

Economic evaluation of different suture closure methods: barbed versus traditional interrupted sutures

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Abstract: Healthcare systems are receiving increasing pressures from payers, such as the Centers for Medicare and Medicaid (CMS), to reduce the costs associated with procedures, and with the implementation of the Affordable Care Act, high costs are addressed through pay-for-performance programs. Thus, multiple areas of total knee arthroplasty (TKA) surgery are under scrutiny, including surgical times, material costs, and the costs of associated complications and readmissions. Suture type has been determined to be a factor that may influence closure times, as well as direct material costs. Therefore, the purpose of this review was to compare: (I) the cost of using barbed *vs.* conventional interrupted sutures; (II) the additional cost of differences in complications, if any; (III) to extrapolate cost savings on a hospital and national level; and (IV) to discuss the role of these findings on hospital savings and the effect on bundled payments. It was found that the main factors affecting differences in overall costs between barbed and standard interrupted suture were material cost and closure time. Many studies have demonstrated greater cost savings with the barbed suture due to shorter operative times, despite the higher material costs. The majority of studies also demonstrated similar complication rates between the suture types, and thus these are unlikely to affect the cost difference. However, to the best of our knowledge, there are no TKA studies in the literature evaluating the effect of suture type and associated complications on lengths of stay and readmission rates. Thus, it is unclear how these cost savings will translate to reimbursements rates and the role that they might play in bundled payments. Several studies in other specialties demonstrate decreased infection rates with the use of barbed sutures, which, if found to be true for TKA can be extrapolated to 3 million dollars of savings in revision TKA costs. Further studies on this topic are needed to define these relationships.

Keywords: Wound closure; economic evaluation; sutures; barbed sutures; interrupted sutures; total knee arthroplasty (TKA)

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Introduction

Along with the success of total knee arthroplasty (TKA) comes the economic burden associated with these surgeries. With the onset of newer policies and the dynamic state of the healthcare system, hospitals are having a higher degree of financial accountability. Healthcare systems are also receiving increasing pressures from payers, such as the Centers for Medicare and Medicaid (CMS) to reduce the costs associated with procedures, and the implementation of the Affordable Care Act aims to address high costs through pay for performance programs. Thus, multiple areas of the TKA surgery are under scrutiny, including surgical times, material costs, and the cost of associated complications and readmissions (1). There are a multitude of variables that affect these factors, one of which is wound closure. Closure can often be a time consuming and considerable part of the surgery, and reducing this time has been targeted as a method of cost management. Suture type has been determined to be a factor that may influence closure time and thus costs, as well as having effect on direct material costs (2).

Traditionally, wound closure for TKA involves using interrupted sutures for multiple layers of fascia, subcutaneous, and cutaneous tissue. Disadvantages associated with this method were thought to be the increased operative time, local tissue ischemia, and increased material use with subsequent costs. Barbed sutures, and those that are bidirectional in nature, were recently introduced to allow for simultaneous closure from the wound center (3). Studies have demonstrated that the use of barbed knotless sutures allows for a faster and more efficient closure with less material used, while providing a watertight arthrotomy closure (2).

However, whether these purported advantages translate to lower overall costs has been questioned. The purpose of this literature review was to compare: (I) the costs of using barbed to conventional interrupted sutures; (II) the additional costs of differences in complications, if any; (III) to extrapolate cost savings on hospital and national level; and (IV) to discuss the role of these findings on hospital savings and the effects on bundled payments.

Methods

A thorough literature search was conducted using three electronic databases: PubMed, EBSCO Host, and SCOPUS. All available studies between 1989 and 2017 were

evaluated. Searches were performed using the following terms: arthroplasty* (title), knee (title), post-operative outcome (title), complication (title), wound closure (title), suture (title), deep (title), superficial (title), barbed suture (title), cost (title); CMS (title); closure time (title), bundled payments (title) and closure technique (title), and 'knee', and 'suture'. Other search terms included: 'knee arthroplasty', 'knee replacement', and 'wound closure review'. This yielded 646 reports. We included reports on costs associated with barbed and traditional interrupted sutures in TKA. Through a title and abstract review, we determined the relevant manuscripts, which were subsequently recovered in full and studied. A total of 17 reports satisfied the criteria. We also searched reference lists of retrieved reports and articles and added another 3 reports. Preference was given to meta-analyses, randomized-controlled trials, and data from national registries. However, all studies thought to be relevant to our topic were included. A total of 20 studies were included in this review (*Figure 1*). We primarily used 9 TKA reports, but when necessary, we referred to reports for other orthopaedic fields as well as non-orthopaedic specialties, to corroborate our findings.

Cost comparison between barbed and interrupted sutures

Many studies have compared costs between barbed and standard interrupted sutures, and many have shown that shorter operative times in the barbed cohorts correlated with lower costs (*Table 1*). Ting *et al.* (8) conducted a prospective, randomized trial comparing outcomes in 65 TKA or THA patients who underwent primary closure with barbed suture or a combination of interrupted sutures (traditional cohort). For individual suture cost, it was found that the cost per stitch for monofilament absorbable sutures ranged between 1.75 to 1.83 USD, and the cost per stitch for barbed sutures was 19.96 USD. In the TKAs, the mean cost per patient for barbed sutures was significantly higher than for traditional interrupted (53 *vs.* 9 USD; $P=0.002$). However, when the authors factored in the mean savings in closure time associated with the barbed sutures (+4 minutes), the authors determined that the cost per unit of operative time was actually lower in the barbed cohort. The mean savings in dollars per patients closed using the barbed suture was 364 USD for TKAs (8).

Chan *et al.* (4) compared the costs of barbed versus traditional sutures in 109 primary TKAs. Suture material cost was calculated by multiplying the cost of each suture

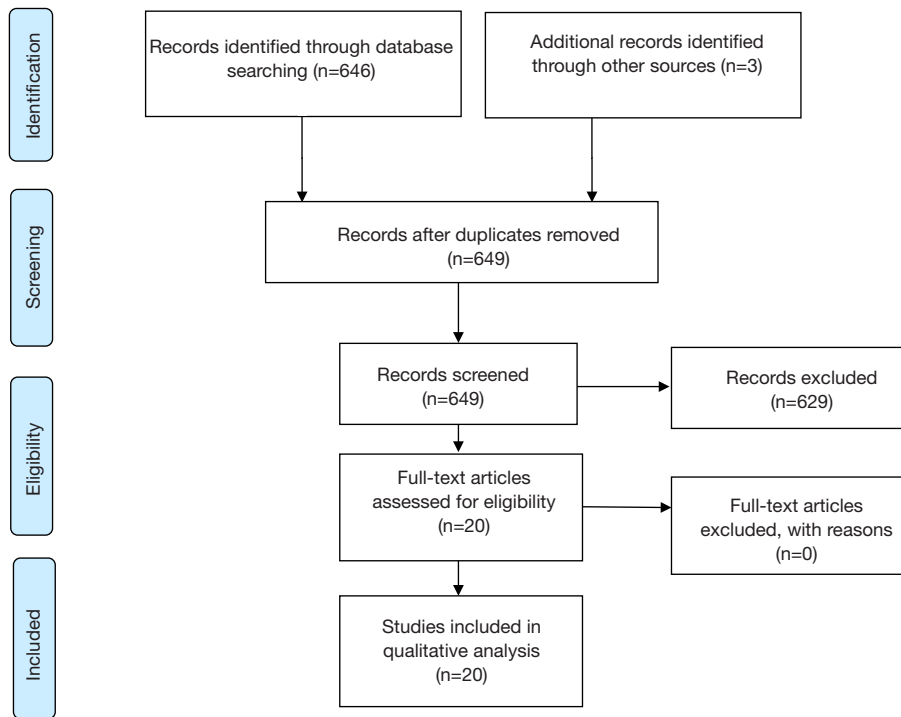


Figure 1 PRISMA flowchart.

Table 1 Suture cost

Reference	Study groups	Suture material costs per case (\$)	Costs savings per case (\$)
Chan <i>et al.</i> (4) [2017]	Control [54]	14.5	48.8
	Barbed [55]	61.9	
Sah (5) [2015]	Control [50]	32	175
	Barbed [50]	82	
Maheshwari <i>et al.</i> (6) [2015]	Control [75]	82.6	15.8
	Barbed [115]	66.8	
Gililland <i>et al.</i> (7) [2014]	Control [203]	419±116	95
	Barbed [191]	324±118*	
Ting <i>et al.</i> (8) [2012]	Control [29]	9.43±1.91	364.62±239.99
	Barbed [31]	52.84±19.96*	
Gililland <i>et al.</i> (9) [2012]	Control [85], 87 TKAs	6	32
	Barbed [98], 104 TKAs	43	

*, P value <0.05. TKA, total knee arthroplasty.

and the number of sutures used per TKA. The cost of barbed suture material is 47.4 USD more than the traditional suture for each TKA. They noted that traditional sutures led to slower arthrotomy closure time (491 *vs.* 325 seconds), thus leading to higher savings in the barbed cohort. Considering both suture material and operation cost, barbed suture on average saved USD 48.8 per TKA (4). In addition, Zhang *et al.* (10) conducted a systematic review and meta-analysis of 9 studies comparing the use of knotless barbed sutures to standard interrupted sutures. Based on an analysis of the pooled data, it was noted that the barbed suture was associated with USD 290.72 lower costs than the standard knotted sutures, taking into account material cost and closure time (10).

Sah (5) compared barbed to traditional interrupted sutures in 50 TKA patients. The author noted that the barbed suture led to a mean faster closure time of 4.7 minutes ($P < 0.001$). Although the material cost was higher in the barbed suture cohort compared to the interrupted group (82 *vs.* 32 USD), the barbed sutures still led to greater savings (+175 USD per case, range 100 to 250 USD), which were attributed to faster closure time. The author noted no significant differences in post-operative Knee Society Scores (93 *vs.* 93 points; $P = 0.6$) or range of motion (127 *vs.* 126 degrees; $P = 0.4$) between the groups, thus demonstrating that cost savings with barbed sutures do not come at cost to the patient outcomes (5).

Studies have also demonstrated lower costs with barbed sutures despite no differences in closure time when compared to standard interrupted sutures. Maheshwari *et al.* evaluated the cost-effectiveness of barbed versus standard sutures in 333 TKAs and noted that there were no significant differences in closure time between the cohorts (31 *vs.* 30 minutes; $P > 0.05$) but barbed sutures had a lower overall material cost (66.78 *vs.* 82.59 USD) (6). The lower overall material cost in barbed suture cohort might be attributed to lower number of individual sutures needed to close a layer of the wound. A single barbed suture might suffice for an area that needs 2 or more standard sutures.

Conversely, studies have demonstrated no differences in cost. In a retrospective study, Gililland *et al.* (9) compared closure time, costs, and associated complications between barbed sutures and an interrupted suture technique in 191 primary TKAs. As with most of the above studies, mean closure time was faster in the barbed cohort compared to the standard interrupted group (20 *vs.* 22 minutes; $P < 0.009$). However, they noted that the material cost of the barbed

sutures was higher (43 versus 6 USD). As a result, there was no difference in total closure cost between the groups (595 *vs.* 627 USD; $P = 0.26$). Furthermore, the rate and type of perioperative complications between the groups was similar, thus not affecting overall cost (9). However, in a prospective study, Gililland *et al.* (7) found that final costs per case reported, which included operative room consumables and suture materials, were significantly lower in the barbed suture group (barbed *vs.* traditional: 324±118 *vs.* 419±116 USD; $P < 0.001$).

The majority of the above studies demonstrate that the main factors affecting the differences in overall cost between barbed and standard interrupted suture are material cost and closure time. Material cost of an individual barbed suture is certainly higher than that of a conventional interrupted suture. However, in many cases, a single barbed suture may be sufficient for closure of a single wound layer, while multiple conventional suture is required for interrupted closure. Therefore, despite the higher material cost of barbed sutures, they may lead to an overall lower, or at least equivalent, cost burden due to shorter operative times and smaller number of individual sutures needed for closure.

Costs associated with complications

The costs associated with post-operative complications and readmissions can be considerable. Areas that are highly targeted for cost reduction include post-operative surgical site infections, hospital length of stay, and subsequent risk of readmission. Often, wound complications after surgery are associated with closure method and include wound dehiscence, stitch abscess, and drainage, among others, which may subsequently affect length of stay and readmissions (Table 2). In El Bitar *et al.* (16) study using the Nationwide Inpatient Sample (NIS), both infection and mechanical wound complications were among the top factors associated with increased length of stay in primary TKA (odds ratio, 10.25 and 10.37) (16). Furthermore, Sibia *et al.* (17) demonstrated that hospital costs for emergency department visits or readmissions exceeded 150,000 USD, and the largest collective costs were incurred with treatments for wound infections (17).

However, there is limited evidence on the effect of wound closure type on post-operative length of stay. Eggers *et al.* (18) conducted a prospective, randomized study comparing adhesives, staples, and Monocryl sutures for

Table 2 Wound complications

Reference	Study groups	Total wound complications (%)
Chan <i>et al.</i> (4) [2017]	Control [54]	9 (16.7)
	Barbed [55]	2 (3.6)*
Chawla <i>et al.</i> (11) [2016]	Control [243]	0 (0.0)
	Barbed [89]	8 (9.0)*
Maheshwari <i>et al.</i> (6) [2015]	Control [75]	4 (5.3)
	Barbed [115]	1 (0.9)
Smith <i>et al.</i> (12) [2014]	Control [36]	Minor 2 (5.5); major: 0 (0.0)
	Barbed [98]	Minor: 8 (8.2); major: 2 (2.0)
Gililland <i>et al.</i> (7) [2014]	Control [203]	12 (5.9)
	Barbed [191]	11 (5.8)
Ting <i>et al.</i> (8) [2012]	Control [29]	3 (10.3)
	Barbed [31]	3 (9.7)
Gililland <i>et al.</i> (9) [2012]	Control [85]	8 (9.4)
	Barbed [98]	4 (4.1)
Patel <i>et al.</i> (13) [2012]	Staples [181]	7 (3.9)
	Biosyn [51]	4 (7.8)
	Barbed [46]	6 (13.0)
Eickmann <i>et al.</i> (14) [2010]	Control [88]	5 (5.7)
	Barbed [90]	3 (3.3)
Campbell <i>et al.</i> (15) [2014]	Control [247]	18 (7.3)
	Barbed [169]	33 (19.5)*

*, P value <0.05.

cutaneous closure in 90 TKAs. The cost was highest for the suture cohort, followed by the adhesive cohorts, then the staples (75 *vs.* 70, 62, and 57 USD, respectively). The authors factored in labor costs and staple removal cost. However, the staple cohort had a 33% higher length of stay, and when the associated medical expenses were included, it was found that the staple group had an 18% increase in cost when compared to the suture cohort. Therefore, it is important to note that costs associated with closure are not only attributed to the material or closure time, but are also affected by differences in post-operative complications and length of hospital stay (18).

When evaluating complications specifically associated

with barbed versus traditional sutures, it is theorized that knots may place uneven pressure on tissue causing ischemia, or they may cause local tissue inflammation and serve as a nidus for infection. In addition, it is thought that knotless barbed sutures provide a more uniform tension on the tissue and therefore reduce the risk of local tissue ischemia (10).

Borzio *et al.* (1) conducted a systematic review and meta-analysis comparing four level one studies that evaluated costs associated with different suture types in THA and TKA. Factors included in costs were complication rates, cost of suture material, and closure time. It was found that major and minor complication rates between barbed suture and conventional suture cohorts were nearly the same (95% CI: 0.31–0.54; $P=0.95$), thus not contributing to cost differences between the groups. Closure time was significantly faster in the barbed cohorts, which ultimately led to greater cost savings in barbed closure cohorts compared to standard suture in TKA patients (58 to 365 USD) (1). Similarly, Maheshwari *et al.* (6) compared barbed to standard sutures in 333 TKAs and noted similar complication rates, but the barbed cohort had a lower overall cost (6).

There are no TKA studies evaluating the effect of wound complications such as infection or dehiscence and subsequent readmission and re-operation on costs between barbed and conventional sutures. Several studies in other specialties demonstrate decreased infection and dehiscence rates in closure with barbed, when compared to conventional sutures. Ahmed *et al.* (19) performed a retrospective study of 715 wound closures (273 barbed, 442 conventional) after power-injectable dual-lumen chest port placement and demonstrated lower dehiscence (0 *vs.* 1.6%; $P=0.04$) and infection (5.1% *vs.* 9.5%; $P=0.03$) rates in barbed *vs.* conventional closure. If the use of barbed sutures decreases the rate of revisions for infection and readmission in TKA patients, tremendous cost savings could be achieved. Kapadia *et al.* (20) performed retrospective review of prospectively collected single hospital infection database and identified 21 patients who underwent revision TKA for infection and matched them to 21 patients who had an uncomplicated primary TKA. The annual mean healthcare cost for infected TKA was significantly higher than for non-infected TKA (116,383 *vs.* 28,249 USD; $P<0.0001$), which amounted to 88,134 USD difference. According to a NIS database study by Bozic *et al.* (21), there were 73,878 revision total knee arthroplasties due to infection performed in a 5-year period between 2005 and 2010. If the infection rate in TKA was reduced by 44%, as in a study of chest port

Table 3 Suture cost on hospital and national level

Reference	Suture type	Suture material costs per case (\$)	Costs savings per case (\$)	Costs savings hospital level (\$) (3,000 annually)	Costs savings national level (\$) (402,100 in 2003)
Chan <i>et al.</i> (4) [2017]	Control	14.5	48.8	146,400	19,622,480
	Barbed	61.9			
Sah (5) [2015]	Control	32	175	525,000	70,367,500
	Barbed	82			
Maheshwari <i>et al.</i> (6) [2015]	Control	82.6	15.8	47,400	6,353,180
	Barbed	66.8			
Smith <i>et al.</i> (12) [2014]	Control	14.4	550	1,650,000	221,155,000
	Barbed	106.3			
Gililland <i>et al.</i> (7) [2014]	Control	419±116	95	285,000	38,199,500
	Barbed	324±118*			
Ting <i>et al.</i> (8) [2012]	Control	9.43±1.91	364.62±239.99	1,093,860	146,364,400
	Barbed	52.84±19.96*			
Gililland <i>et al.</i> (9) [2012]	Control	6	32	96,000	12,867,200
	Barbed	43			

*, P value <0.05.

placement by Ahmed *et al.*, there would be 32,506 less cases of revision TKA for infection over a 5-year period, which would account to almost 3 billion USD in savings.

Hospital and national level extrapolation

The cost savings achieved by using barbed sutures for the individual procedures may not amount to marked cost savings. However, when these savings are extrapolated to a hospital and, more importantly, to a national level, they constitute a considerable amount of healthcare budget (*Table 3*). We extrapolated these costs to a single center (3,000 cases annually) and to national level (402,100 cases in 2003) (22). The cost savings on the hospital level amounted to a mean of 549,094 USD (range, 47,400 to 1,650,000 USD). The cost savings on the national level amounted to a mean of 73,561,323 USD (range, 6,353,180 to 221,155,000 USD).

Does this have a role in bundled payments?

Many of these studies that have demonstrated faster closure time show differences of a few minutes. Although

these have been represented to be statistically significant, it is questionable whether such a small margin of time is clinically relevant. Thus, the purported time saved may not actually translate into real healthcare dollars. This is particularly true when many hospitals bill on an hourly rate, and thus it can be argued that if the time saved does not exceed an hour, then these minute reductions may do nothing to affect overall cost (23).

The bundled payment for care improvement (BPCI) initiative has been developed by the Centers for Medicare and Medicaid Services to promote efficient and low-cost care. Per Miletic *et al.* (24), 1% of TKA patients had an unplanned hospitalization for a surgical site infection within the year, and 30% of these were subsequently re-hospitalized, each associated with a mean cost of 20,000 USD (24). In order to reduce the incidence of unplanned readmissions, surgeons are targeting the causes of surgical infections post-operatively. Therefore, determining the complications and incidence of infections associated with different wound closure techniques is crucial in reducing the risk of penalty in the bundled payment scheme. Based on the above studies, complication rates have been shown to be similar so far, but there is limited study on the costs

associated with these in TKA patients. There must be more focus on the effect of different suture types on readmissions and revisions, particularly as this plays a considerable role in reimbursements.

A further limitation in these cost analyses is the difficulty in comparing outcomes between institutions. Standard protocols vary between hospitals. The number of sutures used and speed vary between surgeons, let alone among different practices. These are among the many variables that influence the purported cost savings and prevent consistent and reliable comparisons, which may ultimately be why no true consensus has yet been reached on this topic.

Although the majority of the literature has demonstrated no differences in actual complication rates, there are no studies to our knowledge that systematically evaluate whether the complications associated with these suture types are linked to an increased need for readmissions. However so far, barbed sutures may prove to be a promising modification to improve the TKA experience, but further studies are needed to directly correlate the direct costs of specific complications and associated readmissions in TKA patients.

Conclusions

There is a considerable economic burden associated with TKAs, and hospitals are under increasing pressures to drive down cost. Areas of interest include reducing operative time, material cost, and incidence of post-operative complications. The use of barbed sutures has been shown to reduce operative time and thus total cost when compared to interrupted sutures, while demonstrating similar post-operative complication rates. However, based on the available literature, there is no evidence on the direct costs of complications associated with different suture material, nor are there studies on the effect of these complications on length of stay and readmissions in TKA patients. Due to the lack of these studies in TKA patients, we have demonstrated potential costs savings associated with the use of barbed sutures in TKA patients based on the lower infection rates in other specialties. Reduction in TKA infection and subsequent revision rates could amount to almost 3 billion dollars in cost savings. In order to determine the true effect of the cost reductions associated with shorter closure time and decrease in infection burden when using barbed sutures, further prospective studies are needed to answer these questions. Specifically, studies that compare revision rates due to infection between patients who receive barbed versus

conventional sutures for TKA, as well as their correlation with costs need to be performed.

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Footnote

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