Original Article

Time-Driven Activity-based Costing for Anterior Cruciate Ligament Reconstruction: A Comparison to Traditional Accounting Methods

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Purpose: The primary purpose of this study was to compare the cost of care of one of the most common sports medicine surgical procedures, anterior cruciate ligament reconstruction (ACLR), using the time-driven activity-based costing (TDABC) method to traditional accounting methods such as activity-based costing (ABC). Our secondary purpose was to identify the main drivers of the cost of ACLR using both of these techniques. **Methods:** A process map of ACLR was constructed through direct observation in the clinical setting according to established techniques to identify drivers of fixed, direct variable, and indirect costs. An episode of care consisted of each step in the surgical process from admission to discharge. Personnel costs were combined with the process map to determine the cost drivers and overall cost of the procedure. The cost generated from the TDABC method was compared with the cost from our institution's internal accounting system, which used an ABC method. **Results:** The total cost of ACLR was $5,242.25 when using TDABC versus $10,318 when using the traditional ABC method. The largest difference between the 2 methods was within the domain of direct variable costs. **Conclusions:** When compared with TDABC, the hospital's traditional cost-accounting estimate for ACLR is nearly twice as costly. These findings highlight the variability of cost calculation for the same clinical episode between the 2 accounting methods. For the traditional accounting method, the direct variable cost was the main cost driver, whereas for the TDABC method, the direct fixed cost was the main cost driver. **Clinical Relevance:** This study is important because it elucidates important cost drivers for one of the most common sports medicine orthopaedic surgical procedures and attempts to identify the true overall cost of the procedure.

Under current predictions, the cost of health care as a function of the United States national budget will continue to rise 5.6% each year until 2025.[1] As the cost of health care continues to increase at an unsustainable rate, it will be imperative to both re-engineer how we account for the cost of care and consider the value—defined as health outcomes achieved per dollar spent over the full care cycle—of services rendered for each clinical encounter.[2] However, measuring costs in health care can be extremely challenging owing to the opacities of direct and indirect costs and limitations of traditional accounting methods. Without accurate cost accounting and an understanding of the major drivers of these costs, health care value cannot be effectively addressed and optimized. Little research has been performed regarding cost accounting in sports medicine surgical procedures and, in particular, anterior cruciate ligament reconstruction (ACLR).

Recently, increased emphasis has been placed on new tools that are more effective in cost accounting than are traditional methods. One such analytical tool that has displayed promising results is time-driven activity-based costing (TDABC). When compared with traditional models such as activity-based costing (ABC), TDABC calculates cost by focusing on 2 major factors: (1) the cost per unit of time and (2) the amount of time required for each process in a task or job to be completed.[3] In traditional ABC methods, costs are calculated by taking the total expenses of a department and dividing them by the quantities of each activity in

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which the department participates. For example, an orthopaedic surgery department takes its total expenses and divides them by the quantities of each activity or procedure. Thus, costs by each activity are generated and can be further broken down into subcategories for a more detailed analysis. The major limitation of the ABC method is the enormous amount of computing power necessary to generate costs for specific activities, even with the current ability of computers.[3] Along with this, the ABC method is limited because each time there is a new variation for a particular activity, more complexity is added to the model, further complicating the analysis. In contrast, TDABC improves cost accounting through the use of time maps, which can break down costs of any activity simply based on the amount of time spent by an employee. As a result, the TDABC cost models can calculate the costs using much less computing power as compared with the ABC method. Within health care, TDABC has shown improved cost accounting in total hip, knee, and shoulder arthroplasty.[3-6] In addition to these areas, TDABC has computed decreased calculated costs with open carpal tunnel surgery as compared with the endoscopic approach.[7]

The primary purpose of this study was to determine the cost of care of one of the most common sports medicine surgical procedures, ACLR, using the newer TDABC method in comparison to traditional accounting methods. Our secondary purpose was to identify the main drivers of the cost of ACLR with both of these techniques. We hypothesized that direct variable costs would be disproportionately weighted in the traditional ABC method, resulting in higher reported costs overall, when compared with the TDABC method.

Methods

Because no patient information was collected for this study, institutional review board approval was waived. To understand the accounting analysis of both the TDABC and traditional hospital accounting methods (ABC), different cost categories must be defined. Overall, there are 2 main categories: (1) direct costs, which can be further broken down into fixed and variable costs, and (2) indirect costs.

Direct costs are the costs associated with a doctor or nurse providing care for a patient. The variable cost subcategory can change depending on the number of patients who are served. Direct variable costs can include the salaries of the employees involved in patient care (orthopaedic surgeon, nurse, and anesthesiologist). On the other hand, direct fixed costs are the costs that are connected to a doctor or nurse providing care to a patient but do not change regardless of the number of patients. Direct fixed costs can include the costs of power and water to ensure the necessary supplies for adequate patient care.[8,9] Finally, an indirect cost is one that is necessary for proper patient care but it is not directly tied to patient care itself. Some examples of indirect costs are costs related to hospital administrative salaries, marketing, and building maintenance.

Constructing Process Map

The first step was to generate a time map for the entire process of a hospital-based primary ACLR with no meniscal work to accurately account for each provider's interaction time with the patient. The time map was constructed and focused on the operative phase of an ACLR (Fig 1). To obtain accurate measurements of each component of the time map, direct observation of ACLR performed by the senior author (E.C.M.) was performed on 3 occasions. The average of each component of the time map from the 3 separate surgical episodes was calculated to determine the typical time required for each step. This served the additional purpose of validating each step in the time map and ensuring there were no missing components. The time map generated included all major aspects from the preoperative phase until the postoperative period in the postanesthesia care unit (PACU) (Fig 1).

The time map began with patient admission into the preoperative area. The check-in process began with the secretary and was followed by admission into the preoperative area, in which a registered nurse (RN) assisted in answering questions and placing an intravenous catheter. In our hospital, perioperative nurses typically care for 2 patients at a time. Therefore, the amount of time the nurse spent during the preoperative and postoperative periods was divided by 2 to account for the nurse managing 2 patients simultaneously. The process map then included all providers who interacted with the patient, and it concluded with the time required for monitoring in the PACU.

Establishing TDABC Cost Drivers

The next step was to determine the cost per unit of time for each provider who had a role in the surgical encounter, as identified in the time map. The salary of each employee from the time map was obtained from a conglomerate of salaries in the study institution's metropolitan area of Detroit, Michigan.[10] The labor rates were then condensed into a cost-per-minute format to smoothly incorporate the time map with the costs. In addition, the practical capacity of each employee was approximated to be 80% of the theoretical maximum capacity.[3,4] This assumption ensures that the cost per unit of time is only capturing the actual time the employee spends doing his or her job.[5] In essence, this accounts for breaks and other stoppages in work that do not pertain specifically to the employee's job. Finally, each provider was assumed to have 4

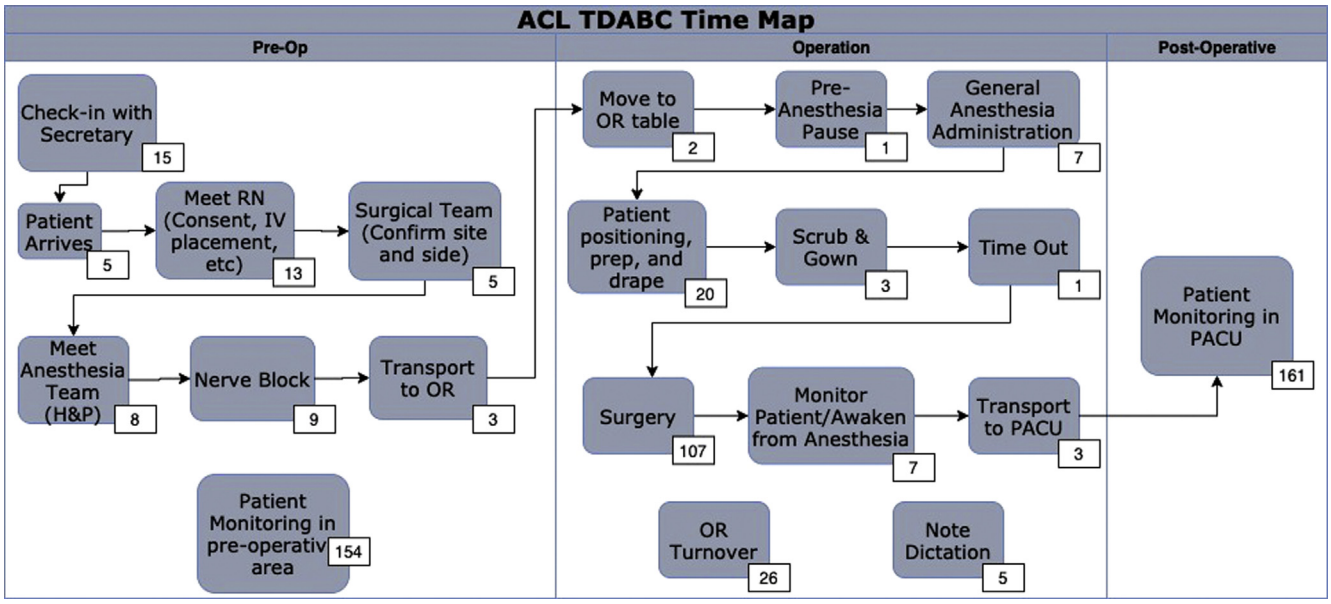

Fig 1. Constructed time map for anterior cruciate ligament (ACL) reconstruction. (H&P, history and physical examination; IV, intravenous catheter; OR, operating room; PACU, postanesthesia care unit; Pre-op; preoperative; prep, preparation; RN, registered nurse; TDABC, time-driven activity-based costing.)

weeks of vacation per year.[3,4] This ensures that only minutes spent actively working during an ACLR are taken into account. The amount of time each provider worked during that period was then multiplied by the respective cost per unit of time to determine the total direct variable costs. The total per-case direct fixed costs were subsequently calculated using hospital accounting data from all ACLRs performed by 3 orthopaedic surgeons (E.C.M.) from January 2018 to June 2019, with the results averaged. The direct costs were held constant for both accounting methods.

Last, the indirect costs included administrative costs and costs related to human resources and other departments that were necessary for operations but not directly tied to patient care. The TDABC method did present some challenges in terms of allocating indirect costing. The TDABC method is unable to account for every indirect cost, such as building maintenance, water, and electricity costs, because it would take an inordinate amount of time to determine each indirect cost. Other authors have noted this dilemma and have used a fixed ratio to determine the indirect costs for TDABC.[4,6] This rate was determined by the average ratio of indirect to direct costs for an ACLR.

Traditional ABC Accounting

The traditional accounting values of indirect costs, direct fixed costs, and direct variable costs for a primary ACLR were determined according to an internal hospital protocol via a computer program (EPSi; Allscripts, Libertyville, IL). The subsequent comparison between the 2 methods was made similarly to comparisons in previous studies.[4,6]

Results

Time Map

The amount of time each step took is listed in the process map (Fig 1). The check-in process started with the secretary and took, on average, 15 minutes to complete. Then, in the preoperative area, the nurse answered the patient's questions and placed an intravenous catheter, which took on average 13 minutes. The nurse continued to monitor the patient in the preoperative area for an average of 154 minutes.

Before the surgical procedure began, the attending orthopaedic surgeon spent 5 minutes, 3 minutes, and 1 minute meeting the patient to review the surgical site and procedure, scrubbing and gowning, and performing the timeout, respectively (Fig 1). Then, the orthopaedic surgeon performed the ACLR operation, with an average duration of 107 minutes from incision to final skin closure. This was followed by 161 minutes of monitoring in the PACU by the nurse. Finally, the operative documentation and dictation of the operative note took on average 5 minutes for the orthopaedic surgeon to complete.

Cost

The total amount of time (in minutes) per provider, along with the cost per minute using the TDABC method, was calculated and is displayed in Table 1. For example, the attending orthopaedic surgeon spent, on average, a total of 156 minutes for the entire process of the ACLR. Then, by use of the average salary of a sports medicine orthopaedic surgeon in the regional area of study ($570,538.00), in combination with the average

Table 1. Providers and Associated Cost of TDABC Method for ACLR

Personnel	Total Minutes	Average Salary, $	Weeks per Year	Hours per Day	Total Minutes per Year	Cost per Minute, $	Personnel Cost for Single ACL Surgical Procedure, $
Senior orthopaedic surgeon	156.33	570,538	48	6.4	92,160	6.19	967.79
Orthopaedic resident	159.00	63,393	48	6.4	92,160	0.69	109.37
Anesthesiologist	25.22	364,763	48	6.4	92,160	3.96	99.81
Anesthesia technician	8.42	35,230	48	6.4	92,160	0.38	3.22
RN	170.92	63,126	48	6.4	92,160	0.68	117.07
PA	149.50	93,838	48	6.4	92,160	1.02	152.22
Scrub technician	134.72	42,002	48	6.4	92,160	0.46	61.40
Surgical RN	174.30	63,126	48	6.4	92,160	0.68	119.39
CRNA	152.05	69,270	48	6.4	92,160	0.75	114.29
Cleaning staff	25.67	34,960	48	6.4	92,160	0.38	9.74
Surgical secretary	15	31,857	48	7.4	106,560	0.30	4.48

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CRNA, certified registered nurse anesthetist; PA, physician assistant; TDABC, time-driven activity-based costing.

total minutes worked per year (92,160 minutes), the cost per minute was generated. The cost per minute for the orthopaedic surgeon was $6.19 dollars/min. This process was repeated to generate the cost per minute for each provider in the time map.

By use of the cost-per-minute drivers in combination with the time spent by the orthopaedic surgeon during each phase of the ACLR, the direct variable cost attributable to the orthopaedic surgeon in each phase was determined. For example, the orthopaedic surgeon spent 156 minutes on direct patient care throughout the process of a primary ACLR. Then, multiplying the $6.19/min cost driver by each phase's duration generated the direct variable cost for the orthopaedic surgeon. Thus, the direct variable cost of the surgical episode for the orthopaedic surgeon was $967.79. This process was repeated for each provider present throughout the process of the ACLR (RN, physician assistant, anesthesiologist, surgical resident, scrub technician, certified registered nurse anesthetist, and cleaning staff). Overall, the total direct variable cost was calculated by summing the previously mentioned aspects, which resulted in a total direct variable cost for the operative period of $1,758.78.

The orthopaedic attending was the highest personnel cost contributor when considering per-minute costs, as well as total time spent during the episode of care. The next highest costs were for physician assistants, RNs, certified registered nurse anesthetists, orthopaedic residents, and anesthesiologists, in that order.

Cost Comparison

There was a substantial difference between the traditional ABC and TDABC cost analyses. For the ABC method, the costs associated with direct variable, direct fixed, and indirect costs were $4,795.34, $2,143.49, and $3,379.40, respectively. The costs for the ABC method were obtained from the accounting department at the study institution, which included 121 ACLRs over an 18-month time frame. For the TDABC method, the direct variable, direct fixed, and indirect costs were $1,758.76, $2,143.49, and $1,340.00, respectively (Fig 2). Thus, there was a difference of $3,036.58 in direct variable costs and a difference of $2,039.49 in indirect costs between the TDABC and traditional ABC methods (Fig 3). The direct fixed costs were equal with the 2 methods, given that the fixed costs for an ACLR would not change regardless of the costing-analysis method. The percentage of the total cost for direct variable costs, direct fixed costs, and indirect costs with the TDABC method was 34%, 41%, and 26%, respectively (Table 2). The percentage of the total cost for direct fixed costs, direct variable costs, and indirect costs with the traditional ABC method was 21%, 46%, and 33%, respectively (Table 3). The overall cost of an ACLR was $10,318 when calculated by the traditional ABC method versus $5,242.25 using the TDABC method (Fig 2). This resulted in a cost difference of $5,076.06 between the 2 methods.

Discussion

When compared with TDABC, the hospital's traditional cost-accounting estimate for ACLR is nearly twice as costly. As our health care system continues to scrutinize the value of services rendered, we must also appreciate the significance of cost-accounting methodologies and how varying techniques impact value. Our goal in this study was to compare the traditional ABC method that is used by the senior author's institution versus the TDABC method for the ACLR episode of care. Additionally, we implemented TDABC to identify the major cost drivers underlying the procedure. Overall, this analysis showed that TDABC calculated an approximately 50% decreased cost of ACLR when compared with a traditional ABC method, after triaging patient encounters to the level of service rendered. Our study is in congruence with previous orthopaedic surgery studies

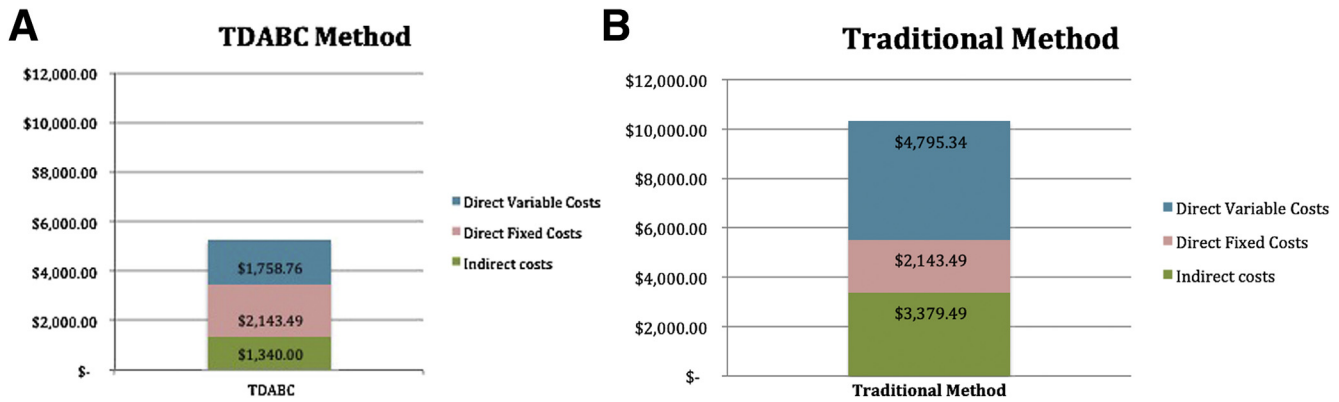

Fig 2. Costs of time-driven activity-based costing (TDABC) method (A) and traditional activity-based costing method (B) for anterior cruciate ligament reconstruction.

that have applied TDABC to different procedures.[4,5,7,11] According to Palsis et al.,[6] the true cost of a procedure likely lies between the costs calculated by the TDABC and ABC methods; similarly, the true cost of an ACLR most likely lies between the 2 calculated costs, given that the 2 approaches use different methods for determining cost. The TDABC method may underestimate the true cost of an ACLR, but it is still the more accurate method when compared with ABC.[4,5]

Through the application of the time map (Fig 1), we determined that the RN was the employee who spent the greatest amount of time providing direct patient care throughout the process of an ACLR (Table 1). This is a fairly intuitive finding because the RN is responsible for patient care throughout the process of an ACLR and should have the most direct time with the patient. However, the main contributor to personnel cost was the orthopaedic surgeon (Fig 1). This was because the orthopaedic surgeon spent a substantial amount of time with the patient and the orthopaedic surgeon had the highest salary of the employees throughout the process. The largest difference in the percentage of total cost came from the direct fixed cost category, which was 21% of the total cost with ABC versus 41% of the total cost with the TDABC method (Tables 1 and 2). Under the TDABC model, direct fixed costs, such as maintenance of tools and equipment, were one of the major cost drivers. As a result, this could be an area of focus for reducing the cost of ACLR performed at a hospital. This could be accomplished by negotiation with manufacturers for improved costs of fixed supplies that are needed during the process of an ACLR or an increase in vendor competition.

One of the inherent challenges of applying the TDABC method is the calculation of indirect costs. In this study, indirect costs included services that support the team performing the ACLR but are not directly tied to patient care. Some examples of these indirect costs are the billing department, administration, and overhead personnel. Calculating every indirect cost using the TDABC method has been cited as being a significant problem by other authors, and as a result, it has been left to assumptions.[5] In our study, we used a ratio for indirect costs, but this assumption could leave room for error because the TDABC method may undervalue the true indirect costs of an ACLR. Therefore, more

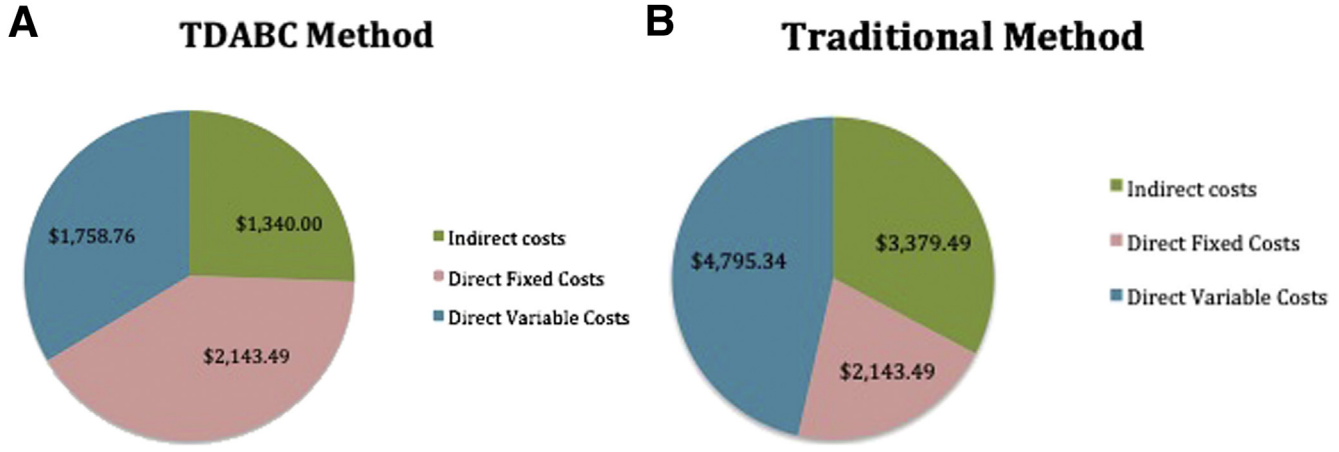

Fig 3. Pie charts of costs of time-driven activity-based costing (TDABC) method (A) versus traditional activity-based costing method (B) for anterior cruciate ligament reconstruction.

Table 2. TDABC Values for ACLR

	TDABC Method	
	Cost, $	% of Total
Indirect costs	1,340.00	26
Direct fixed costs	2,143.49	41
Direct variable costs	1,758.76	34
Total	5,242.25	

ACLR, anterior cruciate ligament reconstruction; TDABC, time-driven activity-based costing.

research must be conducted in the field of health care economics to determine whether this assumption for indirect costs is accurate enough to continue to be the standard.

As noted by other authors, another challenging aspect of using the TDABC method is generating the time map and collecting accurate data for it.[3,12,13] This is because there has to be intimate knowledge of each step of the ACLR, even aspects that do not directly pertain to the orthopaedic surgeon. The time map that we generated was limited to ACLRs at our institution, but there are aspects of the time map that could be applied more broadly. For example, many of the aspects of the preoperative time map could be applied to other orthopaedic surgical procedures, with minor alterations. Therefore, this time map could be used as a template to guide future TDABC research on similar orthopaedic procedures. As a result, one of the most time-consuming steps could be bypassed, expediting future research in the area of TDABC.

TDABC is a powerful tool that continues to show promise in cost analysis for the field of orthopaedic surgery. As other authors have shown, TDABC's cost-analysis method computes a decreased cost for orthopaedic procedures when compared with traditional cost-accounting methods.[3-5,7] However, these costs may be more accurate than standard ABC-derived amounts, therefore warranting continued study and implementation. The TDABC method requires a detailed understanding of the cost of each step in the procedure and identifies high-cost processes that can be improved on. As a result, there can be workflow modifications that can improve cost efficiency while maintaining the highest level of patient care. Although cost efficiency is important, the safety of the patient throughout the procedure must remain of paramount concern. Thus, workflow alterations for the sake of cost efficiency should be established only if there is no compromise to patient care.

Limitations

Our study is not without limitations. The findings of this study were specific to this particular institution and surgeons, which potentially limits the generalizability of the TDABC method to ACLR more broadly. Another limitation was that our current model did not account for possible complications that could occur, either during the procedure itself or in the postoperative period. Moreover, we did not take into account whether a translator was needed for patients who did not speak English. Although this is a limited occurrence at our institution, it may have a more notable impact at other institutions, which would alter the time map and TDABC cost.

Another possible limitation was the number of patients chosen for observation to record times for the time map. Despite the fact that the sample size would normally be considered small, the observed times serve as an estimation of the true time for each aspect of the procedure. In addition, multiple orthopaedic surgeons validated the times of each aspect through years of intimate knowledge of the average duration of the procedure. Finally, the procedure that took the longest added only 50 minutes to the average time and had an overall cost $128 higher the average cost, whereas the shortest procedure took 59 minutes less than the average time and had an overall cost $159 lower than the average cost.

An additional limitation was the use of Glassdoor (Mill Valley, CA) to obtain the salaries of the employees for the generation of the cost per unit of time. However, the yearly salary of the sports medicine orthopaedic surgeon was reported to be $570,538, and data published by Merritt Hawkins (Dallas, TX) showed that nationwide, orthopaedic surgeons make on average $536,000 per year.[14] Merritt Hawkins has published yearly data on the salaries of various physician specialties and in large part can be regarded as accurate. These values are within 6% of each other, which shows that the values obtained from Glassdoor can be considered reliable.

Conclusions

When compared with TDABC, the hospital's traditional cost-accounting estimate for ACLR is nearly twice as costly. These findings highlight the variability of cost calculation for the same clinical episode between the 2 accounting methods. For the traditional method, the direct variable cost was the main cost driver, whereas for the TDABC method, the direct fixed cost was the main cost driver.

Table 3. Traditional Costing Values for ACLR

	Traditional Method	
	Cost, $	% of Total
Indirect costs	3,379.49	33
Direct fixed costs	2,143.49	21
Direct variable costs	4,795.34	46
Total	10,318.31	

ACLR, anterior cruciate ligament reconstruction.

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