The Journal of Arthroplasty 30 (2015) 1699–1704

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Template-Directed Instrumentation Reduces Cost and Improves Efficiency for Total Knee Arthroplasty: An Economic Decision Analysis and Pilot Study

Alexander S. McLawhorn, MD, MBA [a], Kaitlin M. Carroll, BS [b], Jason L. Blevins, MD [a], Scott T. DeNegre, PhD [c], David J. Mayman, MD [b], Seth A. Jerabek, MD [b]

[a] *Academic Training, Hospital for Special Surgery, New York, New York*
[b] *Adult Reconstruction and Joint Replacement Division, Hospital for Special Surgery, New York, New York*
[c] *Operational Excellence, Hospital for Special Surgery, New York, New York*

ARTICLE INFO

Article history:
Received 1 January 2015
Accepted 29 April 2015

Keywords:
knee replacement arthroplasty
decision modeling
digital radiography
template
organizational efficiency

ABSTRACT

Template-directed instrumentation (TDI) for total knee arthroplasty (TKA) may streamline operating room (OR) workflow and reduce costs by preselecting implants and minimizing instrument tray burden. A decision model simulated the economics of TDI. Sensitivity analyses determined thresholds for model variables to ensure TDI success. A clinical pilot was reviewed. The accuracy of preoperative templates was validated, and 20 consecutive primary TKAs were performed using TDI. The model determined that preoperative component size estimation should be accurate to ± 1 implant size for 50% of TKAs to implement TDI. The pilot showed that preoperative template accuracy exceeded 97%. There were statistically significant improvements in OR turnover time and in-room time for TDI compared to an historical cohort of TKAs. TDI reduces costs and improves OR efficiency.

Preoperative planning is critical prior to total knee arthroplasty (TKA). When consistently accurate, preoperative determination of implant sizes allows the surgical team to anticipate necessary instrumentation and components required in the operating room (OR), and it assists orthopedic surgeons delivering reproducible outcomes. Furthermore, correct implant sizing plays an essential role in the long-term success of TKA, reducing the risk of postoperative complications, including reduced range of motion, instability, and persistent pain [1–3].

Historically, preoperative determination of component sizes was performed on radiographic films using acetate overlays with fixed magnification factors [4]. The introduction of digital radiography has allowed physicians to use software programs within picture archiving and communication systems (PACS) to create digital surgical plans. Planning on digital radiographs is at least as accurate as it is using acetate templates [4]. Digital plans are simple, uniform, and can be saved and disseminated to all stakeholders in the surgical team [4,5]. When the surgical plan is easily shared, it may facilitate strategies that streamline TKA instrumentation and overall surgical workflow [6].

Patient-specific instrumentation (PSI), which utilizes expensive, disposable, cutting guides, has been proposed as one such strategy [7]. However, it may not deliver patient outcomes superior to conventional TKA and is likely not a cost-effective option [8–10]. Template-directed instrumentation (TDI) couples conventional instrumentation with PSI principles to limit the amount of intraoperative equipment needed to perform TKA [6], without the increased cost associated with custom cutting guide fabrication [8,11]. By limiting instrumentation to the essential tools and trials necessary to complete the operation for a specific patient, TDI may decrease the number of trays necessary to perform a TKA by up to 60% [6]. Cost-savings are dependent on the accuracy of the preoperative plan, tray reduction, and any costs related to implementing the strategy. The influence of each of these factors on the economics of TDI has not been studied, and the impact of TDI on OR time utilization has not been reported previously.

The primary aim of this study was to report on the development and early implementation of a TDI strategy at one hospital. The following questions were asked: (1) What accuracy is required for preoperative TKA component size estimation in order for TDI to be cost-saving? (2) What is the accuracy of preoperative size estimation in a modern TKA practice? (3) What are the operational efficiencies realized in a pilot series of TDI TKA cases? For the former question, a decision model was created and analyzed; retrospective clinical analyses were performed to answer the latter questions.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2015.04.043.

Ethical board review statement: This study received institutional review board approval prior to initiation.

Work performed at the Hospital for Special Surgery, New York, NY.

Reprint requests: Alexander S. McLawhorn, MD, MBA, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021.

http://dx.doi.org/10.1016/j.arth.2015.04.043
0883-5403/

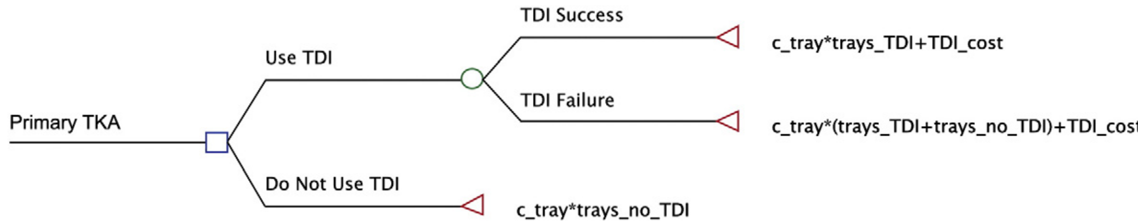

Fig. 1. The decision tree is illustrated. The initial decision occurs at the root decision node (blue square) at the leftmost side of the tree where one of two treatment options is selected at random. For the "Use TDI" branch of the tree, progression to "TDI Success" or "TDI Failure" at the chance node (green circle) is based on the probability of preoperatively planning the TKA within ±1 size for both the tibial and femoral components. The terminal nodes (red triangles) describe the cost of the final result of each treatment path. For the "Do Not Use TDI" branch, 100% of cases proceed to a single terminal node. Cost equations are shown to the right of each terminal node. TKA = total knee arthroplasty; TDI = template directed instrumentation; c_tray = cost of sterilization for one instrument tray; trays_TDI = number of instrument trays required for one TKA to be performed using TDI strategy; trays_no_TDI = number of instrument trays required for one conventional TKA to be performed; TDI_cost = any additional cost required for TDI strategy.

Methods

Decision Model

A decision tree was constructed using TreeAge Pro (Williamstown, MA, USA). It modeled a hypothetical clinical scenario of a patient presenting for primary, unilateral TKA. From the root node (primary TKA), two treatment options were available: (1) use TDI, and (2) do not use TDI (Fig. 1). In the model, the treatment option is selected at random. If the TDI strategy was selected, its success or failure was 93.7% ± 5.8%. This was dictated by the weighted average probability of preoperatively estimating the femoral and tibial components to within ±1 size, which was derived from literature (Table 1) [1,4–6,12–16]. The associated cost equation for each treatment path is detailed in Fig. 1. For the base case, the cost of sterilizing and packaging one instrument tray was $40/tray, which is the cost at the study hospital. The Genesis II Total Knee System (Smith and Nephew, Inc., Memphis, TN, USA) was modeled, which usually consists of 6 trays. It was estimated that a TDI strategy could be executed with 3 trays per case [6]. There were two principal model assumptions: (1) in the base case, there were no additional incremental costs (fixed or variable) for executing the TDI strategy, and (2) if there was failure of the TDI strategy, an entire set of trays for the conventional system would be required to complete the procedure.

Expected value analysis was used to compare the costs of conventional TKA to TDI TKA. In the base case scenario for the decision tree, the pathway was determined that leads to the least expected value (cost) based on the initial estimates of each parameter (cost and probabilities) in the tree. For this analysis, calculations proceeded from right to left along the tree branches. The cost at each branch was multiplied by its respective probability. The sum of the products of each branch was compared, and the pathway with the lowest sum determined the strategy with the optimal outcome (i.e., lowest cost).

Table 1
Summary of Studies Reporting the Accuracy of Digital Templates for Primary TKA.[a]

Reference	TKA N	Exact Femur %	±1 Femur %	Exact Tibia %	±1 Tibia %
Miller and Purtill [12]	25	52.0%	100.0%	48.0%	96.0%
Trickett et al [1]	40	48.0%	98.0%	55.0%	100.0%
Kniesel et al [13]	46	42.5%	97.0%	71.0%	98.0%
Hsu et al [14]	48	58.0%	96.0%	50.0%	88.0%
Specht et al [4]	50	48.0%	92.0%	52.0%	94.0%
The et al [15]	65	55.0%	92.0%	52.0%	94.0%
Hsu et al [6]	82	83.0%	100.0%	90.0%	100.0%
Peek et al [16]	92	71.0%	100.0%	60.0%	100.0%
Levine et al [5]	176	69.0%	100.0%	63.0%	97.0%
Overall	**624**	**63.2%**	**97.9%**	**62.6%**	**96.8%**

TKA = total knee arthroplasty.
[a] All studies used radiographs with a calibration marker of known size.

Since uncertainty and variability existed for each of the estimates used in the decision tree, one-way, two-way and Monte Carlo probabilistic sensitivity analyses were performed in order to further scrutinize the base case results and to determine the necessary threshold value for each parameter for TDI to be a financially viable strategy. Tray sterilization costs were varied based on the base case value ($40/tray) and values reported in the literature (mean $27.32/tray; range $16.36–$50.00 per tray) [6]. The mean number of conventional TKA trays required for primary, unilateral TKA was 7.5 trays (range 4–10 trays) [7]. The target number of TDI trays was set at the mean number of trays for PSI TKA, which was 4.3 trays (range 3–8 trays) [7]. The range rule, which stipulates that the standard deviation is approximately 25% of the range of the data (high value minus low value), was used to calculate a standard deviation for each of these means. In the one-way sensitivity analyses, only one variable was changed over a range of values, while all other parameters were held constant. The value of each parameter that leads to a change, if one existed, in optimal strategy was reported as a threshold value for that parameter. Two-way sensitivity analyses allowed varying two parameters at a time, and the probabilistic sensitivity analysis allowed all parameters to be varied simultaneously. For the latter analysis, one thousand model iterations were performed, beta distributions were assumed for all model probabilities, and gamma distributions were assumed for costs.

Preoperative Planning Accuracy

Seventy-one consecutive patients (76 knees) undergoing primary TKA by a single surgeon, from October 2012 through November 2013, were reviewed in order to determine the accuracy of the preoperative digital plans of the senior surgeon. Institutional review board (IRB) approval was obtained prior to the retrospective review of all clinical data.

Patients were included if they received primary TKA by the lead author for knee osteoarthritis (OA). Patients were excluded if calibration markers were absent on preoperative digital radiographs, if a preoperative digital template was not saved to the hospital's PACS, or operative records were unavailable for review. Radiographs were accessed using the institution's PACS, and component size estimation was performed using its proprietary software (Sectra AB, Linköping, Sweden). One week prior to surgery, standing anteroposterior (AP) and lateral digital radiographs of the operative knee were obtained. Radiographs were calibrated using a calibration marker of known size (25 mm). The lead author planned each case digitally to determine implant sizes (Fig. 2A). Patient demographics including age, gender, body mass index (BMI), laterality, and preoperative alignment were recorded (Table 2).

TKAs were performed using a medial parapatellar approach and standard surgical instruments. The Genesis II Total Knee System was used in all cases. Posterior referencing was used for femoral sizing and rotation, and an extramedullary tibial cutting guide was used for the tibial resection. Posterior stabilized implants were used in all patients (Fig. 2B).