The procedure value index: a new method for quantifying value in shoulder arthroplasty

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Background: The purpose of this study was to introduce the procedure value index (PVI) and apply this value instrument to shoulder arthroplasty. The PVI uses the value equation in units of minimal clinically important difference (MCID) to provide an objective system of quantifying value-driven care. Secondarily, we describe the PVI for both primary anatomic total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA) to highlight value differences between these patient populations.
Methods: Patients undergoing primary shoulder arthroplasty with minimum 2-year follow-up were identified retrospectively. MCIDs were determined for the Simple Shoulder Test (SST) score, American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) score for pain, and Single Assessment Numeric Evaluation (SANE) score. Cost data were reported as total hospitalization costs, total charges, and total reimbursements. The PVI was calculated as the ratio of outcome improvement in units of MCID over the cost of care. Mean PVIs for TSA and RSA were compared.
Results: Five hundred thirty-four patients met the inclusion criteria. MCIDs for the SST, ASES, VAS pain, and SANE scores were 3.61, 29.49, 3.28, and 37.05, respectively. With the exception of the ASES score, improvements in units of MCID were not different between TSA and RSA. However, total hospitalization costs and charges were significantly higher for RSA ($P < .001$). PVIs based on total hospitalization costs and total charges for the SST, ASES, and VAS pain scores were significantly greater for TSA ($P < .05$). No other PVI was significantly different.
Conclusions: The PVI was greater for TSA when total hospitalization costs and total charges were considered. The PVI helps highlight value differences in shoulder arthroplasty.
Level of evidence: Basic Science Study; Development or Validation of Outcome Instrument
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Modern health care continues to emphasize improvement in patient outcomes with concomitant cost reduction.[1] However, recent emphasis on quality has focused on process-of-care measurements rather than clinical outcomes.[2] Nonetheless, numerous resources, technological advancements, and provider models are aimed at the achievement of better clinical outcomes. The rising costs of health services have ignited discussion on the importance of minimizing health care–related expenditures in an attempt to increase affordability for beneficiaries. Experts have warned against cost cutting without regard to consequences posed to the quality of care.[6,7] It has thus become important to weigh both patient outcomes and cost when determining the value of a given health care intervention. A "value equation" has been proposed by Porter[7] that defines value as "outcomes achieved per dollar spent." Nwachukwu et al[6] have taken this concept further and proposed several guidelines for developing a useful value equation for the field of orthopedic surgery. They acknowledged the importance of using disease-specific patient-reported outcomes as well as the complexity of measuring cost variables when calculating this value equation.

Patient-reported outcome measures (PROMs) have become the benchmark by which many high-level orthopedic studies have quantified results of various surgical interventions. For shoulder arthroplasty patients, several studies have determined the minimal clinically important differences (MCIDs) in PROMs that are required to achieve a meaningful improvement.[5,8,10,12,15] However, MCIDs tend to vary among patient populations and are not always consistent.[5,8,10,12,15] It is therefore of interest to calculate new MCIDs for each patient population. MCIDs also do not take into account the monetary costs associated with achieving these results.

Although MCIDs have been shown to be similar for both anatomic total shoulder arthroplasty (TSA) and reverse shoulder arthroplasty (RSA),[10,15] the pathology being treated and patient populations often differ significantly.[10] It is unclear, however, whether the value of these 2 procedures differs. By integrating the MCID into the value equation, it is possible to understand value differences relative to meaningful improvements in clinical outcomes. The purpose of this study was to introduce the procedure value index (PVI) and examine value differences between TSA and RSA. Our hypothesis was that the PVI would be different between TSA and RSA.

Materials and methods

Data set

A retrospective query of our institutional shoulder and elbow surgical repository was used to identify patients treated with primary shoulder arthroplasty. The indication for surgery was noted by the operating surgeon and recorded in the database. PROMs including the Simple Shoulder Test (SST) score, American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) score for pain, and Single Assessment Numeric Evaluation (SANE) score were collected for each patient preoperatively and at each postoperative appointment as part of the standard repository protocol. Patient satisfaction with surgery was reported as excellent, good, satisfactory, or unsatisfactory at postoperative intervals.

Inclusion criteria

Patients were included in the analysis if they underwent a primary TSA, as indicated by Current Procedural Terminology code 23472, from 2007 to 2015. No revision cases were included. Furthermore, patients were only included if they had preoperative PROM data, follow-up PROMs for a minimum of 2 years, and all 3 elements of cost data. Third-party payers included both Medicare and private payers. The clinical indications for shoulder arthroplasty were queried from the repository (Table I). Patients with acute proximal humeral fractures were excluded.

Calculation of MCID

MCIDs for this study population were calculated using a previously defined, anchor-based method.[10] This was performed for the SST, ASES, VAS pain, and SANE outcome scores. Mean preoperative to postoperative improvement for each outcome score was calculated for patients reporting good, satisfactory, or unsatisfactory results. The MCID for each PROM was calculated as the difference in mean improvement between the satisfactory-good satisfaction group and the unsatisfactory group. Patients with excellent

Table I Indications for surgery in patients undergoing anatomic TSA or RSA

Indication	TSA		RSA	
	No. of patients (315 total with indication data)*	%	No. of patients (206 total with indication data)*	%
Osteoarthritis without cuff tear	302	95.9	28	13.6
Osteoarthritis with cuff tear	4	1.3	181	87.9
Inflammatory arthritis	8	2.5	7	3.4
Avascular necrosis	4	1.3	8	3.9
Malunion or nonunion	0	0.0	19	9.2
Locked anterior dislocation	0	0.0	5	2.4
Massive rotator cuff tear with pseudoparalysis	0	0.0	5	2.4

TSA; total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.
  * Some patients had more than 1 surgical indication listed and were thus included in multiple categories.

satisfaction were excluded from MCID analysis as these patients were said to be beyond minimal change.[10]

The following equation was used for calculation of the MCID for each PROM (MCID$_{PROM}$): MCID$_{PROM}$ = Mean preoperative to postoperative improvement in PROM for satisfactory-good group – Mean preoperative to postoperative improvement in PROM for unsatisfactory group.

Costs

Cost-related data for hospitalization were obtained via complete hospital financial records and imported into the repository. Three different economic cost perspectives were evaluated to better characterize different stakeholders' perspectives. "Total hospitalization cost" was calculated as the sum of all itemized costs accrued during each patient's hospital stay during the time of surgery. "Total charges" referred to charges directly billed to each patient by the hospital. "Total reimbursement" was defined as the amount paid to the hospital by the respective patient's insurance provider. Multiple different payers were included in this analysis.

Calculation of PVI

The PVI was calculated as the ratio of PROM improvement in units of MCID over the mean cost of care; the resultant value was then multiplied by 10^x to yield a normalized integer: PVI$_{PROM/Cost\ measurement}$ = (Mean ΔMCID$_{PROM}$ × 10^x)/Mean cost$_{Cost\ measurement}$.

PVI analysis was performed for the 4 PROMs for which MCIDs were calculated (SST, ASES, VAS pain, and SANE scores) and the 3 cost measurements reported in this study (total hospitalization cost, total charges, and total reimbursement). This yielded a total of 12 different PVI calculations for each patient. This approach allowed a better estimation of different perspectives, that is, payer, patient, and hospital system.

PVI comparison between anatomic TSA and RSA

The study patients were separated into 2 groups based on whether they underwent TSA or RSA. Mean PVIs for the SST, ASES, VAS pain, and SANE scores with total hospitalization costs, total charges, and total reimbursements were compared between the study groups by independent-samples t tests (SPSS software, version 24; IBM, Armonk, NY, USA), with significance set at $P < .05$. The same MCIDs for each PROM were used when calculating PVIs for both TSA and RSA patients, as MCIDs have not been found to vary based on arthroplasty type.[10] To determine potential contributing factors to any PVI differences, PROM improvements in units of MCID, as well as cost measurements, were individually compared between the TSA and RSA cohorts.

Results

Our query of the shoulder and elbow repository identified 624 patients treated with primary TSA or RSA with complete hospitalization cost data. Of these patients, 534 met the inclusion criteria, with a mean follow-up period of 47 months (range, 24-124 months). Of these, 319 underwent TSA and 215 underwent RSA. The surgical indications were quite different, as 95.87% of patients undergoing TSA had a primary surgical indication of osteoarthritis without rotator cuff tear whereas 87.9% of RSA patients were treated for osteoarthritis with rotator cuff tear. The surgical indications for patients included in the study are shown in Table I. Demographic data are presented in Table II.

Of the patients, 379 (70.97%) reported excellent satisfaction with surgery, 131 (24.53%) reported good or satisfactory results, and 21 (3.93%) reported unsatisfactory results. Satisfaction data were not available for 3 patients (0.56%). Mean improvements in the SST, ASES, VAS pain, and SANE scores for patients reporting satisfaction as excellent, good or satisfactory, and unsatisfactory are shown in Table III. MCID for the SST score was 3.61. MCID for the ASES score was 29.49. The MCID for the VAS pain score was 3.28. The MCID for the SANE score was 37.05 (Table III).

Mean PVIs for patients undergoing TSA and RSA based on each PROM and cost measurement are shown in Table IV. All PVIs were significantly greater for TSA ($P < .05$) except those calculated using the SANE score or reimbursement data (Table IV).

Analysis of the components of the PVI showed that improvements in all PROMs (in units of MCID), with the exception of the ASES score (1.72 vs 1.49, $P = .010$), were not significantly different between TSA and RSA (Table V). For patients undergoing RSA, mean total hospitalization costs were $1263.78 greater ($P < .001$) and mean total charges were $6168.00 greater ($P < .001$) than those for patients undergoing TSA. TSA had mean reimbursement that was $1256.62 greater than that for RSA ($P = .011$, Table V).

Table II Demographic data for primary shoulder arthroplasty patients

	Overall	Anatomic TSA	RSA	P value
No. of patients	534	319	215	
Mean follow-up (range), mo	47 (24-124)	49 (24-113)	44 (24-124)	
Gender distribution, n				.005
Male	238 (44.6%)	158 (49.5%)	80 (37.2%)	
Female	296 (55.4%)	161 (50.5%)	135 (62.8%)	
Mean age (range), yr	71.9 (45.4-88.9)	69.9 (45.4-88.9)	75.0 (46.2-88.3)	< .001

TSA; total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty.

Table III Calculated MCIDs for various patient-reported outcome measures

	SST score		ASES score		VAS pain score		SANE score	
	Mean improvement	n	Mean improvement	n	Mean improvement	n	Mean improvement	n
Satisfaction with surgery								
Excellent	6.50 ± 3.06	320	52.86 ± 24.45	328	5.76 ± 2.99	329	47.31 ± 35.31	282
Good or satisfactory	4.25 ± 3.53	104	39.10 ± 26.13	103	4.35 ± 3.33	104	33.13 ± 36.91	99
Unsatisfactory	0.64 ± 3.15	14	9.62 ± 20.33	15	1.07 ± 3.23	15	−3.92 ± 22.63	12
MCID	3.61		29.49		3.28		37.05	

MCID, minimal clinically important difference; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *SANE*, Single Assessment Numeric Evaluation.

Table IV Mean PVIs for primary anatomic TSA and RSA based on patient-reported outcome measures and cost measurements

PVI	TSA	RSA	P value
SST score			
Total costs*	1.63 ± 1.00	1.43 ± 0.98	.039
Total charges[†]	2.44 ± 1.45	2.13 ± 1.36	.022
Total reimbursements*	1.28 ± 0.98	1.20 ± 0.75	.338
ASES score			
Total costs*	1.73 ± 0.96	1.41 ± 1.05	.001
Total charges[†]	2.56 ± 1.33	2.08 ± 1.45	<.001
Total reimbursements*	1.34 ± 1.19	1.17 ± 0.77	.067
VAS pain score			
Total costs*	1.68 ± 1.04	1.40 ± 1.12	.006
Total charges[†]	2.48 ± 1.44	2.08 ± 1.57	.006
Total reimbursements*	1.32 ± 1.38	1.20 ± 0.88	.233
SANE score			
Total costs*	1.06 ± 1.08	1.16 ± 0.94	.379
Total charges[†]	1.60 ± 1.57	1.73 ± 1.32	.420
Total reimbursements*	0.84 ± 0.90	0.96 ± 0.72	.164

PVI, procedure value index; *TSA*; total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *SANE*, Single Assessment Numeric Evaluation.

* Original values multiplied by 10^4 to yield normalized integer.

† Original values multiplied by 10^5 to yield normalized integer.

Discussion

The purpose of this study was to highlight differences in value between TSA and RSA using an index of value that takes into account the minimal improvement necessary to achieve patient satisfaction—PVI. The PVI can be easily replicated and used to study the value impact of improvements in health care delivery as well as differences in value among treatments or procedures. By use of the PVI, our results showed significant differences between TSA and RSA. In addition to having completely different indications, patients undergoing TSA were generally found to have greater value achievement than patients undergoing RSA. Given that the cost of RSA was significantly higher and improvements in PROMs were quite similar, the results of this study suggest that the value differences between TSA and RSA relate to the higher costs associated with managing patients with rotator cuff insufficiency requiring RSA.

In this study, MCIDs were used to calculate the PVI for shoulder arthroplasty. For the 534 primary shoulder arthroplasty patients with minimum 2-year follow-up (mean, 47 months), anchor-based MCIDs were determined to be 3.61 for the SST score, 29.49 for the ASES score, 3.28 for the VAS pain score, and 37.05 for the SANE score. Anchor-based methods have been used in several studies to determine MCIDs for various PROMs after shoulder arthroplasty. Simovitch et al[8] reported anchor-based MCIDs of 13.5 for the ASES score, 1.5 for the SST score, and 1.6 for the VAS pain score. Similarly, Werner et al[15] determined an MCID of 13.5 for the ASES score. In addition, Tashjian et al[10] determined MCIDs of 20.9 for the ASES score, 2.4 for the SST score, and 1.4 for the VAS pain score. The MCIDs calculated in our study are somewhat higher than those previously reported, possibly because of population-specific factors. Patient expectations related to what constitutes a meaningful improvement may vary depending on the disease treated and the treatment modality. Furthermore, as shown earlier, MCIDs can vary considerably even when calculated for similar indications and treatment modalities. It is therefore important to determine the MCID for the population of interest when calculating the PVI.

With the goals of incentivizing efficiency and value in the delivery of health care services, there has been considerable discussion regarding the bundled-payment initiative. Inherent to the bundled-payment initiative are attempts at cost savings with the hope of maintaining or enhancing quality. With each cost-saving effort, it is important to monitor the impact on outcome and, ultimately, value. This type of analysis will be important in determining what services to include in each bundle, as well as the funds allocated to each bundle. Teusink et al[11] asserted that shoulder arthroplasty is an ideal model for the bundled-payment initiative because of its reproducible nature but that improved measures of outcome and cost associated with these procedures are needed. The PVI related to shoulder arthroplasty as discussed in our study provides a measurement that incorporates both meaningful clinical improvement and cost. Use of the PVI to track changes and improvements within the episode of care can certainly impact the bundled-payment initiative.

As the PVI is the ratio of outcome improvement to cost, it is not to be used as a stand-alone measurement. Rather, it is intended to be used as a tool for comparing "value" between

Table V Mean improvement (in units of MCID) for each PROM and mean cost measurements for anatomic TSA versus RSA

	TSA	RSA	*P* value
Mean PROM improvement in units of MCID			
SST score	1.65 ± 0.98	1.52 ± 0.91	.159
ASES score	1.72 ± 0.86	1.49 ± 0.97	.010
VAS pain score	1.66 ± 0.94	1.50 ± 1.08	.105
SANE score	1.09 ± 1.04	1.23 ± 0.90	.150
Mean cost measurements, $			
Total costs	10,599.74 ± 2384.85	11,863.52 ± 3561.38	<.001
Total charges	67,872.73 ± 7363.03	74,040.73 ± 12,921.70	<.001
Total reimbursements	14,629.80 ± 6548.31	13,373.18 ± 4702.51	.010

MCID, minimal clinically important difference; *PROM*, patient-reported outcome measure; *TSA*; total shoulder arthroplasty; *RSA*, reverse shoulder arthroplasty; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *SANE*, Single Assessment Numeric Evaluation.
NOTE. Mean costs were calculated using all patients with complete cost data and 2-year follow-up regardless of whether PROM data were reported.

different patient populations or interventions through the use of consistent measures. Furthermore, owing to the various methods of measuring outcome improvement and cost, there are many ways to calculate the PVI. Using only 1 PVI calculated from a single outcome and cost measurement provides too narrow a focus and likely prevents investigators from detecting important differences. However, when analyzing value among different patient groups, investigators must only compare PVIs that are calculated using the same outcome scores and cost measurements.

To exemplify the aforementioned concepts, this study used 12 different PVI measurements for each type of shoulder arthroplasty: TSA or RSA. The PVI was greater for TSA with few exceptions (the PVI for the SANE score and reimbursement costs). Furthermore, the improvements in units of MCID were not different for nearly all PROMs examined (except the ASES score). The greater PVI for TSA was thus largely related to significantly greater total hospitalization costs and total charges associated with RSA procedures. As the cost of RSA implants decreases over time, the value of RSA will likely increase, potentially exceeding the value of TSA.

Our study found the PVI based on reimbursement costs to be similar between TSA and RSA. This is likely due to the fact that shoulder arthroplasty is typically performed in patients with Medicare reimbursement, which is identical for both TSA and RSA. As shown in this study (Table V), reimbursements were only marginally higher for TSA, and this small difference was likely a result of non-Medicare reimbursements in younger TSA patients.

It is important to emphasize that although our study determined that TSA had a higher PVI than RSA, these procedures were performed in patients with completely different surgical indications (Table I). The study findings should not be misinterpreted as suggesting that TSA be selected over RSA for any specific patient pathology. In contrast, the differences in value seen in the TSA and RSA patient populations help to reinforce the opinion stressed by Nwachukwu et al[6] that value analytics should be disease specific.

Few studies have focused on the value impact of shoulder arthroplasty. While examining the risk factors for poor functional improvement after RSA, Hussey et al[4] defined value as ASES score improvement divided by total cost and multiplied by $10,000. At the same institution, Steen et al[9] used this method in a matched-cohort study involving 120 patients. Similar to our study, they found the "value" for TSA to be greater than for RSA (26.2 vs 15.0, *P* = .003), likely owing to greater RSA costs, which were $7274 greater than TSA costs.[9]

There are important differences between the value measurements used in the aforementioned studies and the PVI method used in our study. By using units of MCID to define changes in outcome (numerator of value equation) rather than overall improvements in specific PROMs, the PVI focuses on the minimal improvement needed to achieve a meaningful result. Furthermore, use of multiple different PROMs helps to identify consistency in value improvement. This is evident in our study, in which mean ASES score improvement in units of MCID was an outlier in comparing TSA with RSA. In addition, use of multiple different cost indicators (denominator of the value equation) helps to further differentiate the PVI analysis of this study. Because many elements of cost, such as implant costs, supply costs, and non-Medicare reimbursement, relate to hospital contract negotiations, analysis of costs using total hospital costs, total hospital charges, and hospital reimbursement helps to eliminate the bias inherent in these variations.

With the recent emphasis on value-based initiatives in health care, there is a trend toward an emphasis on the process of care.[2] Quality-based payment systems have been created using process-of-care surveys to influence reimbursement. Yet, for surgeons, innovations in practice management, treatment protocols, clinical guidelines, implant design, surgical techniques, and devices remain focused on maximizing clinical outcomes. The PVI provides a tool by which value can be tracked with a focus on the outcome of treatment. This index may prove useful among large health care systems interested in understanding the differences among providers and hospitals in delivering high-quality care and may provide an alternative metric to process-of-care initiatives.

This study has several limitations. First, the percentage of patients reporting unsatisfactory results was small for each PROM and thus may have influenced the accuracy of anchor-based MCID calculations. However, this percentage is consistent with most studies reporting MCIDs for shoulder arthroplasty.[8,10]

Second, the denominator of the PVI was calculated using only costs related to each patient's inpatient hospitalization for surgery. Nwachukwu et al[6] suggested that cost measurements for the value equation should encompass all areas related to the patient's condition. However, previous studies have shown that 80%-90% of costs for TSA and RSA are related to inpatient hospitalization,[13,14] and therefore, the impact of this limitation is minimal. Finally, this study was conducted at a single institution, with all procedures performed by 1 surgeon. As previously mentioned, population-specific factors have the potential to impact MCID and PVI calculations. For example, high-volume centers have been shown to have lower shoulder arthroplasty costs than low-volume centers.[3] Therefore, investigators must use caution when directly comparing PVI calculations from other populations with those in our study. It is important to determine new MCIDs prior to calculating the PVI in a different population.

Conclusion

The PVI provides a useful tool for making value comparisons based on the outcome of care, as it incorporates meaningful clinical improvement together with cost. By use of the PVI, the value of primary TSA was shown to be significantly different than that of primary RSA for nearly all PVI metrics, likely related to the higher costs associated with management of the rotator cuff–deficient shoulder. We anticipate that the PVI will be used to show how system-wide interventions or new technology introductions impact value over time.

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Disclaimer

References

1. Black EM, Higgins LD, Warner JJ. Value-based shoulder surgery: practicing outcomes-driven, cost-conscious care. J Shoulder Elbow Surg 2013;22:1000-9. http://dx.doi.org/10.1016/j.jse.2013.02.008
2. Graham B, Green A, James M, Katz J, Swiontkowski M. Measuring patient satisfaction in orthopaedic surgery. J Bone Joint Surg Am 2015;97:80-4. http://dx.doi.org/10.2106/JBJS.N.00811
3. Hammond JW, Queale WS, Kim TK, McFarland EG. Surgeon experience and clinical and economic outcomes for shoulder arthroplasty. J Bone Joint Surg Am 2003;85:2318-24.
4. Hussey MM, Steen BM, Cusick MC, Cox JL, Marberry ST, Simon P, et al. The effects of glenoid wear patterns on patients with osteoarthritis in total shoulder arthroplasty: an assessment of outcomes and value. J Shoulder Elbow Surg 2015;24:682-90. http://dx.doi.org/10.1016/j.jse.2014.09.043
5. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. J Shoulder Elbow Surg 2002;11:587-94. http://dx.doi.org/10.1067/mse.2002.127096
6. Nwachukwu BU, Hamid KS, Bozic KJ. Measuring value in orthopaedic surgery. JBJS Rev 2013;1. http://dx.doi.org/10.2106/JBJS.RVW.M.00067
7. Porter ME. What is value in health care? N Engl J Med 2010;363:2477-81. http://dx.doi.org/10.1056/NEJMp1011024
8. Simovitch R, Flurin PH, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. http://dx.doi.org/10.1016/j.jse.2017.09.013
9. Steen BM, Cabezas AF, Santoni BG, Hussey MM, Cusick MC, Kumar AG, et al. Outcome and value of reverse shoulder arthroplasty for treatment of glenohumeral osteoarthritis: a matched cohort. J Shoulder Elbow Surg 2015;24:1433-41. http://dx.doi.org/10.1016/j.jse.2015.01.005
10. Tashjian RZ, Hung M, Keener JD, Bowen RC, McAllister J, Chen W, et al. Determining the minimal clinically important difference for the American Shoulder and Elbow Surgeons score, Simple Shoulder Test, and visual analog scale (VAS) measuring pain after shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:144-8. http://dx.doi.org/S1058-2746(16)30191-4
11. Teusink MJ, Virani NA, Polikandriotis JA, Frankle MA. Cost analysis in shoulder arthroplasty surgery. Adv Orthop 2012;2012:692869. http://dx.doi.org/10.1155/2012/692869
12. van Kampen DA, Willems WJ, van Beers LW, Castelein RM, Scholtes VA, Terwee CB. Determination and comparison of the smallest detectable change (SDC) and the minimal important change (MIC) of four-shoulder patient-reported outcome measures (PROMs). J Orthop Surg Res 2013;8:40. http://dx.doi.org/10.1186/1749-799X-8-40
13. Virani NA, Williams CD, Clark R, Polikandriotis J, Downes KL, Frankle MA. Preparing for the bundled-payment initiative: the cost and clinical outcomes of reverse shoulder arthroplasty for the surgical treatment of advanced rotator cuff deficiency at an average 4-year follow-up. J Shoulder Elbow Surg 2013;22:1612-22. http://dx.doi.org/10.1016/j.jse.2013.01.003
14. Virani NA, Williams CD, Clark R, Polikandriotis J, Downes KL, Frankle MA. Preparing for the bundled-payment initiative: the cost and clinical outcomes of total shoulder arthroplasty for the surgical treatment of glenohumeral arthritis at an average 4-year follow-up. J Shoulder Elbow Surg 2013;22:1601-11. http://dx.doi.org/10.1016/j.jse.2012.12.028
15. Werner BC, Chang B, Nguyen JT, Dines DM, Gulotta LV. What change in American Shoulder and Elbow Surgeons score represents a clinically important change after shoulder arthroplasty? Clin Orthop Relat Res 2016;474:2672-81. http://dx.doi.org/10.1007/s11999-016-4968-z