydrogel polymer is commonly formed from a gelled and crosslinked hydrophilic monomer solution to form a three dimensional polymeric meshwork anchoring macromolecules. Crosslinking of the hydrophilic monomer solution can be accomplished by free radical polymerization of hydrophilic monomers, such as hydroxyethyl-methacrylate (HEMA). Hydrogel polymers formed by free radical polymerization of monomer solutions require crosslinking to form the three dimensional network to gel the aqueous solution. HEMA monomer solutions typically can be crosslinked to gel by dimethacrylate, although other crosslinking agents, such as ethylene glycol dimethacrylate or methylmethacrylate, can also be used during polymerization to modify the hydrogel. A wide variety of other hydrophilic monomers may also be suitable for purposes of the invention.

Inorganic gels from which the hydrogel of the invention can be selected include, by way of example and not by way

of limitation, silica, alumina, and ferric oxide. In addition, an adhesive can be introduced via a catheter to initially help seal the neck of an aneurysm, and can be selected from the group consisting of cyanoacrylates, gelatin/resorcinol/formol, mussel adhesive protein and autologous fibrinogen adhesive. It should thus be apparent that the hydrogel of the invention can be of a type that dissolves over time or one that remains as a permanent occlusive agent within the aneurysm.

The radiopaque material that is incorporated into the hydrogel of the invention is preferably fine particles of a selected radiopaque metal, such as gold, platinum, tantalum or the like. The therapeutic agent incorporated into the hydrogel of the invention is preferably one or more human growth modulating factors such as interleukins, transformation growth factor b, gene therapy agents, congeners of platelet derived growth factor, and monoclonal antibodies directed against growth factors, drugs, drug producing cells, cell regeneration factors, progenitor cells of the same type as those from the aneurysm, and progenitor cells that are histologically different from those of the aneurysm, to accelerate the healing process. The therapeutic agent can be administered in the form of fine particles mixed with the polymer so that it gels within the aneurysm to concentrate the effect of the therapeutic agent within the aneurysm.

According to the method of the invention, a catheter is typically positioned in a parent vessel of the aneurysm, and the hydrogel of the invention is delivered through the catheter into the aneurysm, where the hydrogel becomes more viscous upon reaching body temperature, or upon exposure to bodily fluids. During introduction of the hydrogel into the aneurysm, the hydrogel can be imaged by common fluoroscopic techniques to allow the physician to monitor the treatment of the aneurysm. Once introduced into the aneurysm, the hydrogel preferably further crosslinks to solidify to block blood flow into the aneurysm, and the one or more therapeutic agents carried by the hydrogel gradually diffuse and disperse from the hydrogel into the aneurysm, to promote the growth of a cellular layer across the neck of the aneurysm.

It will be apparent from the foregoing that while particular forms of the invention have been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention. Accordingly, it is not intended that the invention be limited, except as by the appended claims.

What is claimed is:

1. A method for treating an aneurysm, the aneurysm having a dome portion and a neck opening into a parent vessel, the method comprising the steps of:

introducing an embolus generating vasoocclusive device into the aneurysm; and

delivering a hydrogel into the dome portion of the aneurysm and adjacent to the neck of the aneurysm, the hydrogel containing a radiopaque material and a therapeutic agent that is released from the hydrogel in the aneurysm to promote cellular growth across the neck of the aneurysm to close the neck of the aneurysm.

2. The method of claim 1, wherein said hydrogel is selected from the group consisting of organic gels and inorganic gels.

3. The method of claim 1, wherein said hydrogel is selected from the group consisting of biodegradable polymers and non-degradable polymers.

4. The method of claim 1, wherein said hydrogel is selected from the group consisting of gels formed from