

Mathematics taking guesswork out of plastic surgery tissue transfer

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Plastic surgeons are turning to mathematics to take the guesswork out of efforts to ensure that live tissue segments that are selected to restore damaged body parts will have enough blood and oxygen to survive the surgical transfer.

In the world's first published [mathematical model](#) of [tissue](#) transfer, mathematicians have shown that they can use differential equations to determine which tissue segments selected for transfer from one part of the body to another location on the same body will receive the level of oxygen required to sustain the tissue.

The most common tissue transfers are used to restore body parts destroyed by cancer and trauma. The researchers say reliable mathematical modeling of the blood supply and oxygen in tissue segments will not only reduce failures in reconstructive surgery, but will also improve understanding of conditions in which an adequate blood supply is a basic problem, such as [heart disease](#), cancer and stroke.

To obtain tissue for reconstructive surgery, plastic surgeons cut away a segment of tissue, called a flap, that is fed by a single set of perforator vessels - an artery and vein that travel through underlying muscle to support skin and fat. Surgeons generally agree that vessels at least 1.5 millimeters in diameter are required to sustain oxygen flow within the flap intended for transfer.

"That guideline is based upon experience, trial and error. What we need

is a more precise ability to determine what the necessary blood vessel size really is," said Michael Miller, professor of surgery and director of the division of [plastic surgery](#) at Ohio State University and a senior author of the research.

"I'm convinced that there is a relationship that's probably very predictive between the diameter and blood flow in the vessel and the ability of the piece of the tissue we're transferring to survive based on that."

Mathematicians working on the problem have set out to model that relationship. They have shown that under certain relationships between the size of the tissue flap and the diameter of the perforator vessel, the oxygen level in the flap will remain above 15 percent of the normal level, thus ensuring a successful flap transfer. If this relationship is not satisfied, the most distant tissue from the vessel will start to die - something already observed by clinicians.

"This is still just a concept. But this initial system of five differential equations gives us a range between the flap size and the required diameter of the supporting artery that would ensure survival," said Avner Friedman, a senior author of the paper and a Distinguished University Professor at Ohio State.

The research appears this week in the online early edition of the *Proceedings of the National Academy of Sciences*.

The routine use of a patient's own tissue from the lower abdominal wall to restore deformities on the chest dates to 1982. In the early days of full removal and transfer of tissue, surgeons took muscle along with skin and fat, resulting in loss of strength where the muscle was removed.

"As time has gone on, we have learned that we don't have to take the muscle, but we can take a single blood vessel coming through the muscle

and transfer the tissue on that vessel," Miller explained. "What we're finding is that the more we design flaps like this, the less reliable the tissue is becoming. The motivation to try to reduce injury to muscle is leading to an increase in problems with part of the flap failing because it doesn't have enough blood."

Miller asked Friedman, founding director of Ohio State's Mathematical Biosciences Institute, to work on a model that could add more predictability to tissue transfer.

To create the initial model, Friedman and colleagues needed to determine a number of values: the level of oxygen in the tissue, which comes from tiny capillaries spaced just microns apart; the rate of exchange of oxygen from vessels to tissue; and the pressure under which the blood is flowing in those vessels.

"The fact that there are thousands of capillaries makes it difficult to compute the oxygen levels, so we found a method of averaging. We average the oxygen concentration in the capillaries, think of capillaries as being uniformly spread all over, and look at the transport of oxygen from vessels into tissue," Friedman said.

The model's outcomes exploited clinical observations, in that if the oxygen pressure fell below 15 percent during the few days following the tissue transfer, fat tissue on the outer edges of the flap would start to die. When that happens on actual surgical cases, doctors must replace the dead tissue, and sometimes have to redo the entire operation.

More work lies ahead to make the model truly useful in a surgical setting, Miller and Friedman agreed.

In live human tissue, the pattern of blood vessels and capillaries is not uniformly spread throughout the flap. In many cases, there is a gap in the

presence of branching vessels at the point at which the feeder artery and vein enter the fat and divide.

And to add accuracy to the parameters used in the equations, the researchers agree that animal studies of tissue transfer are needed to make the model more reliable.

Imaging technology is also expected to factor into the future of reconstructive surgery. Surgeons currently use three-dimensional CT scans to image a potential flap and the perforator vessels that are feeding that flap. But the imaging available to date can't display the entire vasculature of a flap.

Friedman said he and colleagues hope to provide surgeons with software that could be combined with advanced imaging to supply more reliable information about the likely survival of a tissue flap.

"The surgeon will take an image of a flap that will give an idea of the distribution of vessels. Then the surgeon will use the software to determine that with this given vasculature, a specific size of tissue can be cut," Friedman said.

Miller, a specialist in breast reconstruction, said the abdomen is a common source for tissue to be transferred because it contains a lot of tissue in a location that allows the resulting scar to be hidden by clothing.

"But theoretically, we can make flaps from anywhere on the body," he said. "The whole body is divided up on this vascular tree. So if you can isolate a flap of tissue on a blood supply, you can remove it and reattach it."

Source: The Ohio State University ([news](#) : [web](#))

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