AN EVIDENCE BASED APPROACH TO SOFT TISSUE APPROXIMATION: A Review of Suture Selection for Optimal Skin Closure

Cathy O. Coker, DPM

INTRODUCTION

Skin reapproximation has not received much attention in regard to evidence based medicine. A surgeon's preference for suture selection generally originates more on tradition passed down from teacher to student and less on the available scientific data. There is however a vast amount of clinical experience that can aid in choosing the ideal suture material and achieving the desired skin closure. The various types of sutures that can be used for optimal skin closure will be discussed.

WOUND HEALING

Sutures function primarily to maintain wound closure and promote wound healing during the time when the wound is most vulnerable.[1] The wound healing process can be affected by the type of suture material and the amount of tension placed on the skin. There are three main stages of wound healing. The first stage is the inflammatory phase or the lag phase, which is an acute response to tissue injury initiating an accumulation cells like fibroblast, proteins, and angiogenic cells. Damaged tissue debris are degraded and removed by proteolytic enzymes that help prepare the site for tissue repair. This phase lasts 3 to 4 days and accounts for 10% of the healing phase. Tensile strength is solely dependent upon the suture material used for reapproximation.

The next phase of wound healing is the proliferative phase. Fibroblasts produce collagen fibers that help to promote the formation of granulation tissue. The presence of collagen is the main component of connective tissue and determines the tensile strength of a healing wound. Randomly arranged collagen fibers are orientated in a more orderly fashion thus promoting wound contraction. This phase lasts for 14 to 21 days and accounts for 35% of the healing process.

The maturation phase lasts from 3 weeks to 1 year and accounts for 70% of tensile strength. Collagen fibers become more orderly arranged with a significant increase in tensile strength. The formation of a scar during the healing process is proportionally related to the amount of collagen deposition. One important aspect of wound healing is that only 7% of the final tensile strength of the wound is achieved by 2 weeks, and optimally wound strength never returns to more than 80% of normal intact skin.[1]

SUTURE CHARACTERISTICS

The United States Pharmacopeia (USP) has determined a list of terms to better describe the various characteristics of sutures, and serves as a guideline for producing and packaging sutures. According to the USP, suture characteristics can be described, based on suture properties, handling characteristics, and tissue reactivity (Table 1).

Table 1

CHARACTERISTICS OF SUTURE MATERIAL

- Physical characteristics
  - Physical configuration
  - Capillarity
  - Fluid absorption ability
  - Diameter
  - Tensile strength
  - Knot strength
  - Elasticity
  - Plasticity
  - Memory
- Handling characteristics
  - Pliability
  - Tissue drag
  - Knot tying
  - Knot slippage
- Tissue reaction characteristics
  - Inflammatory and fibrous cell reaction
  - Absorption
  - Potentiation of infection
  - Allergic reaction

Some examples of suture properties are elasticity, plasticity, and memory. Elasticity refers to inert ability of a suture to regain its original form of length after being stretched. Plasticity is the suture ability to retain its new length. Plasticity and elasticity are significantly related in terms of choosing a suture that will expand with the tissue edema and not cut into the tissues. Memory is the ability of a suture to return back to its original shape after deformation. The more memory a suture has the less likely that suture will maintain the security of the tied knot. Sutures with a significant amount of memory will need more throws of knots to maintain the security and the integrity of the knot tied. Memory also affects the handling characteristic of the suture material. The more memory a suture has, the more cumbersome handling the suture is for the surgeon.

Physical configurations are the capillarity, pliability, and the tensile strength of a suture. The capillarity correlates to the tendency of the suture to attract and retain bacteria. Double stranded or multifilament suture have a high capillarity factor and should not be used in the presence of a contaminated wound or an infection. Single stranded or monofilament sutures are less likely to harbor bacteria and are ideally used in contaminated and infected wounds.

Pliability refers to how easy the suture can bend. Multifilament sutures are braided or twisted and are more pliable, handling easier than monofilament sutures. Tensile strength refers to the amount of load necessary to break a suture divided by the cross sectional area. As diameter of the suture increases, so does the tensile strength. Tensile strength also describes coefficient of friction as well as the knot security. The coefficient of friction describes the ability of the suture to glide through tissues with little drag resistance. Sutures with a high coefficient of friction tend to have a difficult time maintaining the security of a tied knot. A knotted suture has about one third the tensile strength of an unknotted suture.[2]

Tissue reactions are exponentially related to the amount of suture material implanted. The degree of tissue reactions is related to the number of passes the needle with the suture makes through the tissues. The more sutures thrown or implanted in the skin, the greater the likelihood of developing tissue reactions. Tissue reaction peaks 3 to 7 days after suture placement. Unfortunately, prolonged tissue reaction can result in wound dehiscence, wound infection, and delayed wound healing. The idea that less is more has to be adopted in regard to the amount of suture placement for skin closure. Sutures are foreign objects within the body. Accurate placement of the needles coupled with minimal tissue handling, can decrease the development of tissue reaction.

SUTURE MATERIALS

Absorbable sutures temporarily reapproximate wound edges until signs of wound healing are present. Natural forms of absorbable sutures are either made of collagen from mammals or from synthetic polymers. A larger amount of collagen present correlates with an increase in tensile strength. Also, the more collagen present, the better the body is able to absorb the suture material without having adverse reaction.

Depending on the composition of the suture, some are absorbed rapidly while others may be chemically treated to prolong their degradation process. Coated material may be added to increase the smoothness of the suture as it passes through the tissues. Both natural and synthetic absorbable sutures are available undyed or dyed for better visibility in tissues.

Natural absorbable sutures are degraded by body enzymes. Synthetic absorbable suture is degraded by hydrolysis, a process by which water gradually penetrates the suture filaments, causing a breakdown and disruption of the suture's polymer. The hydrolyzation process of synthetic absorbable suture tends to cause less tissue reaction than the natural degradation process.

The degradation process of absorbable suture begins with a gradual decrease in tensile strength in a linear fashion.[3] The absorption process initiates a cellular response of leukocytes to the site of suture implantation to remove cellular debris and suture material. The absorption rate of suture material increases significantly in the presence of fever, infection, and protein deficiency. An increase in the degradation process of suture causes a decline in tensile strength. Patients with known wound healing deficiency are not candidates for this type of suture.

Absorbable Sutures

Catgut is a natural form of absorbable suture that is rarely used today for suturing skin however, it represents the standard with which modern materials are frequently compared.[2] Catgut or surgical gut is made of the submucosa of sheep or intestinal serosa of cattle. Catgut is composed of 98% pure ribbon collagen. This suture must remain wet in alcohol since drying makes the suture material brittle. The degradation process of catgut is initiated by proteolytic enzymes 12 hours after implantation. Tensile strength of catgut lasts for 7 to 10 days, and is typically completely absorbed within 70 days.[3] Plain gut may be used on rapidly healing tissues that require minimal support, like ligating vessels and suturing subcutaneous layers. However, catgut is highly reactive and significantly inhibits wound healing. The unpredictability of this material makes its use in cutaneous surgery obsolete. Use of catgut is limited to percutaneous interrupted sutures since the suture material weakens quickly and loosens within 3 to 4 days.[2] Chromium salts may be added to catgut creating a stronger and tougher suture called chromic gut. Chromic gut may be used to promote the proliferation of granulation tissue in wounds healing by secondary intention.

Polyglycolic acid (dexon), the first synthetic absorbable suture was introduced in the 1970s. This suture is made of a homopolymer of glycolic acid and is the only suture categorized as a drug. It is approved by the Food and Drug Administration for implantable use in the human body.[2] The coated form of dexon, dexon S, glides through tissues allowing for smoother handling than that of uncoated dexon. Dexon is degraded by the hydrolysis process resulting in carbon dioxide and water. Dexon takes 90 to 120 days to be completely absorbed and is significantly less reactive when compared with catgut.[4] Dexon may be used in a buried suture technique for apposition of cutaneous wounds. This braided suture should not be used in infected or contaminated wounds.

Polyglactin 910 (vicryl) is a synthetic, braided suture made of polyglactin 370, a copolymer composed of 90% glycolic acid and 10% lactic acid. This suture is available either dyed or undyed; however the undyed suture picks up blood as it passes through the tissue making it easily visible. Vicryl may also be coated with calcium stearate for smoother passage through tissues. Due to the high tensile strength and very low plasticity and elasticity of vicryl, coated vicryl handles easier, ties down smoother, and maintains its knot security.[3] This suture is completely hydrolyzed in 60 days. Vicryl buried too close to cutaneous wounds may spit or extrude before being fully absorbed.[2] Suture abscesses within the subcutaneous layer may be present as a palpable "lump" within the incision line and are more commonly associated with newer coated Vicryl suture.

Polydioxanone (PDS) is monofilament suture composed of polyester paradioxanone polymer. PDS has a low affinity for bacteria and ideally can be used for skin closure, however, an increase in tensile strength makes handling this suture very difficult for cutaneous suturing. Tensile strength of the suture is 70% present 2 weeks after implantation and is completely absorbed in 120 days, lasting longer than dexon or vicryl.

Monocryl (poliglecaprone 25) is a monofilament made of a copolymer of glycolide and epsilone-aprolactone. This suture may be used for subcutaneous and skin closure. Dyed monocryl retains 60 to 70% of its original strength 7 days after implantation, with all original strength lost by day 28. At day 7, undyed monocryl retains 50 to 60% of the original strength, with the tensile strength lost 21 days after implantation.[3] Monocryl is completely absorbed 91 to 119 days after implantation.

Coated vicryl plus antibacterial (polyglactin 910) is made of the same material as vicryl with the addition of an antibacterial agent triclosan (Irgacare MP). Triclosan is an antiseptic not an antibiotic agent. In vivo, vicryl plus antibacterial suture created a zone of inhibition effective against pathogens commonly associated with surgical site infections such as Staphylococcus aureus, methicillin-resisitant Staphylococcus aureus, Staphylococcus epidermidis, and methicillin-resisitant Staphylococcus epidermidis.[3] Triclosan is neither toxic nor genotoxic and has been used in over-the-counter health products like toothpaste and bodywash. Vicryl plus antibacterial has no effect on wound healing, and its tensile strength and rate of degradation is similar to that of coated vicryl.

Nonabsorables Sutures

Nonabsorbable sutures are made of a variety of non-biodegradable materials. These sutures are eventually encapsulated or walled off by fibroblasts.[2] Nonabsorbable sutures used for skin closure are removed after adequate healing has occurred and may have a tendency to perpetuate tissue hypertrophy or keloidal tendency.[2] There are some nonabsorbable sutures that undergo a gradual degradation process similar to absorbable sutures.

Silk is a braided, naturally-occurring nonabsorbable protein suture called fibroin fiber made by silkworm larva. For increased visibility, the natural white fiber of silk suture is dyed with black vegetable dye. The braided characteristic of silk allows for better handling. Once implanted, silk swells and allows for an in-growth of tissue between the braided fibers, which makes suture removal difficult. Gelatin may be added to silk allowing for easy handling and minimal tissue in-growth. Silk loses tensile strength when exposed to moisture and should be used dry. In vivo studies have shown that silk loses most if not all its tensile strength in 1 year and cannot be detected in the tissues 2 years later, thus behaving like a slowly absorbing suture.[3]

Nylon is a synthetic polyamide polymer fiber. The monofilament form of nylon, Ethilon is often used for percutaneous suturing. Monofilament nylon is more pliable when damp or wet then dry nylon. Multifilament braided nylon suture are called Surgilon or Nurolon. Nylon is available in many colors. Undyed nylon suture is readily used for deep tissue reapproximation because it is not visible through the skin. The tensile strength of nylon is significantly high when compared with silk suture. Handling nylon can be cumbersome due to the memory and stiffness of the material, which enables the nylon to cut through the tissues.[2] Nylon causes less tissue reaction and like silk undergoes a gradual degradation process similar to that of absorbable sutures. Nylon in vivo undergoes hydrolysis at the rate of 15 to 20% per year.

Prolene (polypropylene) is a monofilament plastic suture made of the polymerization of prolene. Prolene is commonly dyed blue with copper phthalocyanine. This suture is very smooth and causes little drag through the tissue making it ideal for intradermal closure. Prolene does not adhere to tissues and is often used as a pull-out suture postoperatively.[3] Prolene is a durable inert suture and is often used in contaminated and infected wounds to minimize sinus tract formation and suture extrusion. Prolene stretches easily and is accommodating to the edematous wound; however, when wound edema subsides, the loosened suture may cause separation of wound edges.

Polyester is a multifilament braided suture made of nylon polymers. This suture is green and may be coated or uncoated. The uncoated polyester is known as Mersilene, which is the first synthetic braided suture known to last indefinitely. Polyester may also be coated with teflon (Ethefix), silicone (Tri Cron), or polybutilate (Ethibond). Polybutilate was the first synthetic coating developed specifically as a surgical lubricant for sutures. Polyester coated with teflon and silicone tend to have fragments separate from the suture into the surrounding tissues, thereby triggering a foreign body reaction.[1] Polybutilate, on the other hand has a high affinity for polyester causing a decrease in tissue reactions unlike Teflon and silicone-coated polyester.

NEEDLES

Needle selection is based on the specific type of tissues that are to be sutured. Surgical needles are made of stainless steel. The needle is divided into 3 parts, the point, the body, and the swage or the shank. The swage of the needle will determine the size of suture tract through the tissues.

The most commonly-used suture needles for skin closure are reverse cutting and conventional cutting needles. Skin closure is predominately done with reverse cutting needles. This needle is ideal for difficult to penetrate areas like skin, tendon, and sheath. The needle has a triangular tip with 2 opposing cutting edges on the inside of the curvature and a third cutting edge on the outside.[1] The advantage of using a reverse cutting needle is when the needle transects the skin, the outside cutting edge is pointed away from the wound edge and the flat inner surface is parallel to the wound.[2] The CE, FS, P, PS, PRE, and SBE are all reverse cutting needles.[3]

The conventional cutting needle is similar to the reverse conventional cutting needle. The cutting edge is along the inner curvature of the needle. The position of the conventional needle increases the tendency to cut through the tissue. PC needles are a type of conventional needle that are typically used for fine suturing of the skin.

Round needles with tapered points can be used for subcutaneous closure. The tapered points have less of a tendency to tear the tissues because there are no cutting edges on the needle. However, the round shape of the needle makes it difficult to stabilize in needle holders.

Surgeons must be knowledgeable on the different types of suture materials available for selecting the appropriate material for skin closure. Optimally the ideal suture must handle easily, secure knots well, cause minimal tissue reaction, and not inhibit wound healing. The ideal suture stretches to accommodate wound swelling and does not promote wound infection. Unfortunately, no single suture posses all of these characteristics; thus with proper suture selection better results in skin closure can be achieved.

REFERENCES

1. Moy RL, Waldman B, Hein DW. A review of sutures and suturing techniques. *J Dermatol Surg Oncol* 1992;18:785-95.
2. Bennett R. Continuing medical education: selection of wound closure materials. *J Am Acad Dermatol* l988;18:619-35.
3. Dunn DL. *Wound Closure Manual*. Ethicon; 2007.
4. Eliert JB, Binder P, McKinney PW, et al. Polyglycolic acid synthetic absorbable sutures. *Am J Surg* 1971;121:561-5.