The suture anchor and transosseous drill hole techniques for reattachment of the distal biceps tendon to the radius have been found to have similar clinical and biomechanical outcomes. However, a comparison of the cost effectiveness of these techniques is lacking. The purpose of this study was to determine whether the use of suture anchors decreases operative time enough to offset the additional cost of the implants. The records of all patients undergoing a distal biceps tendon reattachment were reviewed to determine the method of fixation, operative time, and associated surgical costs. Two surgeons used a technique of fixing the tendon directly to the bone (transosseous group), whereas 3 surgeons used suture anchors. Given the standard nature of the surgical procedure (other than the fixation technique), only the costs that differed between the 2 groups were included. Surgical center costs were obtained from the local outpatient surgical center in 2011 US dollars. Five surgeons treated 70 men (mean age, 45.9 ± 9.2 years). Mean time from injury to surgery was 14 days. Mean operative times for the transosseous and suture anchor groups were 97.6 ± 14.9 and 95.8 ± 25.8 minutes, respectively (P = .74). Two anchors were used in 79% of the anchor cases. The use of anchors cost $474.33 more per patient. However, this value is sensitive to the cost of the individual anchors, intersurgeon variation in operative time, and per-minute value of saved operative time. No operative time was saved with the use of suture anchors. This cost comparison framework can be used to evaluate the balance in surgical resource use due to implant cost vs savings in operative time.
A vulsion of the distal biceps brachii tendon from its attachment to the radius is a pathology primarily seen in middle-aged men who sustain a sudden eccentric flexion load to the forearm.1-7 Although some advocate that conservative management may be appropriate in selected cases, multiple studies have shown that this results in a substantial reduction in supination strength, and to a lesser extent flexion strength, over the long term.1,2,4 In this regard, surgical reattachment of the distal biceps tendon to the bone is currently recommended. Reattachment of this tendon has traditionally been performed by tying the distal tendon stump into a bone trough through transosseous drill holes using a single anterior or 2-incision technique.4,8,9

The progressive development of orthopedic implants for the fixation of tendon to bone has led to the use of suture anchors, tenodesis screws, and suture button constructs for distal biceps tendon reattachment. The cost effectiveness of new implants should be evaluated in light of their clinical outcome. Biomechanical studies have demonstrated that the load to failure of the suture anchor technique and the transosseous drill hole technique are similar.10-16 Clinically, the return of elbow range of motion and strength are also similar with these 2 fixation methods.3,5

Given that the biomechanical and clinical effectiveness of these 2 techniques have not been found to be different, an evaluation of the differences in costs associated with these techniques is required to complete the cost-effectiveness evaluation.

The purpose of this study was to determine whether the use of a suture anchor technique could save sufficient operative time to offset the associated variable costs when compared with a transosseous (implant-free) technique for the fixation of distal biceps tendon ruptures. The hypothesis was that the use of suture anchors would decrease operative time but not enough to offset the additional cost of the implants.

**Materials and Methods**

A retrospective review was performed of all patients who underwent distal biceps tendon reattachment at an outpatient surgery center over a 6-year period. Patients were treated by 1 of 5 orthopedic surgeons (J.E.C., B.S.M.) in a university-based sports and upper-extremity practice. Patients were identified by searching for Current Procedural Terminology code 24342 in the surgical case database. Inclusion criteria were: (1) age 18 years or older and (2) acute repair to bone performed 30 days or less from injury. Exclusion criteria were: (1) use of grafts, (2) repairs or tenodesis to the brachialis tendon, and (3) revision surgery. Operative and anesthesia records were reviewed to extract data regarding patient demographics, operative time (incision to bandage), and the use of suture anchors. The number and type of suture anchors used were recorded.

Seventy patients met the inclusion and exclusion criteria and were categorized as to whether suture anchors were used for the distal biceps tendon reattachment. Two surgeons directly sutured the tendon to the bone through drill holes (ie, no suture anchors). Surgeon 1 used a single anterior incision technique and surgeon 2 used a 2-incision modified Boyd and Anderson technique.4 Three surgeons used a single anterior surgical approach with suture anchors placed in the radial tuberosity for tendon fixation.

Previous studies have identified that the long-term clinical outcomes of suture anchor and direct transosseous distal biceps tendon repair are similar.1,5 As such, the current study was designed as a cost-minimization analysis.17 From a cost point of view, the method of tendon fixation was the only independent variable in this study, and as such, only costs associated with the differences in the fixation method were included in the cost comparison. Given the substantial variability in patient charges and payer reimbursement, the base cost to the surgical center for operative time and consumable items was used for the cost comparison. These costs were obtained from the financial office for the outpatient surgical center. These costs included $320 for each suture anchor, $77.50 for each bone burr, $28.75 for a 2-mm drill bit, and $29.00 to $78.24 for high-strength suture. The bone burr, drill bit, and high-strength suture were used by the surgeons who used the transosseous fixation technique. The anchors included suture and were placed with a reusable drill bit. Therefore, the cost of the transosseous technique varied between $135.25 and $184.49. The cost of the suture anchor technique varied depending on the number of anchors used.

The cost of operative time was estimated by the financial officer for the outpatient surgical center under 3 categories: (1) staffing (eg, scrub technician, circulating nurse, medical assistant, and nurse anesthetist): $8.60/minute, (2) overhead (eg, utilities, administration, and building and equipment depreciation): $6.61/minute, and (3) surgical supplies: $8.71/minute. Given that the bulk of surgical supplies are opened at the beginning of the case and that the surgical consumables that differ between the 2 fixation methods were separately costed, the surgical supply cost was not included in the calculated cost per minute of operative time ($8.60+$6.61=$15.21/minute).

Patient demographics were descriptively analyzed. Mean operative time (in minutes) for each surgeon and each fixation technique was calculated and descriptively analyzed with means, medians, and boxplots. Student’s t test was used to compare the operative times between the fixation techniques (transosseous vs suture anchor). Given the primary purpose of the study and the similarity of mean operative time, surgeons 1 and 2 were combined as the transosseous group for analysis. Sensitivity analyses were performed to (1) evaluate how the number of anchors and the type of high-strength suture used affected the cost difference and (2) deter-
mine the effect of the maximum possible operative time saved with the use of suture anchors on the difference in variable costs between the 2 fixation techniques. Statistical analysis was performed with Stata version 6.0 software (Stata Corp, College Station, Texas). Ethical approval was obtained from the university’s medical institutional review board.

RESULTS

Five surgeons treated 70 patients. All patients were men with a mean age of 45.9±9.2 years. Mean time from injury to surgery was 14 days for both groups. Mean operative time for each surgeon is listed in Table 1. Substantial variability existed in operative time between the surgeons. The distribution of mean operative time by surgeon is shown in the Figure. The upper fence for surgeon 4 and the lower fence for surgeon 5 represent 1 outlying patient each. Mean operative time for surgeons 1 and 2 (transosseous group) was 97.6±14.9 minutes. Mean operative time for surgeons 3, 4, and 5 (suture anchor group) was 95.8±25.8 minutes. Thus, the difference in mean operative time between the transosseous and suture anchor groups was 1.8 minutes (P=.74).

Two anchors were used in 79% and 3 anchors were used in 19% of the anchor cases. The cost minimization analysis compared the cost of the anchors with the combined cost of the disposable items and the difference in operative time (2 minutes) associated with the transosseous technique. In the current example, the costs varied depending on the number of anchors used and the type of suture used in the transosseous technique. Two sensitivity analyses were performed. The first sensitivity analysis held the per-minute cost of operative time constant ($15.21/minute) and varied the use of intraoperative consumables (Table 2). The reference comparison (ie, clinically most common) used 2 suture anchors (anchor group) and the least expensive suture for the transosseous group. In the reference comparison, the incremental cost of using suture anchors was $474.33 per patient (range, $425.09-$554.33). Given this result, the cost of each anchor would need to be $107.46 (range, $55.22-$107.46) to make the use of suture anchors cost neutral relative to the transosseous technique (Table 2).

Within the anchor group, a significant difference existed in mean operative time between surgeon 5 and surgeons 3 and 4 (P=.001). Given this intersurgeon vari-
ability, the purpose of this study, and the minimal difference in mean operative time between the 2 fixation groups, a second sensitivity analysis was performed to determine how the difference in variable costs would change with the most extreme difference in operative time demonstrated between the 2 groups in this study. To assess the greatest potential impact from using the suture anchor implants, the surgeon with the longest mean operative time in the transosseous group was compared with the surgeon with the shortest mean operative time in the suture anchor group. In the transosseous group, surgeon 2 had a longer mean operative time (98.8±14.0 minutes) than surgeon 1 (93.9±18.0 minutes). The surgeon with the lowest mean operative time in the suture anchor group was surgeon 4 (81.5±23.8 minutes). Therefore, the maximum difference in operative time between the 2 fixation groups was 17.3 minutes.

Using this maximum difference in mean operative time, the comparison of variable cost scenarios (as per the first sensitivity analysis [Table 2]) was repeated (Table 3). In this analysis, the incremental cost of using suture anchors in the reference comparison was $241.62 per patient (range, $192.38-$321.62). This sensitivity analysis demonstrated that even with an operative time savings of more than 17 minutes, the use of suture anchors was still more expensive than a transosseous technique by at least $192.38. Given this result, the cost of each anchor would need to be $223.81 (range, $132.80-$223.81) to make the use of suture anchors cost neutral relative to the transosseous technique (Table 3).

**Discussion**

The current study demonstrated no significant savings in operative time with the use of suture anchor fixation compared with a transosseous technique for the reattachment of distal biceps tendon ruptures. However, surgeon-specific factors may be a primary factor in determining operative time given the large amount of variation in the suture anchor group’s mean operative times (Table 1; Figure). The reattachment was performed with 2 suture anchors in the majority of cases. However, the number and cost of the anchors are major determinants in the cost effectiveness of their use. The incremental cost of using suture anchors ranges between $425 and $560 per patient. Even if suture anchors saved 17 minutes of operative time per case, their use would still cost more (range, $190-$320) than the transosseous technique.

As a specialty, orthopedic surgery is a large consumer of medical implants. These implants are continually being updated and improved in hopes of improving patient care outcomes. Some procedures completely depend on the use of implants, whereas in other procedures, such as distal biceps tendon reattachment, they are an option to reduce operative time. Given the plethora of available implants, surgeons and hospitals need to determine which of these new implants should be incorporated into practice. Specifically, a wide range of implants is currently available for the reattachment of distal biceps tendon ruptures. Multiple companies produce suture anchors, tenodesis screws, and suture button–type devices for tendon fixation. With this variety of implant options produced by multiple companies comes a range of associated costs.

Although biomechanical testing algorithms vary between studies, the EndoButton (Smith & Nephew Endoscopy, Andover, Massachusetts) has been shown to have higher loads to failure (range, 259-584 N) than suture anchors (range, 147-381 N) and transosseous suture fixation (range, 177-310 N). These, in turn, have higher loads to failure than tenodesis screw constructs (range, 192-232 N). The majority of studies have found these fixation techniques to fail at over 200 N, which is substantially more than the 52 N of flexion force estimated to statically hold the unweighted forearm at 90° of flexion. Biomechanically, these constructs should be able to withstand passive elbow range of motion for early rehabilitation.

Theoretically, use of these implants might result in shorter operative times, reduced surgical dissection at the reattachment site (perhaps reducing complication risk), and improved fixation, allowing for earlier motion. However, clinical studies comparing transosseous suture fixation with suture anchor fixation are consis-

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**Table 3**

**Sensitivity Analysis of Varying Intraoperative Consumables With an Operative Time Difference of 17.3 Minutes**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cost, $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anchor</td>
</tr>
<tr>
<td>2 anchors vs expensive suture</td>
<td>640.00</td>
</tr>
<tr>
<td>2 anchors vs least expensive suture</td>
<td>640.00</td>
</tr>
<tr>
<td>3 anchors vs expensive suture</td>
<td>720.00</td>
</tr>
<tr>
<td>3 anchors vs least expensive suture</td>
<td>720.00</td>
</tr>
</tbody>
</table>

*No anchor cost includes bone burr, drill bit, suture, and 17.3 minutes of additional operative time.

*Cost of each anchor to have its use be cost neutral relative to the transosseous technique (no anchor cost divided by the number of anchors used).*
tent with the biomechanical studies in that no long-term differences in outcome are observed. Extension, supination, and pronation range of motion and strength were similar, as were elbow functional scores. El-Hawary et al reported mild improvements in flexion range of motion with suture anchor fixation but better flexion strength with 2-incision transosseous fixation at 3 and 6 months postoperatively, but no differences at 1 year.

In the current climate of health care cost consciousness, the biomechanical and clinical similarities between the transosseous and suture anchor fixation techniques for distal biceps tendon reattachment present an opportunity to evaluate whether the use of implants is cost effective. Previous research demonstrating the similar clinical effectiveness of the 2 techniques allows for a cost-minimization analysis. The 2 main variables in this analysis were the cost of intraoperative consumables (most notably the suture anchors) and cost savings that may be realized due to decreased operative time. Ozyurekoglu and Tsai reported that tourniquet and operative time were reduced by 40 and 50 minutes, respectively, using a suture anchor technique compared with a 2-incision transosseous technique. These time savings are substantially greater than the minimal difference in operative time seen in the current study. These differences demonstrate the potential variation in operative time between surgeons. The retrospective cohort study by Ozyurekoglu and Tsai was performed over a 9-year period and did not define how many surgeons were involved, the experience level of the surgeons, whether all surgeons performed both techniques, or whether a progression in technique occurred from the transosseous to the suture anchor technique. All of these factors could affect the relative differences in operative time. Apart from this report of shorter operative time with the suture anchor technique, to the current authors’ knowledge, no previous studies have evaluated the cost effectiveness of distal biceps tendon repair.

Determining the method by which the resources used in a surgical procedure are valued (cost assignment) is challenging. The valuation of cost based on patient charges (ie, amount the hospital or surgeon bills for the procedure) is the most straightforward method and has been used in previous orthopedic studies. However, patient charges are an abstract amount given that reimbursement can vary widely depending on payor contracts. In addition, patient charges may vary depending on the location, volume, and reputation of the hospital. These factors may be more related to what the market will bear as opposed to the actual costs of delivering care. Net income is the difference between reimbursement and the total cost to the hospital to provide the care, providing a measure of profit. However, given the wide variation in reimbursement, the cost to the hospital to provide the care may be a more stable measure of resource use. These costs can be categorized into fixed or variable costs. Fixed costs include those that are not dependent on patient volume, such as overhead, rent, capital equipment purchase and depreciation, salaries, and administration. Variable costs relate to the incremental cost of providing care for an additional patient and include single-use or disposable items and labor, if employees are paid on an hourly basis.

In the comparison of 2 similar surgical procedures, only the costs that potentially differ between the 2 procedures need to be compared. This allows for simplified but accurate microcosting (bottom-up costing) and can specifically identify the line items responsible for cost variation that can be adjusted to improve cost effectiveness. Supply costs, such as suture anchors and bone burrs, are an important component of the variable costs associated with the procedure. The current study demonstrated that the supply costs of the transosseous technique are substantially less than the cost of the suture anchors (Tables 2, 3).

To specifically identify where cost differences occur when comparing these 2 fixation techniques, the current authors separated the variable costs of the procedure (ie, anchors, bone burr, drill bit, suture) from the fixed costs of the operative time (ie, staffing and overhead). Previous studies have reported the cost per minute of operative time to range between $17.56 and $27.29 (indexed to 2010 US dollars). These values are in line with the per-minute cost of operative time in the current study ($15.21 fixed costs and $8.71 variable costs = $23.92/minute). Operative time saved is beneficial if multiple similar procedures can be booked consecutively to allow an additional case to be performed in the time saved. In a sports medicine and upper-extremity practice, this may be reasonable for anterior cruciate ligament reconstructions or rotator cuff repairs, but distal biceps tendon reattachments are sufficiently uncommon to prevent realizing the benefit of up to 17 minutes saved per case. Time saved could potentially be beneficial if operating room labor (ie, nursing staff) is paid per hour and staff go home earlier or if operating room labor can be redistributed to other operating rooms that are still running to save labor costs. On the surface, 17 minutes of operative time saves $263.13 per case, but if the operating room stands empty for that time, no money is actually saved.

Intersurgeon variability in operative time was identified in the suture anchor group. This variability in individual surgeon’s operative time can be a primary factor in overall costs. An attempt to decrease costs by decreasing operative time is easier when operating room times are predictable. However, numerous factors affect the variability in operative time. Previous studies have reported that surgeons are independently responsible for a significant amount of the intersurgeon variation in operative time within the same surgical procedure. This has been reported for rotator cuff repairs and total
Cost of Suture Anchors in Distal Biceps Repair | Grant et al.

Joint arthroplasty.28,29 Resident education is another factor that has been shown to play a major role in orthopedic operative and clinical time.22,23,30

As expected, surgical and anesthetic times for anterior cruciate ligament reconstruction and total joint arthroplasty are significantly longer when an orthopedic resident is the primary surgeon under the guidance of the attending surgeon.22,23 Orthopedic residents were involved in the majority of cases in the current study. The seniority of the residents and the degree to which the resident was the primary surgeon likely varied between cases and surgeons. A recent study assessing the learning curve of knee and shoulder arthroscopy skills identified that trainees vary in the rate at which they acquire new surgical skills.31 This may be more relevant to junior surgical residents compared with more senior residents. Differences in a surgeon’s experience and surgical pace, as well as resident involvement, may explain some of the variation within the suture anchor group. Therefore, these factors should be considered in future studies involving the evaluation of operative time as an outcome.

The current study included a large sample size and 5 surgeons. Surgery was performed in a single outpatient surgical center allowing bottom-up microcosting of the operative time and supply costs involved with distal biceps tendon reattachment. The abstract nature of patient charges was avoided by using the surgical center’s fixed and variable costs associated with the procedure. Sensitivity analyses were performed to evaluate how the use of different types and amounts of consumables and the differences in operative time savings would change the result of using suture anchors for fixation of the tendon stump.

This study was limited by some factors associated with its retrospective cohort design. Incision to bandage time was recorded by operating room staff as part of their general documentation; therefore, the accuracy of these data was not verifiable. However, it is unlikely that a reporting bias existed favoring 1 surgical technique over another. Each of the 5 surgeons included in this study performed only 1 of the 2 techniques. As such, variability in surgeon factors may play a role in the operative time independent of the tendon fixation technique. Anecdotally, surgeon 5 tended to have more junior orthopedic residents and allowed them a larger role as the primary surgeon in most cases, which may have partially accounted for the significantly longer operative time. This fact could not be objectively verified and was therefore not included in the analysis.

This study is applicable to the outpatient surgery center scenario. Differences in fixed costs may result in a different outcome in a hospital setting. Geographic differences in labor and contracted supply costs may also produce different outcomes. In this manner, the application of this study’s evaluation framework is generalizable, whereas the actual dollar values presented in the current study were used as a local example.

The current study demonstrates a framework for the comparison of costs associated with the use of a transosseous or suture anchor technique for the repair of distal biceps tendon ruptures. Variability exists in cost data between surgical centers, so the study’s framework should be applied in other hospitals and surgical centers to determine whether the results are consistent. A comparison of surgeries performed in an outpatient surgical center to those performed in a full-service hospital may also change the cost differences because the hospital’s higher fixed costs may increase the value of the operative time saved by using suture anchors. Ultimately, a cost-effectiveness analysis performed alongside a randomized clinical trial or prospective cohort study would allow for a confirmation of the clinical equivalence of the 2 fixation techniques and allow prospective microcosting of the associated supply costs and accurate determination of differences in operative time. The cost analysis could also be expanded to involve the postoperative rehabilitation and return to work time. This would allow the evaluation of multiple economic viewpoints, including the hospital, payor, patient, and employer. Given the number of cases per year at 1 institution (n = 12 in this study), this may require a multicenter study.

Conclusion

This study demonstrates that the use of suture anchors did not result in a reduction in operative time. The variation in operative time between surgeons may play a bigger role than the fixation technique in determining operative time for a set procedure. In the authors’ local cost structure, the use of anchors resulted in an overall increased cost to the surgical center despite any possible savings in operative time and its associated cost. This cost-comparison framework can be used to evaluate the balance in surgical resource use due to implant cost vs savings in operative time. This framework can also be extended to evaluate the cost effectiveness of other types of implants, including button or tenodesis screw fixation.

References