Expanding Embolization Success

Livermore development team for the IMPEDE® embolization plug: (from left) Thomas Wilson, Ward Small, Jennifer Rodriguez, and Jason Ortega. (Photo by Julie Russell.)

UNCONTROLLED blood flow through vessels damaged by aneurysm leaks, trauma, and other conditions can increase patients' risk of pain, stroke, and death. Embolization, a minimally invasive treatment, alleviates health risks by blocking blood flow in damaged areas so that it can be diverted back through healthy vessels. Established embolization treatments either stimulate clot formation and enable vessel occlusion, or contract the affected vessel, but these approaches may not be completely effective over time. In some cases, blood flow may recur, or patients may suffer significant adverse effects.

Scientists from Livermore and Texas A&M University along with California-based startup Shape Memory Medical, Inc., have improved upon existing technologies with the IMPEDE® embolization plug, winner of a 2019 R&D 100 Award. IMPEDE offers a more advanced occlusion method, allowing physicians to deliver the highest possible material volume to a targeted vessel using a guided catheter smaller than human veins and arteries. In addition to speeding blood clot formation, IMPEDE reduces adverse side effects and better promotes vascular healing. Livermore researcher Thomas Wilson says, "The IMPEDE embolization plug is the culmination of 20 years of biomedical materials research. The lives of many people—possibly tens of thousands—will be made better through this material."

Quick and Effective

The IMPEDE device is composed of an anchor coil, a radiopaque marker band, and a novel polyurethane, shape-memory-polymer (SMP) foam plug capable of expanding up to 100 times its initial volume when in contact with circulating blood. (SMPs are a class of polymeric materials that remember their primary shape after being molded into a second, temporary shape.) During a medical procedure, the embolization plug is placed inside a guided catheter. The physician navigates the catheter through the patient's vessels using x-ray imaging to deliver the plug quickly and accurately to the damaged vein or artery.

Once the target location is reached, the IMPEDE device's helix-shaped anchor coil holds the compressed foam plug in place as the material expands to fill the blood vessel. The foam's high surface area effectively stops blood flow and speeds the body's ability to form a stable clot. The material is also biodegradable, disintegrating slowly into nontoxic compounds until the plug is ultimately replaced with the body's own collagen and connective tissue, and the once-damaged vessel is healed.

Patients typically leave the hospital the day after treatment, as only a small incision in the groin is required to place

the device. Available in three sizes, a single IMPEDE plug can treat blood vessels ranging from 2 to 10 millimeters in diameter, while competing technologies may require multiple plugs for the same procedure. The IMPEDE embolization plug was cleared by the U.S. Food and Drug Administration (FDA) in 2018 and has been used successfully on more than 300 patients, with no reported adverse side effects.

Material Mission

The SMP foam used in IMPEDE was developed by Wilson and former Livermore physicist Duncan Maitland—now at Texas A&M University. Funding was provided through grants from the National Institutes of Health and supported by earlier investments from the Laboratory Directed Research and Development Program and the Department of Energy's Office of Science.

Maitland started work on SMP concepts in the 1990s, drawing on expertise in materials for defense applications. In 2000, Maitland was joined by Wilson, who sought to apply his experience in the polymer industry to biomedical materials. "In industry, I made products, such as siding and household items, better through materials research," says Wilson. "At Livermore, I have been able to improve the lives of individual people." Wilson designed the molecular structure that optimized SMP foam performance for embolization use.

Livermore's high-performance computing capabilities played a key role in the research and development effort. Using computational fluid dynamics simulations, the researchers analyzed how treatment with an SMP foam could affect blood flow within a vessel and how well the material supports conditions that promote clotting and occlusion. The computer models included variations in device design, foam densities, and patient conditions to provide clinicians a dynamic view of treatment using SMP foam.

After transferring to Texas A&M University in the late 2000s, Maitland continued SMP experimentation, prototyping, and preclinical studies under an Inter-Institutional Agreement with Livermore. Subsequent improvements to the material included higher biodegradability and hydrophobicity (water resistance). Ultimately, the polymer foam achieved the complete shape recovery needed to expand quickly and completely fill several types of damaged blood vessels. The intellectual property portfolio for SMP foam has grown to more than 70 issued and pending U.S. patents.

Maitland founded Shape Memory Medical (previously called Shape Memory Therapeutics, Inc.) and licensed SMP foam technologies from Livermore to further develop the polymer material as a commercial embolization plug. Wilson credits Maitland for driving the technical success of the device and Ted Ruppel, Shape Memory Medical's chief executive officer, for applying his experience in medical device startups to position IMPEDE in the marketplace.

"IMPEDE would not exist without the invention of SMP foam," says Wilson. "However, the device would not have achieved FDA approval and reached the medical community without Duncan's and Ted's tremendous efforts." During its clinical adoption phase, IMPEDE successfully treated multiple medical cases including a life-threatening dissected aorta and a pulmonary arteriovenous malformation when other devices failed to achieve full blood vessel occlusion. A new device utilizing SMP foam and enabling physicians to embolize longer vessel lengths received FDA clearance in 2019.

—Suzanne Storar

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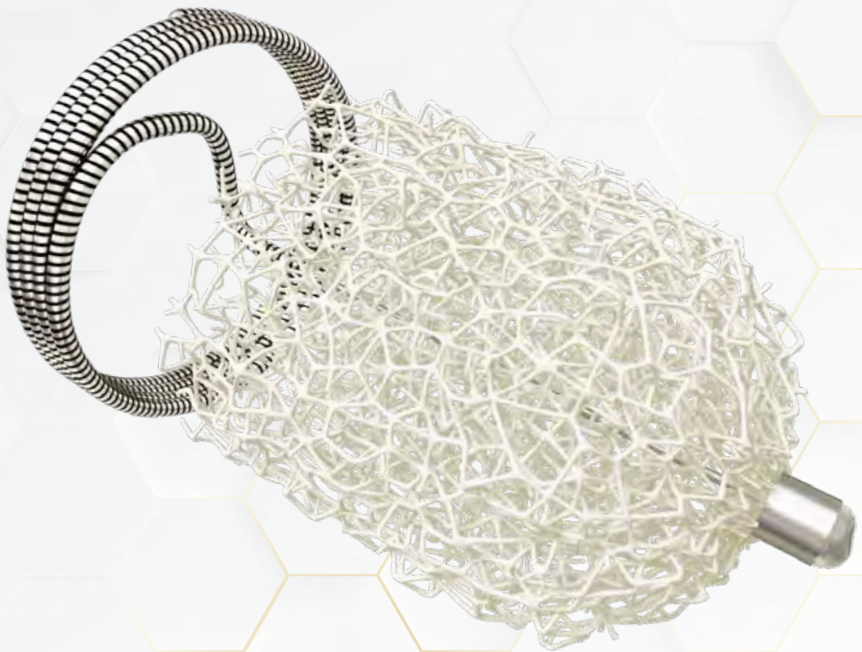

The shape-memory-polymer foam used in the IMPEDE device expands to occlude a damaged vessel, helping the body form a stable clot. The biodegradable plug is ultimately replaced with the body's own