The Use of Barbed Sutures in Obstetrics and Gynecology

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Despite the multitude of different procedures performed with a host of different wound closure biomaterials, no study or surgeon has yet identified the perfect suture for all situations. In recent years, a new class of suture material—barbed suture—has been introduced into the surgeon's armamentarium. This review focuses on barbed suture to better understand the role of this newer material in obstetrics and gynecology.

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Key words: Suture, material • Suture, tensile strength • Suture, absorption rate • Barbed suture, unidirectional • Barbed suture, bidirectional

Sutures and surgery have been tied together since the first operations were performed. Throughout the history of surgery, the variety of materials used to close wounds has included wires of gold, silver, iron, and steel; dried gut; silk; animal hairs; tree bark and other plant fibers; and, more recently, a wide selection of synthetic compositions. Despite the multitude of different procedures performed with a host of different wound closure biomaterials, no study or surgeon has yet identified the perfect suture for all situations.

In recent years, a new class of suture material—barbed suture—has been introduced into the surgeon's armamentarium. Currently, there are 2 commercially available barbed suture products: the Quill™ SRS bidirectional barbed suture product line (Angiotech Pharmaceuticals, Inc., Vancouver, BC, Canada) and the

V-Loc™ Absorbable Wound Closure Device product line (Covidien, Mansfield, MA). These synthetic sutures eschew the traditional, smooth, knot-requiring characteristic of sutures in favor of barbs that serve to anchor the sutures to tissue without knots.

This review focuses specifically on barbed suture to better understand the role of this newer material in obstetrics and gynecology. Given the paucity of published data on the V-Loc sutures, the review will mostly focus on Quill bidirectional barbed sutures.

Classification and Characteristics of Suture Material

Suture material can be classified by numerous different characteristics. For practical purposes, the 6 categories of suture classification believed to best assist surgeons in choosing the proper suture material for their surgeries are:

- Suture size
- Tensile strength
- Absorbable versus nonabsorbable
- Multifilament versus monofilament
- Stiffness and flexibility
- Smooth versus barbed

Suture Size

All suture materials are available in a variety of sizes. There are currently 2 standards used to describe the size of suture material: the United States Pharmacopoeia (USP) and the European Pharmacopoeia (EP). The USP standard uses a combination of 2 numerals—a 0 and a number other than 0 (such as 2-0 or 2/0). The higher the first number, the smaller the suture diameter. The USP is the more commonly used system in the United States. Table 1 summarizes both the USP and the EP standards and their corresponding knot-tensile strength for synthetic suture.[1] The USP standard code also varies between collagen sutures and synthetic sutures with regard to diameter, whereas the EP standard corresponds directly to minimum diameter regardless of material. With all suture materials, increasing the size of the suture increases the tensile strength. However, with both standards, there is a marked reduction in the limits of the average minimum of knot-pull tensile strengths between collagen sutures and synthetic sutures for any given size code. For example, 0 USP (4 EP) chromic gut suture has a minimum diameter of 0.40 mm and is rated to have an average minimum of knot-pull tensile strength of 2.77 kilogram-force (kgf), whereas 0 USP (3.5 EP) polydioxanone suture has a minimum diameter of 0.35 mm and is rated to have an average minimum of knot-pull tensile strength of 3.90 kgf.

Tensile Strength

Each suture material has a recognized tensile strength which, for a given suture size, is most easily discussed as its failure or break load. This is the amount of weight in pounds or kilograms that is necessary to cause the suture to rupture. Typically, this measurement is presented in 2 forms, straight pull and knot pull, to reflect the reduction in any given suture's strength when it is knotted. In practical terms, the knot-pull tensile strength most accurately reflects a given smooth suture's in vivo tissue holding capacity because almost all applications for smooth suture require knotting. In a straight-pull tensile test, tension to rupture is applied at either end of a suture. A knot-pull tensile test is the same except that a

Table 1
USP and EP Size Codes and Corresponding Diameters and Knot-Pull Tensile Strengths for Synthetic Sutures

Collagen Suture	Synthetic Suture		Limits on Average Diameter (mm)		Knot-Pull Tensile Strength (kgf) Limit on Average Min	
USP Size Code	USP Size Code	EP Size Code	Min	Max	Collagen	Synthetic
	8-0	0.4	0.04	0.049		0.07
8-0	7-0	0.5	0.05	0.069	0.045	0.14
7-0	6-0	0.7	0.07	0.099	0.07	0.25
6-0	5-0	1	0.10	0.149	0.18	0.68
5-0	4-0	1.5	0.15	0.199	0.38	0.95
4-0	3-0	2	0.20	0.249	0.77	1.77
3-0	2-0	3	0.30	0.339	1.25	2.68
2-0	0	3.5	0.35	0.399	2.00	3.90
0	1	4	0.40	0.499	2.77	5.08
1	2	5	0.50	0.599	3.80	6.35

EP, European Pharmacopoeia; kgf, kilogram-force; Max, maximum; Min, minimum; USP, United States Pharmacopoeia.

single knot has been tied in the middle of the strand. As an exception, barbed suture strengths are reported only as straight pull because there is no knot. All these measurements are reported as in vitro values and reflect only the suture's immediate, out-of-the-package strength without regard for the tissue milieu in which they will be placed (Table 2).[2-4]

Absorbable Versus Nonabsorbable

All suture materials act as foreign bodies in all wounds and impede wound healing to some extent. In this regard, the "perfect" suture material retains adequate strength through the healing process and disappears as soon as possible thereafter with minimal associated inflammatory reaction. An essential part of choosing the proper suture is determining the balance between the added strength the suture provides to the tissues as they heal versus the negative effects of that suture material with regard to inflammation. This section focuses on absorbable suture materials. Table 3[2-4] lists currently available absorbable sutures and the degradation rates.

Prior to the 1930s, surgical gut (collagen sutures made from sheep or cow intestines) and silk dominated the suture market. In the late 1930s and early 1940s, the introduction of the synthetic fibers nylon, polyester, and polypropylene expanded the choices of nonabsorbable sutures; surgical gut remained the only absorbable suture option.

Surgical gut was and is still available in one of 2 preparations: plain or chromic. The submucosa of sheep intestines or serosa of cow intestines are split into longitudinal ribbons and treated with formaldehyde. Several ribbons are then twisted into strands, dried, ground down, and polished into the correct suture size. The resulting untreated product is called *plain gut*. If the plain gut is then further tanned in a bath of chromium trioxide, it is called *chromic gut*. The chromium treatment delays the absorption of the chromic gut and thereby extends its tensile strength for longer periods.

In the author's opinion, there are few scientific data to support the current use of either plain or chromic gut sutures in any surgical procedure.

As noted above, both plain and chromic gut have been staples of surgical wound closure for a long time. However, the nature of surgical gut's processing and composition makes this suture material somewhat of an anachronism in surgery today. First, the grinding and polishing process of the twisted gut multifilaments produces unpredictable amounts of weak points and fibril tears that yield to the sutures' characteristic fraying when tied. Also, these same processing methods make reproducible strength difficult to achieve.[5] Second, and perhaps more importantly, because surgical gut is a foreign protein, it is degraded and absorbed mainly via proteolytic enzymes from phagocytes and other cells—therefore tending to have a less predictable absorption rate and elicits a much more intense tissue reaction than newer, synthetic absorbable suture. In the author's opinion, there are few scientific data to support the current use of either plain or chromic gut sutures in any surgical procedure.

In the early 1970s, synthetic, absorbable sutures were introduced. As these materials can be produced under precisely controlled manufacturing conditions with uniform

Table 2
Mean Tensile Strengths of 2-0 Smooth Sutures and 0 Barbed Sutures

Suture	Straight-Pull Strength (kgf)*	Knot-Pull Strength (kgf)*
Chromic surgical gut	4.11	2.05
Polydioxanone	4.89	3.34
Coated polyglactin 910 (Vicryl™)	6.93	3.63
Poliglecaprone 25 (Monocryl™)	7.26	3.67
Barbed polydioxanone	3.89*	NA
Polyglyconate (Maxon™)	7.09	4.41
Barbed poliglecaprone 25 (Monoderm™)	4.64†	NA

kgf, kilogram-force; NA, not applicable.
Maxon, Covidien AG, Mansfield, MA; Monocryl and Vicryl, Ethicon, Inc., Somerville, NJ; Monoderm, Angiotech Pharmaceuticals, Vancouver, Canada.
*Straight-pull strength reflects practical in vivo strength with barbed suture, whereas knot-pull strength reflects practical in vivo strength with smooth suture.
†0 barbed suture is rated as 2-0 smooth suture.

Table 3
Absorption Rates of Absorbable Sutures

Suture	Time to 50% Loss of Tensile Strength (d)	Time to Complete Loss of Tensile Strength (d)	Time to Complete Mass Absorption (d)
Plain surgical gut*	3-5	14-21	70
Fast-absorbing coated polyglactin 910 (Vicryl Rapide™)	5	14	42
Polyglytone 6211 (Caprosyn™)	5-7	21	56
Poliglecaprone 25 (Monocryl™)	7	21	91-119
Barbed poliglecaprone 25 (Monoderm™)	7-10	21	90-120
Chromic surgical gut*	7-10	14-21	90-120
Coated polyglycolide (Dexon II™)	14-21	28	60-90
Polylycomer 631 (Biosyn™)	14-21	28	90-110
Coated polyglactin 910 (Vicryl™)	21	28	56-70
Polyglyconate (Maxon™)	28-35	56	180
Polydioxanone (PDS II™)	28-42	90	183-238
Barbed polydioxanone	28-42	90	180

*Extreme variability based on tissue type, infection, and other biologic conditions.
Biosyn, Caprosyn, Dexon II, and Maxon, Covidien AG, Mansfield, MA; Monocryl, PDS II, Vicryl, and Vicryl Rapide, Ethicon, Inc., Somerville, NJ; Monoderm, Angiotech Pharmaceuticals, Vancouver, Canada.

chemical compositions, they consistently demonstrate more reliable strength and degradability inside biologic environments than natural products. Further, as nonproteins, these materials generally elicit less intense tissue reactions which, in turn, promote faster wound healing and strength.[6]

The first synthetic, absorbable sutures to be commercialized were based on polyglycolic acid—polyglycolide and glycolide-L-lactide random copolymer or polyglactin 910. Both are synthesized using melt spinning of chips. The fibers are stretched to several hundred percent of their original length and heat-set to improve their dimensional stability and inhibit shrinkage. As a result of their high density of ester functional groups, both of these materials are too rigid in larger sizes to be of practical use as a suture. Therefore, individual smaller fibers are braided into final multifilament strands of various sizes to allow for a product that has predictable absorption and strength profiles, as well as acceptable handling characteristics.[7] Synthetic materials such as these are mostly degraded in vivo via hydrolysis, and thus involve less of an inflammatory reaction than their natural protein analogs.

Following the commercialization of braided, synthetic, absorbable sutures came the introduction of absorbable, synthetic monofilament sutures in the 1980s. Both poly-*p*-dioxanone or polydioxanone (PDO) and polyglycolide-trimethylene carbonate copolymer or polyglyconate are absorbable monofilament sutures that have the predictable strength and absorption requirements of their earlier polymer cousins but with the flexibility that allows for a monofilament configuration.

Finally, as the evolution of suture continued, biomaterial technology led to the introduction of segmented block copolymers consisting of hard and soft segments that allowed for synthetic monofilament sutures with shorter absorption rates and better handling characteristics. These materials included glycolide and ε-caprolactone or poliglecaprone 25; the triblock copolymer glycolide, dioxanone, and trimethylene carbonate or polylycomer 631; and the newest quadblock copolymer glycolide, ε-caprolactone, trimethylene carbonate, and lactide or polyglytone 6211, introduced in 2002. The purpose of soft segments is to provide good handling properties like pliability whereas the hard segments provide the strength.[8] These newer monofilament sutures consistently demonstrate better handling profiles while lowering the complete absorption rates to 119 days, 110 days, and 56 days, respectively. To address the apparent need for a polyglycolic acid–based suture with a shorter absorption profile, a fast-absorbing variety of standard polyglactin 910 suture material pretreated with ionizing beams to accelerate hydrolysis was introduced in 2003. As a result of its pretreatment, this newer suture material has an average absorption of 42 days.[9]

Multifilament Versus Monofilament

Multifilament refers to the use of more than 1 fiber of suture material in the manufacturing of a single finished strand of suture. From the perspective of wound healing, there are no advantages of a multifilament over a monofilament. As compared with monofilament sutures, multifilament sutures inflict more microtrauma as they pass through tissues.[10] Multifilament sutures also induce a more intense inflammatory response and contribute to larger knot volumes than monofilament sutures of equal size.[11,12] Finally, multifilament sutures demonstrate enhanced capillarity with a resultant increase in the transport and spread of microorganisms.[13] That said, there are other suture characteristics that can outweigh the beneficial wound healing properties of monofilament suture as compared with multifilament suture. Specifically, currently available multifilament sutures tend to exhibit more favorable handling properties and material flexibility than comparably strong monofilament materials.

Stiffness and Flexibility

A suture's stiffness and flexibility give the material its handling or feel. It is stiffness that makes a suture soft or hard, gives it memory or recoil, and determines the ease with which knots can be tied. Further, it is the stiffness that tends to be associated with the presence or absence of mechanical irritation of the suture due to its ability or inability to comply with the topology of the surrounding tissues.[14] Specifically, stiffer sutures tend to lead to more problems with stitch abscesses and granulomas.

As a general rule, at any given size, monofilament suture materials tend to have higher bending stiffness than multifilament braided configuration. Natural multifilament twisted sutures, such as chromic catgut, tend to act more like monofilaments than braided multifilament sutures in this regard.

Smooth Versus Barbed

In 1956, Dr. J. H. Alcamo was granted the first US patent for a unidirectional barbed suture,[15] although the concept dates back to 1951 when the idea of using barbed sutures was presented for tendon repairs.[16] The first US Food and Drug Administration (FDA) approval for barbed suture material was issued in 2004 to Quill Medical, Inc., for its Quill bidirectional barbed polydioxanone suture.[17] In March 2009, the FDA approved the V-Loc 180 barbed suture from Covidien. Whether bidirectional or unidirectional barbed suture is better is unknown, although there are reported complications of unidirectional barbed sutures migrating or extruding.[18,19] This problem is thought to have been due to the lack of counterbalancing forces on the suture line.

Barbed sutures are available in a variety of both absorbable and nonabsorbable monofilament materials. Specifically, currently available bidirectional and unidirectional barbed suture materials include PDO, polyglyconate, poliglecaprone 25, glycomer 631, nylon, and polypropylene. Bidirectional barbed sutures are manufactured from monofilament fibers via a micromachining technique that cuts barbs into the suture around the circumference in a helical pattern. The barbs are separated from one another by a distance of 0.88 to 0.98 mm and are divided into 2 groups that face each other in opposing directions from the suture midpoint (Figure 1).[20] Needles are swaged onto both ends of the suture length. Owing to its decreased effective diameter as a result of the process of creating barbs, barbed suture is typically rated equivalent to 1 USP suture size greater than its conventional equivalent. For example, a 2-0 barbed suture equals a 3-0 smooth suture.

Unidirectional barbed sutures are similarly manufactured from monofilament fibers, but needles are swaged onto only 1 end whereas the other end maintains a welded closed loop to facilitate initial suture anchoring (Figure 2). Unlike bidirectional barbed suture, unidirectional barbed suture is rated equal in strength to its USP smooth suture counterpart. However, this strength rating difference between the 2 barbed varieties is the result of labeling differences rather than an actual material benefit.

Why Not Knots?

It is difficult for many surgeons to think about suture material without an accompanying knot. Nonetheless, the surgical knot used with a length of smooth sutures is a significant necessary evil that is accepted as the only irrefutable means to anchor suture material within a wound.

A knot-secured, smooth suture inevitably creates an uneven distribution of tension across the wound. Although the closed *appearance* of a wound may be that of equal tension

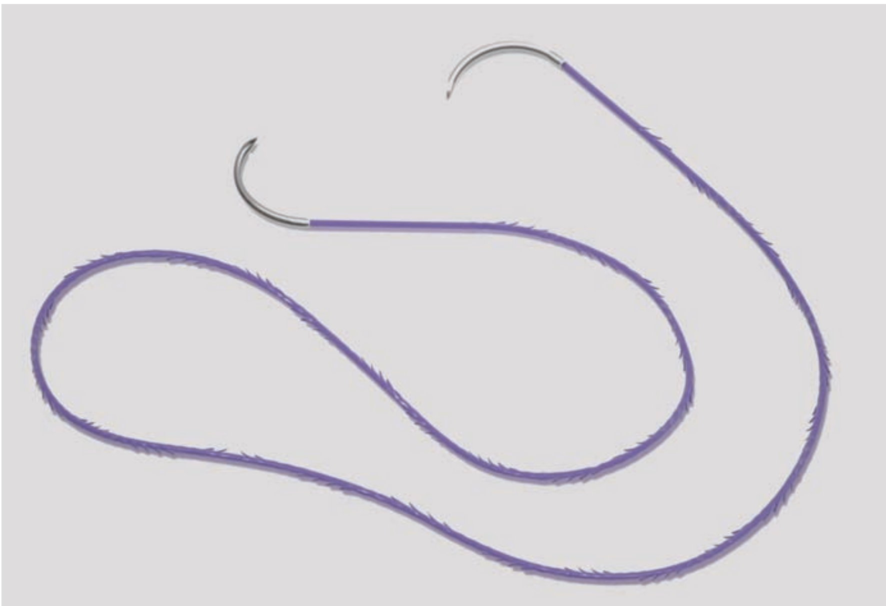

Figure 1. *Quill™ SRS bidirectional barbed suture (Angiotech Pharmaceuticals, Inc., Vancouver, BC, Canada). Photo courtesy of Angiotech Pharmaceuticals, Inc.*

Figure 2. *V-Loc™ Absorbable Wound Closure Device (Covidien, Mansfield, MA). Copyright ©2010 Covidien. All rights reserved. Used with the permission of Covidien.*

distribution, there are unequal tension burdens placed on the knots rather than on the length of the suture line. This tension gradient across the wound may subtly interfere with uniform healing and remodeling.

The weakest spot in any surgical suture line is the knot. The second weakest point is the portion immediately adjacent to the knot, with reductions in tensile strength reported from 35% to 95% depending on the study and suture material used.[21-23] When functional biomechanics are considered, this finding should not be surprising considering both the effects of slippage of suture material through the knot and the unavoidable suture elongation that occurs as a knot is formed and tightened.

Given the excessive relative wound tension on the knot and the innate concerns for suture failure due to knot slippage, there is a predilection toward overcoming these concerns with excessively tight knots. However, surgical knots, when tied too tightly, can cause localized tissue necrosis, reduced fibroblast proliferation, and excessive tissue overlap, all of which lead to reduced strength in the healed wound.[24]

A surgical knot represents the highest amount and density of foreign body material in any given suture line. The volume of a knot is directly related to the total amount of surrounding inflammatory reaction.[12,25] If minimizing the inflammatory reaction in a wound is important for optimized wound healing, then minimizing knot sizes or eliminating knots altogether should be beneficial as long as the tensile strength of the suture line is not compromised.

Finally, with minimally invasive laparoscopic surgeries, the ability to quickly and properly tie surgical knots has presented a new challenge. In cases where knot tying is difficult, the use of knotless, barbed suture can securely reapproximate tissues with less time, cost, and aggravation.[26,27] Although the skills necessary to properly perform intra- or extracorporeal knot tying for laparoscopic surgery can be achieved with practice and patience, this task is a difficult skill that most surgeons still need to master to properly perform closed procedures. In addition, laparoscopic knot tying is more mentally and physically stressful on surgeons[28,29] and, more importantly, laparoscopically tied knots are often weaker than those tied by hand or robotically.[30-32]

Are Barbed Suture Lines as Strong as Smooth, Knotted Suture Lines?

When faced with newer barbed sutures, many surgeons are initially skeptical with regard to the strength of the knotless, barbed suture lines as compared with traditional knotted, smooth suture lines. Although the data are limited and almost exclusively based on studies with bidirectional suture, barbed suture lines appear to be at least as strong if not stronger than traditional knotted, smooth suture lines. Although conventional sutures lose tensile strength at and around the knots, the knotless, barbed suture is not subject to this hazard. This is clearly evident in vitro in a comparison of the straight-pull strengths of barbed sutures versus the knot-pull strengths of their smooth suture equivalent (Table 2), and is further validated in tissue pull-through studies.[33-36] Tellingly, a recent study of porcine gastrointestinal closure burst-strength pressures in wounds closed with barbed suture were no different than repairs performed with traditional knotted, smooth suture lines.[37]

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As barbed suture self-anchors at approximately every 1 mm of tissue, there is a more uniform distribution of wound tension across the suture line than with conventional running smooth suture, yielding more consistent wound opposition. The anchoring of barbed suture resists migration and can be conceptualized as a "continuous interrupted" suture without all the knots. Two separate studies demonstrate this point nicely by looking at suture line strength in hand tendon repairs and parapatellar arthrotomy repairs.[38,39] In both trials, barbed suture lines consistently demonstrated more resistance to suture line failure than traditional knotted suture lines.[38,39] Finally, the use of barbed sutures with more evenly distributed tension may yield stronger wounds by eliminating the high tension spots that are more prone to disrupted healing.[40,41]

Use of Barbed Sutures in Obstetric and Gynecologic Procedures

The choice and use of sutures in obstetrics and gynecology (ob-gyn) is based more on anecdote and experience than data. Though many of the suture materials routinely used in myomectomies, hysterectomies, and cesarean deliveries have endured the test of time, this should preclude neither the application of scientific review nor the quest for improvement. In addition to understanding the physical properties and characteristics of the variety of available sutures, surgeons need to consider the tissue and physiologic milieu into which suture will be placed before choosing the material to use. For example, in general, the suture-holding strength of most soft tissues depends on the amount of fibrous tissue they contain. Thus, skin and fascia hold sutures well whereas brain and spinal cord tissue do not. Further along this line, healthier tissues tend to support sutures better than inflamed, edematous tissues. To choose the best suture material for an ob-gyn procedure, surgeons should take into account all the variables present, such as a tissue's collagen structure, blood supply, disruptive forces, and potential for infection. When these characteristics are considered, the physical characteristics of barbed sutures make these materials an attractive option.

The first use of barbed sutures in gynecologic surgery was reported by Greenberg and Einarsson in 2008.[26] Since that report, numerous print and video publications have followed. In procedures such as laparoscopic myomectomy and hysterectomy, the use of barbed sutures has become commonplace.

Myomectomy

Reapproximation of the myometrium after removal of myomas requires a suture material that adequately addresses the need for a prolonged wound disruptive-force reduction, hemostasis, and minimal tissue reactivity. Traditionally, this suture has been either a polyglycolic acid suture or polydioxanone. However, as noted earlier, braided sutures cause more tissue abrasion and inflammation than monofilaments, and the transition from open to closed procedures has introduced the difficulty of laparoscopic suturing. When considerations for blood loss and hemostatis are added, the need for faster, more secure suture lines becomes readily apparent. To this end, barbed suture materials are an ideal solution. Their synthetic, monofilament configurations should minimize local inflammation, and their absorption profiles and tissue pull-through strengths are well within the parameters needed for reduction of disruptive forces. Further, because barbed sutures allow for only minimal tissue recoiling, closing spaces such as myoma defects is easier with each subsequent suture pass exposed to less tension than the previous bite. Finally, without the need for knot tying, wound closure times and blood loss are significantly reduced.[42-44]

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Hysterectomy

In a total hysterectomy, the suture line of most significance is the closure of the vaginal cuff. Closing the vaginal cuff after hysterectomy is a common but biomechanically complex procedure. First, bacterial contamination from the vaginal vault is a major cause of febrile morbidity and infectious complications such as vaginal cuff cellulitis and pelvic abscess. Even in the absence of infection, the vaginal cuff is prone to persistent granulation tissue with annoying postoperative vaginal discharge and bleeding. With excessive potential disruptive forces on the suture line from coughing, sneezing, vomiting, constipation, and sexual intercourse, the wound requires a suture with some prolonged strength. Finally, the introduction of newer, minimally invasive techniques has increased the use of thermal energy rather than a cold knife to enter the vagina. This change has led, in turn, to less viable tissue at cuff edges and subsequent potential delays in wound healing.[45,46]

Given these variables, the ideal suture for vaginal cuff closure should minimize bacterial growth, elicit minimal tissue reactivity, be pliable, and maintain a reasonable amount of tensile strength for at least 3 to 4 weeks. This suture is not chromic gut, which has been demonstrated to lead to more postoperative granulation tissue.[47] In open or vaginal procedures in which cold-knife techniques are typically used at the cuff, polyglactin 90 usually performs well given its low stiffness pliability and early absorption profile. However, in closed procedures such as laparoscopic or robotic hysterectomies where thermally injured tissues heal more slowly and the risk of cuff dehiscence is increased,[48] polyglactin 90 is a less attractive option.

In the altered environments of laparoscopic and robotic hysterectomies, cuff closures with barbed sutures have flourished. The reduced operative times and simplicity of the closure make the use of barbed suture a good choice for this application.[49,50] In addition, the synthetic monofilament configurations should minimize local inflammation and potential for infection; and their absorption profiles and tissue pull-through strengths are well within the parameters needed for reduction of disruptive forces, even with the added burdens on the vaginal cuff induced by the use of thermal energy. On the downside, there have been reports of patients' partners' complaints of residual suture material causing discomfort during intercourse (dyspareunia), but this problem is more likely a result of the delayed absorption profile of materials like polydioxanone than the barbed nature of the suture.

Sacrocolpopexy

Increasingly, sacrocolpopexy is being used to treat pelvic organ prolapse, specifically vaginal vault prolapse.[51] Unfortunately, although the treatment outcomes are good with sacrocolpopexy, the morbidities associated with an abdominal approach are significant and make the procedure less appealing. The laparoscopic approach to sacrocolpopexy does offset the morbidities associated with laparotomy, but the procedure has not been widely adopted by gynecologic surgeons because of the difficulty of mastering the laparoscopic suturing and knot tying that is needed for the operation.

The introduction of robotic surgery has mitigated some of these suturing challenges, and short-term durability results for the robot-assisted sacrocolpopexies compared with the abdominal approach have been promising.[52] However, although the dissection and suturing are facilitated in some surgeons' hands using the robot, closing the peritoneum can still be tedious and challenging.

A recent article by Ghomi and Askari[53] reports a new technique using a barbed PDO suture to reapproximate the full length of the peritoneum that had been opened to accommodate the mesh from the vaginal apex to the sacral promontory. By the authors' description, the use of the barbed suture demonstrated several advantages: "it is self-anchoring, requires no slack management, and avoids tissue migration."[53] Using this technique, they were able to overcome problems with the rectosigmoid's displacement into the operative field, which invariably proves an area of frustration for surgeons.

Cesarean Delivery

J. Whitridge Williams writes in the first edition of his textbook, *Obstetrics* (1903), ". . . it [the uterus] is then closed by deep silk and superficial catgut sutures, or, if preferred, formol catgut may be used for both."[54] Over 100 years later, the 23rd edition of the same text states, "[t]he uterine incision is then closed with one or two layers of continuous 0- or #1 absorbable suture. Chromic suture is used by many, but some prefer synthetic delayed-absorbable sutures."[55] Considering these 2 statements, one could conclude that either little progress in wound closure biomaterial technology has transpired in the last century or little research has penetrated techniques in cesarean delivery closures.

A search of the literature reveals few nonexperienced-based data to support choosing one suture over another. This paucity of hard data is punctuated by a 2009 Cochrane Collaboration review that identified no studies comparing the type of suture material for the closure of uterine incisions.[56] Nonetheless, the general principles of wound healing apply as much to the peripartum uterus as any other bodily tissues. Therefore, since the introduction of synthetic sutures, one could reasonably argue that chromic gut is obsolete given its comparative marked tissue reactivity, its inconsistent tensile strength retention and reabsorption, and its poor handling characteristics. This point is loosely supported by a bovine study that demonstrated improved healing with a synthetic suture as compared with a catgut suture.[57] Despite the availability of theoretically better materials, the excellent historical record of chromic gut in obstetrics does at least imply 2 important principles: (1) the knotted tensile strength of 0 chromic gut (average minimum of knot-pull tensile strength of 2.77 kgf) is adequate to withstand the disruptive forces on the repaired hysterotomy; and (2) the complete loss of tensile strength (14-21 days) and the reabsorption profile of chromic gut is, at least, a reasonable ballpark estimation of adequacy for a cesarean delivery repair. Building off these 2 principles, a more reasoned suture choice might focus on a monofilament suture that causes less tissue trauma and induces a less intense inflammatory response than the twisted, multifilament surgical gut.

As with myomectomy closures, hysterotomy closures during cesarean delivery are facilitated by the use of barbed suture. The barbed sutures more easily draw the tissue edges together and the 1-mm spacing between the barbs seems to yield better hemostasis. Although there are no data in humans on uterine closures, a recent pilot study by the author of 9 pregnant ewes did demonstrate consistently adequate uterine closures when barbed poliglecaprone 25 was compared with both chromic gut and polyglactin 910.

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For skin closures, a recent trial comparing bidirectional barbed polydioxanone with smooth polydioxanone in 188 women undergoing cesarean delivery did show a cosmesis and safety profile of barbed suture that is similar to that of the conventional suture technique without the drawbacks inherent to surgical knots.[58]

At present, there are no data about the use of barbed or traditional, smooth sutures in cesarean delivery, but given barbed suture's profile, use in this area and studies of its use are likely to proliferate.

Summary

Barbed suture is a relatively new but exciting addition to the variety of suture materials. As experience grows with barbed sutures, more applications for its use will likely arise. Obstetric and gynecologic surgeons who are interested in choosing the best materials for their operations should benefit from better understanding the underlying principles of wound healing and suture material biomechanics, and may discover many advantages to the use of barbed suture. ■

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Main Points

- A new class of suture material—barbed suture—has been introduced; these synthetic sutures eschew the traditional, smooth, knot-requiring characteristic of sutures in favor of barbs that serve to anchor the sutures to tissue without knots.
- The 6 categories of suture classification believed to best assist surgeons in choosing the proper suture material for their surgeries are suture size, tensile strength, absorbability, filament construction, stiffness and flexibility, and surface characteristics (smooth or barbed).
- A knot-secured, smooth suture creates an uneven distribution of tension across the wound. Although the closed *appearance* of a wound may be that of equal tension distribution, there are unequal tension burdens placed on the knots. This tension gradient across the wound may subtly interfere with uniform healing and remodeling.
- Although the data are limited and almost exclusively based on studies with bidirectional suture, barbed suture lines appear to be at least as strong if not stronger than traditional, knotted, smooth suture lines.
- To choose the best suture material for an obstetrics-gynecology procedure, surgeons should take into account all the variables present, such as a tissue's collagen structure, blood supply, disruptive forces, and potential for infection. When these characteristics are considered, the physical characteristics of barbed sutures make these materials an attractive option.

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