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The ratio of patient body mass index to age: a cost-effective implant selection guideline for total knee arthroplasty

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ABSTRACT

Background: We sought to develop an objective implant selection guideline based on the ratio of patient body mass index (BMI) to age in order to select implants preoperatively and reduce cost while maintaining quality. The BMI-to-age ratio can be used to distinguish patient demand and select those patients who may benefit from newer technology and higher cost implants and those who would do well with standard-demand implants.

Methods: A retrospective analysis investigated the types of implants received by patients undergoing total knee arthroplasty from January 2012 to August 2014. Patients with a BMI-to-age ratio >0.60 were categorized as high demand and were eligible for either a high-demand implant or a standard-demand implant. Patients with a BMI-to-age ratio ≤0.60 were recognized as standard demand and would be eligible for only standard-demand implants. The actual implant received was identified and compared with the implant as predicted by the BMI-to-age ratio and potential cost savings were identified.

Results: A total of 1507 operative knees were identified. The high-demand implant carries a 31% greater cost than that of a standard-demand implant. Thirty-eight of 1084 high-demand implants were placed in standard-demand knees. An additional 1.1% cost was realized with 38 standard-demand knees receiving high-demand implants and 28.6% if high-demand knees had been used in all standard-demand patients.

Conclusions: Limiting the use of high-demand implants to high-functional-demand patients based on the BMI-to-age ratio may guide the surgeon's choice in optimizing implant selection while providing value-based purchasing criteria to the selection of total knee arthroplasty implants.

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Introduction

Total knee arthroplasty (TKA) is one of the most common and cost-effective orthopaedic procedures, and carries a high patient satisfaction. Over 700,000 TKAs are performed annually in the United States and the procedure is increasing in prevalence [1]. The number of TKAs performed annually in the United States is expected to grow by 673% to 3.48 million procedures by 2030 [2]. A variety of pathologic conditions affecting the knee can be treated with TKA, leading to pain relief, restoration of function, and increased mobility [3].

A high percentage of the hospital cost of TKA may be attributed to the cost of the prosthetic implant. Implant prices have grown at a much faster rate than any other aspect of the surgical procedure [4]. The American Academy of Orthopaedic Surgeons published a statement in 1992 with 3 major points; orthopaedic surgeons should make decisions relating to the selection of implants, they should establish reasonable criteria for implant selection based on patient's need, and that cost-containment strategies should be developed [4]. The institutional response to restricting the rising cost of implants has taken 3 major forms: competitive bidding, ceiling pricing, and implant selection guidelines based on demand matching. Implant selection guidelines are based on a demand-matching system of stratifying patients into levels of functional stress that is expected to be placed on the prosthesis [4].

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It is still being investigated whether more costly implants have an overall higher survivorship in the general population [5]. However, certain implants may be indicated for specific patient populations, depending on demand. Surgeons take into consideration multiple factors including weight, age, expected activity after replacement, general health, and bone stock when deciding the appropriate implant to use for a particular patient [6]. Generally, younger, heavier patients who are more active may require a high-demand implant. Moreover, high-demand implants historically have incurred a greater price, and is only beneficial if placed in a high-demand patient. If proper demand matching is not used, high-demand implants may be used in standard-demand patients leading to increased cost and inadvertent allocation of implant capability to a patient who may not benefit from it. This scenario would not be cost-effective.

Implant selection guidelines based on demand are an effective approach in predicting patient functional status post-TKA. Because patient activity is correlated with wear, implant selection and resource allocation can be targeted to those patients who may benefit from presumed improvements in implant technology [7]. Preoperative implant selection guidelines based on demand matching or standardization for TKA were developed to provide objective standards for knee implant selection. Guidelines for knee implant selection are based on the demand a patient is expected to place on the knee prosthesis after TKA. The process of demand matching also has been used by hospitals to control and reduce the cost of joint replacement implants [7].

Our institution, an academic, high volume, urban orthopaedic specialty hospital began a program to decrease the price of total joint replacement implants as part of an overall cost saving effort associated with value-based purchasing and the bundled payment for care improvement initiative. Before the implementation of this program, a body mass index (BMI) >40 kg/m^2 and/or age <55 years was the only defining criteria for high-demand implant selection while taking into consideration qualitative analysis of activity level, and patient-specific factors including anatomy and bone quality [8]. Approval for higher cost implants in patients who did not meet the age and weight criteria for high-demand implants were made on a case-by-case basis by a surgeon committee.

In this study, as part of a TKA clinical pathway, we sought to develop a universally objective selection guideline based on the BMI-to-age ratio of patient to select implants preoperatively and reduce cost. The literature contains few validated tools that can accurately and reproducibly predict patient activity after TKA [7]. The BMI-to-age ratio can be used to distinguish patient demand and select those patients who would likely benefit from newer technology and higher cost implants and who will do well with the standard-demand implants. Inappropriate implant selection may effectively be reduced, and thus decrease the overall cost of arthroplasty for an institution. We hypothesize that the implementation of a BMI-to-age ratio as part as a standardized clinical pathway would decrease overall costs and enhance efficiency in implant selection. Rational selection of implants in a value-based health care system is critical to economic survivorship in the new health care paradigm.

Material and methods

Participants

Participants were identified after approval by the institutional review board. Data were collected on TKAs that have occurred over a 2.5-year period with 1363 patients with 1507 TKAs identified from the electronic medical record.

Study methodology

A retrospective review was conducted to assess the types of implants received by patients undergoing TKA from January 2012 to August 2014 under the former implant selection guideline criteria, which included age <55 years, BMI >40 kg/m^2, as well as patient factors including activity level and anatomy. This left that previous guideline system open for interpretation. For our study, patients were stratified based on their BMI-to-age ratio. The BMI-to-age ratio cutoff was developed by a team of surgeons at our institution, taking into consideration the current literature, the previous implant-matching guidelines, and a retrospective analysis of patient outcomes and historical demand-matching patterns. Demand refers to patient requirements in the context of wear rates based on age and BMI, rather than physical-activity demand. Patients with a BMI-to-age ratio >0.60 were categorized as high-demand patients and were eligible for either a high-demand implant or a standard-demand implant. Patients with a BMI-to-age ratio $\leq$0.60 are recognized as a standard-demand patient and should only be eligible for standard-demand implants. Under the ration, standard-demand implants may be placed in both standard-demand patients and high-demand patients, based on several factors the surgeon considers while evaluating what is best fit for the patient's needs. High-demand implants placed in standard-demand patients were considered to be not cost-effective. The actual implant received was identified and compared with the implant as predicted by the BMI-to-age ratio and potential cost savings were identified. Retrospectively, we determined how much cost would have been saved if the BMI-to-age ratio implant selection guidelines had been implemented during this period. In addition, we calculated the maximum potential savings that could be achieved under this model (Fig. 1; Tables 1 and 2).

At our institution, the high-demand implant choices were of newer design and included features such as high flexion, enhanced fixation, more kinematic design, oxidized zirconium, robotic-assisted compatibility and mobile-bearing as well as additional sizing and enhanced instrumentation. The insert choices include standard polyethylene, highly cross-linked polyethylene, and vitamin E—enhanced polyethylene. Previous implant selection guidelines at our institution were determined by the operating surgeon. Selection criteria included weight >300 lbs and/or age <55 years. Cost analysis was performed based on current implant pricing to determine how much cost would have been saved if high-demand implants were limited to use in only high-demand patients with a BMI-to-age ratio >0.60. All high-demand implants used in standard-demand groups were considered to be not cost-effective.

Results

A total of 1363 patients were identified as undergoing TKA between January 2012 and August 2014 with 1507 operative knees. The mean age and standard deviation at the time of surgery was 64.2 years ±10.2, with 4.8% of patients being men and 95.2% of patients being women. One thousand eighty-four TKAs were categorized as standard-demand patients (BMI:age $\leq$0.60), and 423 TKAs were categorized as high-demand patients (BMI:age >0.60). Of the patients categorized as standard-demand, the average age was 67.4 years; and of the patients categorized as high-demand, the average age was 56.0 years.

Under the ratio, high-demand implants may only be placed in high-demand patients, whereas standard-demand implants may be placed in standard-demand or high-demand patients per the surgeon's discretion. Thirty-eight high-demand implants and 1046 standard-demand implants were used in 1084 standard-function-demand

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