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Review article about microvascular arterial anastomosis ,sutures alone versus fibrin glue and minimal sutures

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Abstract: Microvascular anastomosis is a crucial technique in reconstructive surgery. Numerous methods have been developed to enhance vessel patency rates, reduce anastomosis time, and improve hemostasis. Currently, the handheld suture technique is the standard approach for microvascular anastomosis. Traditionally, this involves using simple interrupted sutures after approximating the ends of the vessels. Despite its widespread use, this method can be time-consuming and carries the risk of iatrogenic intimal injury and subsequent vessel thrombosis.

Fibrin glue mimics the final stages of the coagulation cascade to form a natural fibrin clot. Several studies have demonstrated the benefits of fibrin glue in microsurgery. Fibrin sealant, also known as fibrin glue, serves as a valuable and versatile tissue adhesive in various surgical contexts. It effectively stops bleeding and ensures air and fluid tightness. Derived from plasma, fibrin glue offers the advantages of biocompatibility and biodegradability without causing inflammation, tissue necrosis, or fibrosis.

Keywords: *arterial anastomosis, sutures alone versus fibrin glue and minimal sutures*

Introduction

Microvascular anastomosis is a crucial technique in reconstructive surgery. Numerous methods have been developed to enhance vessel patency, decrease anastomosis duration, and improve hemostasis [1].

At present, the established approach for microvascular anastomosis is the handheld suture technique first described by Carrel in 1902. This advanced surgical method demands specialized training and is time-intensive. Even proficient surgeons face risks of complications such as anastomotic leaks, stenosis, and thrombosis [2].

Traditionally, microvascular anastomosis involves using simple interrupted sutures following the approximation of vessel ends. While this method is widely accepted as standard practice, it can be time-consuming and carries the risk of iatrogenic injury to the vessel's intima, potentially leading to thrombosis in the repaired vessel [3].

Additionally, microvascular anastomosis techniques can be widely used in revascularization of partly detached digits or limbs. It was first used in a clinical setting by Kleinert and Kasdan in 1965. The first replantation of a

detached limb was carried out more than 50 years ago by Malt in Boston when he replanted a totally severed arm [4].

Microsurgery Techniques:

There is no universally prescribed standard for performing microvascular anastomosis, as the choice of technique typically depends on the operator. However, certain pitfalls should be avoided, such as narrowing of the vascular lumen, irregular distribution of vessel diameters leading to folds and irregularities, excessive suture material inside the vessel lumen, and especially transmural sutures that close the vascular lumen by biting into the posterior wall [5].

End-to-End Anastomosis:

The most commonly used technique by far is end-to-end anastomosis. Due to its simplicity, even in less experienced hands, it boasts one of the lowest failure rates [6].

Triangulation:

Alexis Carrel described this technique in 1902 with the intention of separating the posterior wall from the anterior, thereby recognizing the risks associated with transmural stitches. The technique involves using three initial sutures, each positioned 120° apart [7].

It was subsequently modified to use only two initial sutures spaced at 120° or 150° apart, considering the longer and more posterior placement of the posterior side. Further refinement proposed using just two initial sutures placed 180° apart. The remainder of the anastomosis is then closed with simple sutures between these initial points [8].

Continuous:

The continuous suture technique saves time and effectively addresses discrepancies of 2-3 mm in vessel size, but it has a drawback known as the "tobacco bag effect." To mitigate this, some authors advocate initially distributing the two vascular lumens with several simple stitches. However, this technique is less favored in venous microvascular anastomosis due to its potential to cause narrowing of the vein [9].

Continuous Interrupted:

Our preferred technique is the continuous interrupted technique, also known as the open-loop technique. This method combines the safety of simple sutures with the efficiency and speed of continuous sutures. It ensures continuous visibility of the vascular lumen while minimizing the required maneuvers [10, 11]. In this approach, a continuous suture with wide loops is initially created, which is then secured by tying each loop separately.

One Way Up:

The one-way-up technique is our preferred choice when manipulating both vessels in microvascular anastomosis is challenging, particularly when rotating them for suturing the posterior wall. In this technique, suturing begins with the posterior side where the needle is inserted from the deep side of the vessel through the intima of the posterior wall and then returns through the intima into the lumen of the opposite vessel's posterior wall. Knots are tied similarly to simple stitches. After placing three or four stitches in an inverted fashion on the posterior wall, the remaining stitches can be completed conventionally [10, 12].

It's crucial to place these posterior wall stitches close together to prevent leaks, as revising the posterior wall can be cumbersome. Finally, the anterior face is sutured. This technique is preferred because it reduces the incidence of transfixing sutures.

End-to-Side Anastomosis:

This type of suture technique is particularly valuable in scenarios where there is a significant size difference between vascular lumens or when preserving flow through a particular vascular axis is critical. For instance, in lower limb reconstructions where one vascular axis is damaged or needs to be preserved, this technique proves beneficial [13].

To perform an end-to-side anastomosis, the flow through the larger vessel that remains in continuity must first be occluded. Our preference is to use two rubber loops with a double pass around the vessel, as they tend to cause less damage to the vessel walls compared to bulldog or baby Satinsky clamps [13].
Then, by applying tension to the vessel wall with a transmural suture, the wall is elongated, and a section is made using straight adventitectomy scissors or a scalpel. The diameter of the hole created should not exceed that of the vessel [6].

Lab Around the World:

Since the advent of microsurgery, there has been significant interest in developing suture techniques to perform anastomoses more efficiently and accurately. In response to this, coupler devices—consisting of two metal rings that are coupled—have been developed [7].
These devices are widely used, particularly for vein anastomoses, although they have also shown 100% patency rates in arterial anastomoses. The vessels are inserted through the rings, and their edges are fixed inside-out on pins arranged in the ring. The hinge of the device then closes to join both sides [14].
Eversion of the vessel edges achieved by this method reduces exposure of the vascular lumen to foreign material, thereby lowering the risk of thrombosis. However, eversion in arterial anastomoses is more complex due to the thicker vascular wall, limiting the popularity of coupler devices in arterial procedures. Some coupler devices now include built-in flap control systems, such as Doppler monitoring [9].
Despite their advantages in reducing anastomosis time, coupler devices have drawbacks. They can be complex to use and may result in some degree of stenosis. Moreover, they are not recommended in areas prone to infection, poorly vascularized regions, or irradiated tissues [14].
Recent guidelines have begun to outline practical tips to improve the outcomes of microvascular anastomosis surgeries. It is crucial to include an adequate amount of intima within each suture to ensure proper eversion and expose a smooth intimal surface to the vascular lumen, minimizing subendothelial collagen or suture material exposure [7].
Knots should be flat and placed to one side with just enough pressure to close the anastomosis, as overly tight sutures can cause ischemia and failure. In cases where veins have inconsistent walls, an immersion technique using heparinized serum to open the vascular lumen can be beneficial. Anastomosis must be leak-free to prevent intraluminal thrombus formation, which can jeopardize the entire repair. Post-anastomosis, assessing patency through methods like a patency test or gentle dilatation with heparinized serum is recommended over classic patency tests to avoid intimal trauma [7].
Proficiency in these techniques typically begins with training in experimental surgery labs using animal models. Dilating the vessel lumen with specific forceps enhances visibility during surgery and facilitates needle retrieval at each stitch, reducing vessel wall trauma. Careful alignment of the needle and thread with the vessels before passing the entire suture through helps prevent tears and friction on the vessel walls [14].
Fibrin Glue: A Magic Innovation:
During World War I, fibrin patches were initially employed to manage bleeding from parenchymatous organs. However, the effectiveness was limited. In the 1940s, the combination of autologous fibrinogen and thrombin solution was introduced for fixing human skin grafts, but it was hindered by poor adhesive properties likely due to insufficient fibrinogen concentration [15].
Two significant advancements revived interest in this technique. Firstly, the ability to produce highly concentrated fibrinogen, and secondly, improvements in microsurgical techniques. In the 1970s, animal studies demonstrated that fibrin glue could reduce the number of sutures required for anastomoses and successfully seal experimental dural lesions in dogs [16].
In 1974, fibrin glue made from autologous cryoprecipitate and thrombin solution was used to repair peripheral nerves in humans. These promising outcomes led to the adoption of fibrin glue in various applications such as wound closure, skin grafting, and promoting bone union in osteotomies [17].

Composition and Mechanism of Action of Fibrin Glue:

The action of fibrin glue mirrors the final stage of blood clotting, where fibrinogen is converted into fibrin. Fibrin glue consists of two components, each drawn up in separate syringes. The first component primarily contains fibrinogen along with factor XIII and other plasma proteins such as fibronectin and plasminogen. The second component is a mixture of bovine thrombin and calcium chloride [18].

When these two solutions are mixed together, thrombin acts on fibrinogen to convert it into fibrin monomers. Simultaneously, the presence of ionized calcium facilitates the formation of hydrogen bonds, causing the mixture to gel. Factor XIII, activated by thrombin, then stabilizes the cross-linking of fibrin monomers within 3-5 minutes, significantly enhancing the tensile strength of the clot. The speed of fibrin clot formation is influenced by the concentration of the thrombin activating solution. This process effectively mimics the natural coagulation cascade's final steps, providing a reliable adhesive and sealing effect in surgical applications [19].

The effectiveness of fibrin glue depends significantly on the concentration of thrombin used during application. A thrombin concentration of 4 IU/ml promotes clot formation within 1 minute, making it suitable for procedures where the glued surfaces may require subsequent adjustment, such as in skin grafts. In contrast, a higher concentration of 500 IU/ml leads to rapid fibrin sealing within a few seconds, making it ideal for situations where immediate hemostasis is critical [20].

Observing the color change of the glue can indicate its solidification process; it typically turns milky white as it begins to gel. The adhesive strength of fibrin glue is directly linked to the concentration of fibrinogen available, achieving optimal strength within 3-5 minutes. Besides its adhesive and hemostatic properties, fibrin glue has been observed to enhance wound healing, possibly due to the presence of fibronectin. This additional benefit underscores its utility in various surgical applications beyond mere sealing and hemostasis [21].

Wound healing begins as fibroblasts from the surrounding tissue migrate into the fibrin clot, which serves as a matrix for their activity. The synthesis of collagen by these fibroblasts initiates the formation of connective tissue. As the healing process advances, the gradual resorption of the fibrin sealant is necessary. Several factors influence this resorption, including the amount of glue initially applied, the fibrinolytic activity present in the wound area, and the phagocytosis carried out by macrophages and granulocytes [17].

In the wound environment, tissue plasminogen activators convert plasminogen into plasmin, which in turn breaks down crosslinked fibrin into soluble fibrin degradation products. To delay the lysis of the clot, especially in regions with high local fibrinolytic activity such as the lung, prostate, uterus, and highly vascularized tissues, an antifibrinolytic agent like aprotinin can be added to either component of the fibrin glue. Aprotinin is a naturally occurring protease inhibitor that helps maintain the integrity and longevity of the fibrin sealant in these challenging environments [18].

Methods of Application of Fibrin Glue:

Fibrin glue application methods vary depending on the specific medical indication. Sequential application of its components is generally discouraged due to the risk of poor mixing, which can compromise the adhesive strength of the glue. This challenge can be addressed by either premixing (preferably with low thrombin concentration) or using a double syringe applicator like the Duploject system [15].

The Duploject system allows single-handed operation and ensures thorough mixing of the fibrinogen and thrombin solutions within the delivery needle, which can be changed if needed during application [19].

For specific surgical contexts, alternative delivery systems are employed. A microdrop delivery system, suitable for middle ear microsurgery, delivers fibrin glue precisely. Spray applications are effective for covering larger surfaces, where a multi-channel catheter connected to a pressurized gas source disperses the fibrinogen and thrombin solutions as a thin film over the wound surface [16].

Furthermore, fibrin glue can be applied using carriers such as collagen fleece, dura, or grafts. The effectiveness of biological adhesives is influenced by the dryness of the tissue surface; drier surfaces tend to promote stronger bonding, a process enhanced when both fibrinogen and thrombin components are kept at body

temperature (37°C). Researchers are also exploring the potential of combining antibiotics with fibrin glue, with drug release occurring via simple diffusion across a concentration gradient. In vivo studies suggest that adequate local antibiotic levels can be maintained for up to 3 days [20].

Contraindications of Fibrin Glue:

The glue must not get into blood vessels, as this could lead to clotting in the form of thromboembolism or disseminated intravascular coagulation, or to anaphylaxis (a severe allergic reaction) [19].

Side Effects of Fibrin Glue:

Possible adverse effects include bleeding disorder and allergic reactions such as flushing, stinging, generalized urticaria, angioedema, bronchospasm, and anaphylaxis. Other adverse effects in studies occurred in roughly equal proportions in treatment and placebo groups [20]. As fibrin glue contains proteins, it may be denatured by ethanol, iodine, and heavy metals. These substances are frequently found in antiseptic solutions [21].

Conclusion and Recommendations:

We concluded that the standard microvascular anastomosis is widely used, but sutures may reduce the patency of the lumen of the anastomosed artery with an increasing possibility of hematoma formation and are more time-consuming. Therefore, we advise using fibrin glue to reduce the time needed for anastomosis, prevent hematoma formation, and preserve the patency and blood flow in the anastomosed vessel. In addition, further studies must be done to analyze all aspects of this issue.

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