Origami-inspired surgical patch seals inner wounds

Surgery is one of the essential areas of medical science specifically for the purpose of structurally modifying the human body by incision or destruction of tissues. A century earlier, no one would have dreamt of the developments now made in the field of surgery. The purpose of surgery depends; it may be advised to make or validate a diagnosis, remove damaged tissue or obstruction, restore or reposition tissues or organs, implant devices, redirect blood vessels, or transplant tissues or organs. Some individuals opt for surgery for cosmetic reasons too. Today, numerous operations are conducted by minimally invasive techniques in which tiny incisions are made, and miniature cameras and surgical instruments are threaded through the body to perform the desired functions. The procedure results in less pain and faster healing times compared to open surgery. Although many operations are done in this manner, surgeons often face difficulties at an essential stage of the process: sealing internal injuries and tears.

The ability to bind tissues is one of the main pillars of general surgery. To this end, the conventional methods for applying mechanical fasteners (sutures and staples) remain the existing standards for binding and tissue repair in both open and minimally invasive operation. However, these approaches have serious shortcomings. Suturing requires intricate manipulations that are time-consuming and require a high level of surgical expertise, rendering them disadvantageous in emergency cases. Meanwhile, surgical staples are associated with a growing number of adverse effects caused by problems, such as staple malformations and staple misfires. In addition, both sutures and staples can be mechanically detrimental to tissues and are vulnerable to dehiscence, bleeding and inflammation.

In the light of these vulnerabilities, bio-adhesive products have earned great recognition as promising substitutes for conventional sutures and staples that offer a safe, non-toxic, bio-compatible and anti-bacterial alternative. At present, the bio-adhesives used in minimally invasive surgeries are often available as biodegradable liquids and glues that can be applied over damaged tissues. However, as these glues solidify, they can harden over the softer underlying surface, forming an imperfect seal. Blood and other body fluids can also contaminate glues, preventing effective adhesion to the wounded site. Glues can also cause infection and scar tissue growth following application and can also wash away before a wound has completely healed. However, the problem with bio-adhesive materials is the complexity of inserting them into patients through narrow incisions typical of keyhole surgery; and this is where the new origami-inspired patch holds the key. Origami is an art of paper folding, mostly associated with Japanese culture. In contemporary context, the word ‘origami’ is used as an inclusive term for any folding practice, regardless of its cultural origin.

Bringing the evolution of surgeries a step forward, the researchers of Massachusetts Institute of Technology (MIT) have developed an origami-inspired biodegradable medical patch that can be wrapped over minimally invasive surgical instruments and wound around the internal organs with minimal hassle. In view of the shortcomings of existing application, the research team developed the alternative that would achieve three functional requirements: It should be able to adhere to the moist surface of the wounded site; prevent binding to something else until reaching its destination, and escape bacterial infection and unnecessary inflammation until applied to the wounded site. It will help tremendously for invasive operations where tiny cameras and surgical instruments are deployed within the body. This new surgical patch would be the perfect cure for surgeons and rehab patients to seal their internal wounds and tears. The patch will easily biodegrade away over time too.

The surgical patch looks like a foldable, paper-like film when it is dry. Coming in contact with moist tissues or organs, it turns into a stretchy gel, equivalent to a contact lens and stays firmly on the wounded area until it heals. The patch consists of three layers – the top layer is an elastomer film composed of zwitterionic polymers that become a water-based skin-like layer. The middle layer is a bio-adhesive hydrogel, which is formed by the compound N-hydroxysuccinimide (NHS) esters to create a tight bond with the tissue surface. The bottom layer is made of silicone oil to keep it away from binding to the surface of the body before reaching the target. This patch technique could be used to fix colonoscopy perforation or seal solid organs or blood vessels after trauma or elective surgery. Instead of trying to conduct a completely open surgical approach, one may go from inside to apply a patch to close a wound at least temporarily and perhaps even for a longer period of time.

After submerging it in fluid for a long time, the research team tested the patch on animal tissue samples, and it succeeded as expected. They also attached the folded patch around equipment usually used in minimally invasive surgeries, such as a balloon catheter and a surgical stapler. These instruments were threaded through animal models of major airways and vessels, including trachea, oesophagus, aorta and intestines. By inflating the balloon catheter or applying light pressure to the stapler, they were able to stick the patch to the damaged organs and tissues and found no evidence of contamination on or near the patch site up to one month after its application.

The material properties of the multi-layer patch make it easy to use origami-inspired manufacturing methods that give it a high degree of customizability. This ability to implement customized form factors facilitates surgical application through a range of deployment mechanisms guided by various surgical end-effectors, providing a promising approach to a broad variety of clinical indications. These bio-adhesives will be created in pre-folded structures that specialists can easily fit around minimally invasive tools as well as instruments that are currently utilized in robotic surgery. Researchers are already collaborating with clinicians and surgeons to optimize the functionality of these bio-adhesive origami patches. The conceptual innovation in the function and structure of this patch can also reflect an exciting step towards addressing translational hurdles in robotic surgery and encouraging the broader clinical use of bio-adhesive materials.

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