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DEFORMITY

Improvements in Outcomes and Cost After Adult Spinal Deformity Corrective Surgery Between 2008 and 2019

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Study Design. A retrospective cohort study.

Objective. To assess whether patient outcomes and cost-effectiveness of adult spinal deformity (ASD) surgery have improved over the past decade.

Background. Surgery for ASD is an effective intervention, but one that is also associated with large initial healthcare expenditures. Changes in the cost profile for ASD surgery over the last decade has not been evaluated previously.

Materials and Methods. ASD patients who received surgery between 2008 and 2019 were included. Analysis of covariance was used to establish estimated marginal means for outcome measures [complication rates, reoperations, health-related quality of life, total cost, utility gained, quality adjusted life years (QALYs), cost-efficiency (cost per QALY)] by year of initial surgery. Cost was calculated using the PearlDiver database and represented national averages of Medicare reimbursement for services within a 30-day window including length of stay and death differentiated by complication/comorbidity, revision, and surgical approach. Internal cost data was based on individual patient diagnosis-related group codes, limiting revisions to those within two years (2Y) of the initial surgery. Cost per QALY over the course of 2008–2019 were then calculated.

Results. There were 1236 patients included. There was an overall decrease in rates of any complication (0.78 *vs*. 0.61), any reoperation (0.25 *vs*. 0.10), and minor complication (0.54 *vs*. 0.37) between 2009 and 2018 (all $P < 0.05$). National average 2Y cost decreased at an annual rate of \$3194 ($R^2 = 0.6602$), 2Y utility gained increased at an annual rate of 0.0041 ($R^2 = 0.57$), 2Y QALYs gained increased annually by 0.008 ($R^2 = 0.57$), and 2Y cost per QALY decreased per year by \$39,953 ($R^2 = 0.6778$).

Conclusion. Between 2008 and 2019, rates of complications have decreased concurrently with improvements in patient reported outcomes, resulting in improved cost effectiveness according to national Medicare average and individual patient cost data. The value of ASD surgery has improved substantially over the course of the last decade.

Key words: adult spinal deformity (ASD), complications, reoperations, health-related quality of life measures (HRQL), total cost, utility gained, quality adjusted life years (QALYs)

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Institutional Review Board approval was obtained before enrolling patients in the prospective database. Informed consent was obtained from each patient before enrollment.

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Surgery for adult spinal deformity (ASD) is an effective intervention, but one that is also associated with large initial healthcare expenditures.[1,2] Patient satisfaction with these procedures is high, which suggest the benefit of surgery in ASD may support the initial expense.[3–5] Beyond extensive healthcare resource utilization for these procedures, the use of implants, interbody devices, and biologics can all further drive the cost of the intervention.[6–11] This has resulted in increased scrutiny of proposed procedures from both patients and providers. Considerations regarding cost-effectiveness rest at the heart of these considerations.[12,13]

As experience with modern techniques use to address ASD have increased over the last 10 to 20 years,[14] including the deployment of minimally invasive procedures,[15] hospital length of stay (LOS), and need for rehabilitation have reduced proportionately.[16–18] At the same time, as surgeons have become more facile with these interventions, the rate of complications and need for extensive postsurgical care have also diminished, factors that not only contribute to improved patient outcomes and satisfaction but also decrease healthcare costs.[19–23] Conversely, the use of interbody devices, biologics, and instrumentation, including minimally invasive procedures, facilitate improved outcomes and reduced hospital stays for patients can also add substantial costs.[24–28] While patients, surgeons and administrators hope that health technology will improve the cost profile for these interventions, the question remains as to whether the increased technologic expenses are offset by improved patient outcomes and reduced resource consumption in the per-operative period.

The effective evaluation of these parameters are hampered by restrictive patient samples and surgical practice at the level of individual clinicians or hospitals, that also lack the ability to evaluate changes in performance over the duration of several years if not decades. In this context, we sought to use the multicenter registry of the International Spine Study Group to evaluate changes in the cost profile and outcomes for ASD surgery over the course of 2008–2019. The high quality, prospectively entered, and robust clinical, sociodemographic and outcome data captured in this registry over the course of the time periods studied allowed us to effectively evaluate changes in the cost-profile and cost-effectiveness of ASD surgery and determine the factors responsible. Based on prior studies supporting improved health-related quality of life (HRQL) and fewer complications in patients receiving these surgeries over the last 10 years, we hypothesized that ASD surgery would be more cost-effective in 2019 as compared with 2008.

MATERIALS AND METHODS

Study Design and Inclusion Criteria

This investigation retrospectively queried data contained in the International Spine Study Group clinical registry. The International Spine Study Group comprises 13 distinct centers across the United States, contributing consecutively enrolled, consented patient data with Institutional Review Board approval to a prospectively enrolled adult spinal deformity (ASD) database. These ASD patients were initially identified for database inclusion by meeting at least one of the following radiographic parameter criteria: sagittal vertical axis (SVA) ≥ 5 cm, Cobb angle $\geq 20°$, pelvic tilt (PT) $\geq 25°$, or thoracic kyphosis $> 60°$. Patients eligible for inclusion in the present study also had baseline (BL) and up to two-year (2Y) HRQL data with a surgical intervention performed between the years of 2008 and 2019. Patients from the years 2008 and 2019 were combined with 2009 and 2018, respectively, as these two years were incomplete (2008 only having data from a latter portion of the year, and 2019 only having data from the earlier portion of the year).

Data Collection and Radiographic Parameters

We abstracted demographic (age, body mass index, biological sex, Charlson Comorbidity Index), surgical (levels fused, operative time, LOS, surgical approach, performance of decompressions, and osteotomies), and clinical [complications, reoperations, diagnosis-related group (DRG) code] data for eligible individuals identified for inclusion in this analysis. The determination of complications was made as reported by study coordinators at the contributing centers and made based on review of imaging, patient reports, and clinical determination. Patient-reported outcome measures [Oswestry Disability Index (ODI), Short Form-36 (SF-36)] were collected at BL and follow-up intervals.

Full length free-standing lateral spine radiographs (EOS or 36-inch cassette if unavailable) were collected and assessed at BL and follow-up. Radiographic images were analyzed using SpineView (ENSAM, Laboratory of Biomechanics, Paris, France) software. Spinopelvic radiographic parameters measured were PT, pelvic incidence (PI), SVA, thoracic kyphosis (T4–12), lumbar lordosis (LL, T12–S1), and mismatch between pelvic incidence and lumbar lordosis (PI-LL).

Utility Calculation

Utility data was calculated converting ODI to SF-6D based on previously published conversion methodology.[29–31] As an assessment of outcome, quality adjusted life years (QALYs) were used via QALYs gained:

$$\text{QALYs gained} = (Q^{i} - Q)\frac{1 - \exp^{-rL}}{r}.$$

A measure of HRQOL, QALYs allow for a calculation of quality of life (Q) while accounting for life expectancy (L), Napier's mathematical constant (e), and the discount rate (r). Quality adjusted life years used a 3% discount rate as recommended by the World Health Organization to account for residual decline in life expectancy (US national average: 78.7 yr). The total utility gained was determined

from the improvement in Q (Q^i–Q) and was multiplied by the life expectancy to determine total QALYs gained.

Cost Calculation

The PearlDiver database was utilized to calculate national average Medicare costs using job order cost accounting ("charge analysis"). We used mean costs associated with procedures based on 2018 ASD DRG. DRG costs for the occurrence of complications and comorbidities, major complications and comorbidities, and revisions were used when applicable and accounted for according to CMS.gov manual definitions. Two-year reimbursement consisted of a standardized estimate developed by regression analysis of Medicare reimbursement for all services rendered within a 30-day window, including estimates regarding costs of postoperative complications, outpatient healthcare encounters, revisions, and medical related readmissions. After accounting for complications and comorbidities, major complications and comorbidities, LOS, revisions, and death, cost per quality adjusted life year (QALY) at 2Y follow-up was calculated.

To check the fidelity of the Medicare payment assessments derived from PearlDiver, we also obtained internal cost data collected from sites participating in ISSG based on individual patient DRG codes for the index procedure and any revisions that occurred within 2Y of the initial surgery.

Statistical Analysis

Analysis of covariance was used to establish estimated marginal means for possible outcomes in this investigation [*e.g.*, complications, reoperations, ODI, total cost, utility gained, QALYs, cost efficiency (cost per QALY)] by year of initial surgery adjusting for covariates including age, sex, decompression or osteotomy, surgical approach, invasiveness, and BL deformity (*e.g.*, PT, PI, LL). We used the trendline slope to determine changes between years. Adjusted costs per QALY were then compared over the course of the time period under study. All statistical tests were performed using SPSS software (v21.0, Armonk, NY), and trend-lines were examined using Microsoft Excel. Statistical significance was established, a-priori, for factors with $P < 0.05$.

RESULTS

Patient Demographics

There were 1236 patients included in the study. The mean age of this cohort was 60.8 ± 14.3 years (median: 64.5 yr), with 75.6% of the cohort being female. The mean body mass index of the cohort was 28.0 ± 6.11 (median: 27.1), with the mean Charlson Comorbidity Index total score being 1.81 ± 1.71.

Surgical Characteristics

The mean estimated blood loss for the cohort was 1611.4 ± 1471.0 mL (median: 1200), and the mean operative time was 363.9 ± 134.2 minutes (median: 358). In all, 49.7% of the cohort had a decompression in their initial surgery, and 62.0% had an osteotomy. By approach, 65% of the cohort had a posterior-only approach and 35% had a combined anterior-posterior approach. The median posterior upper instrumented vertebrae were at T10, with the median posterior lower instrumented vertebrae being at the ilium.

Preoperative Radiographic Alignment

The cohort's mean BL radiographic measurements were as follows: sacral slope: 31.3 ± 12.1, PT: 24.5 ± 10.9, PI: 55.8 ± 12.9, PI-LL: 17.2 ± 21.2, SVA C7–S1: 69.1 ± 70.7.

BL and Follow-up Patient-reported Outcomes

At BL, the mean ODI score for the cohort was 44.8 ± 17.2 (median: 46) and SF-36 Physical Component Score (PCS) was 30.9 ± 9.5 (median: 29.7). At 2Y, these mean scores were 27.2 ± 19.8 (median: 26) for ODI and 39.8 ± 11.3 (median: 40.0) for PCS.

Cohort Breakdown by Year of Initial Surgery

The breakdown of the cohort by their year of initial surgery is in Table 1. There were no significant differences in mean BL ODI by year ($P > 0.05$).

Overall Complication Trends

There was an overall decrease in rates of any complication (0.78 *vs.* 0.61), any reoperation (0.25 *vs.* 0.10), and minor complication (0.54 *vs.* 0.37) between 2009 and 2018 (all $P < 0.05$). Minor complications decreased by 2.48% per year ($R^2 = 0.5179$, $P = 0.012$), with a 1.84% yearly decrease in any complication ($R^2 = 0.8322$, $P = 0.003$), 1.33% decrease in any reoperation ($R^2 = 0.2211$, $P = 0.001$), and 0.82% decrease in major complication ($R^2 = 0.1435$, $P = 0.004$).

HRQOL Trends

BL to 2Y difference in SF-36 PCS had the greatest improvement (0.2526 increase per year, $R^2 = 0.3985$) with ODI BL to 2Y difference improved by 0.3687 per year ($R^2 = 0.3683$).

TABLE 1. Number of Patients Who Underwent Surgery for Adult Spinal Deformity by Year

Year of Initial Surgery	No. Patients
2009	117
2010	97
2011	75
2012	45
2013	106
2014	127
2015	115
2016	204
2017	202
2018	148

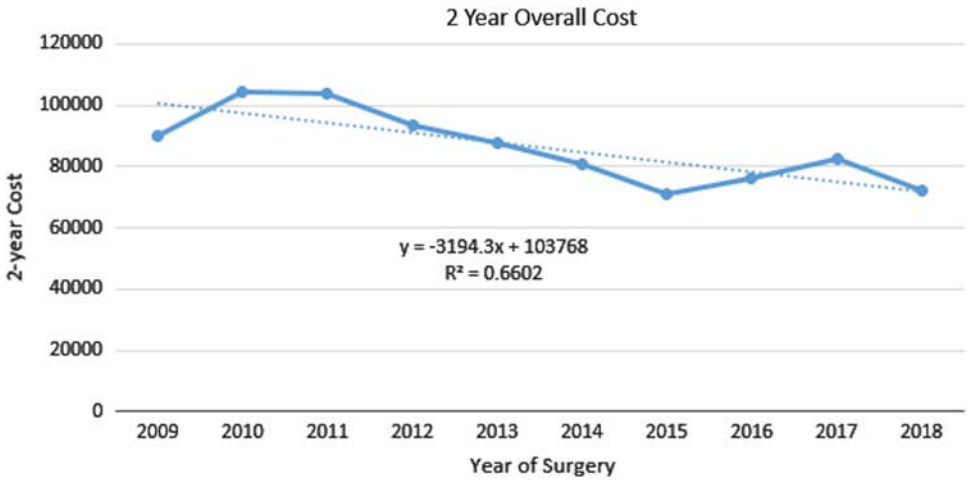

Figure 1. Two-year overall patient costs by year of surgery from 2008 to 2019 in a cohort of 1236 adult spinal deformity patients. full color online

Cost Trends

National average 2Y cost decreased at an annual rate of \$3194 ($R^2 = 0.6602$) (Figure 1), 2Y utility gained increased at an annual rate of 0.0041 ($R^2 = 0.57$) (Figure 2), 2Y QALYs gained increased annually by 0.008 ($R^2 = 0.57$) (Figure 3), and 2Y cost per QALY decreased per year by \$39,953 ($R^2 = 0.6778$) (Figure 4).

Adjusting for inflation since 2009, internal DRG data verified the trend of national average costs, as overall costs (including revisions within 2Y) have decreased at a rate of \$793 each year ($R^2 = 0.0483$). This resulted in a decrease in cost per QALY at 2Y of \$19,903 per year ($R^2 = 0.3181$) (Table 2). Tukey Honestly Significant Difference established homogenous subsets of years based solely on the cost of initial surgery by DRG code. However, these subsets were not listed as chronological years, resulting in no significant differences in initial surgical cost by year.

DISCUSSION

This investigation sought to evaluate changes in the cost profile for ASD surgery over the course of the last decade. These procedures, while shown to be clinically effective in terms of improvement in quality of life and physical function, are also associated with substantive index costs driven by technical aspects of the procedure and resource utilization incurred over the course of recovery.[32,33] Increased efficiency within operative techniques and enhanced recovery pathways have reduced hospital duration and improved rehabilitation trajectories for ASD patients.[34,35] However, costs have increased in other areas of procedural care, including instrumentation and biologics.[36] Furthermore, postsurgical complications remain prevalent, and, in the event of post-surgical morbidity, patient outcomes can be compromised and the need for long-term supportive care may still transpire.[37–39] We sought to determine whether procedural and technical advances were robust enough to offset increased technical costs by improving recovery, limiting residual disability and reducing complications.

Our investigation is advantaged over comparable efforts by the multicenter, multi-surgeon aspects of this study along with the means to account for patient reported outcomes and secular trends in surgical techniques and post-surgical recovery between 2008 and 2019. The robust clinical, procedural, regional, and sociodemographic variation

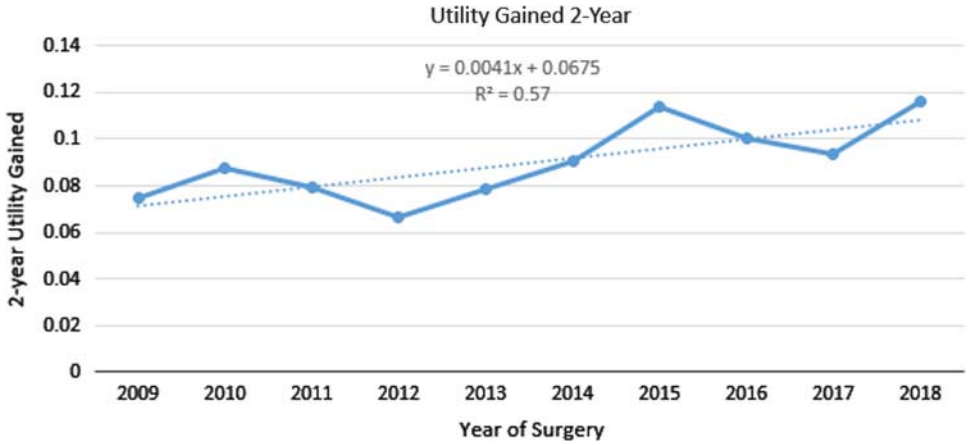

Figure 2. Two-year patient utility gained by year of surgery from 2008 to 2019 in a cohort of 1236 adult spinal deformity patients. full color online

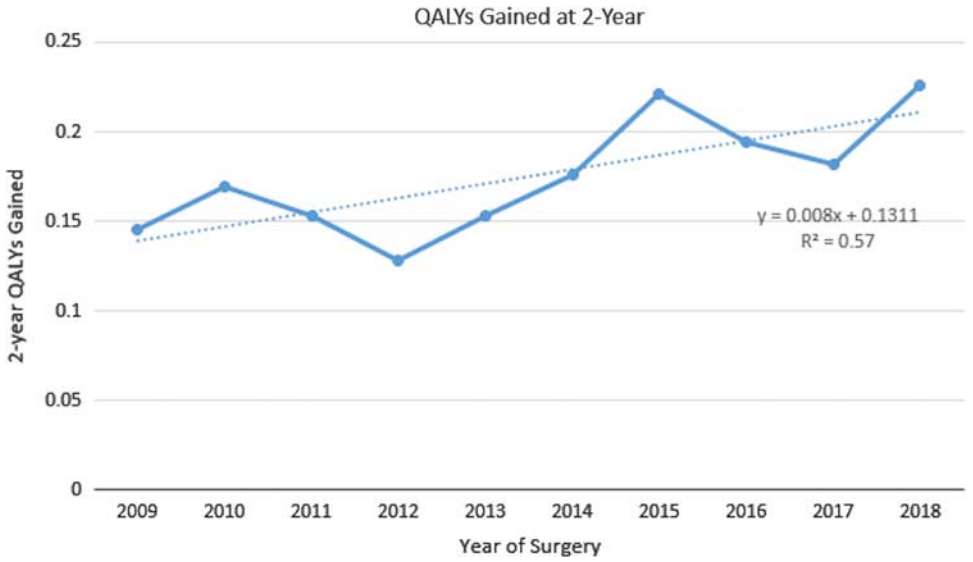

Figure 3. Two-year patient quality adjusted life years (QALYs) gained by year of surgery from 2008 to 2019 in a cohort of 1236 adult spinal deformity patients. full color online

represented in our cohort supports the notion that findings presented here are more likely to be representative of the generalized experience with ASD surgery over the last decade. We found that between 2008 and 2019, the value of ASD surgery improved substantially. This could be attributed to a combination of factors, the most prominent of which appear to be reduced rates of complications and reoperations, as well as improvements in patient reported outcomes. Resulting improvements in costs/QALY as measured by both the national Medicare average and individual patient cost data indicate that by the end of the study period, ASD surgery would be considered a relatively high-value procedure. The final 2Y cost per QALY was calculated slightly more than $300,000 indicating that despite significant improvements over the previous decade, ASD-correction remains a costly intervention. Given the extreme disability and pain of ASD patients, correction remains an indispensable treatment option and we expect cost and patient outcomes to continuously improve.

These results are important for surgeons, administrators, and third-party payers alike. Foremost, our study findings indicate that at the present time, ASD surgery is more cost-effective than at any other time in history and provides good value relative to the initial expenditures when accounting for healthcare utilization at 2Y following the intervention. This is likely to be even more dramatic when one considers that nonoperative treatment for ASD has not been shown to be cost-effective in any way.[40] Second, improvements in

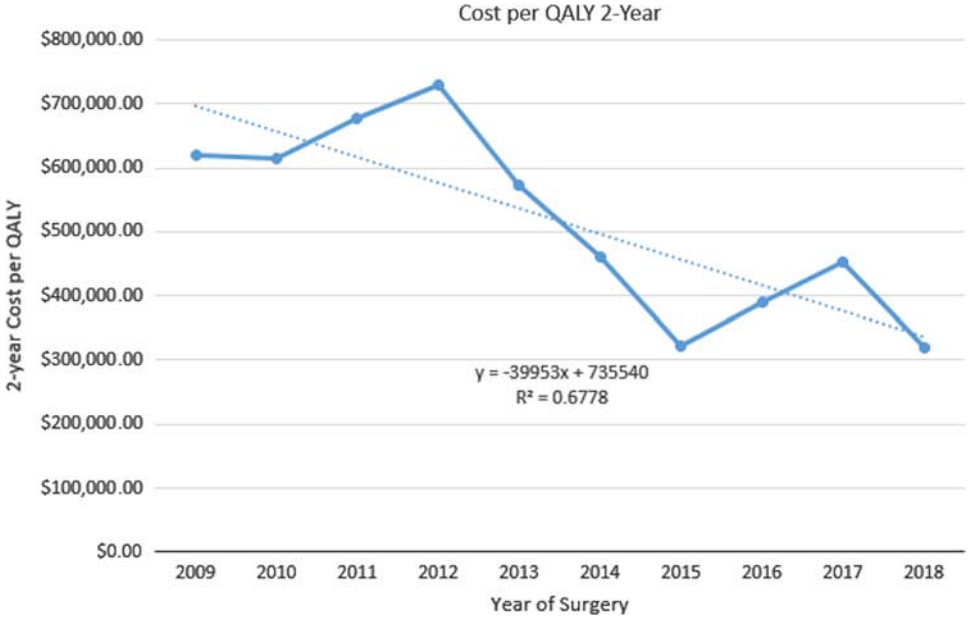

Figure 4. Two-year patient cost per quality adjusted life year (QALY) by year of surgery from 2008 to 2019 in a cohort of 1236 adult spinal deformity patients. full color online

TABLE 2. Change in Outcomes, HRQLs, and Cost at Two-years Following Surgery From 2008 to 2019 in a Cohort of 1236 Adult Spinal Deformity Patients

	Change Per Year	R^2
Outcome		
Minor complications	−2.48%	0.5179
Any complication	−1.84%	0.8322
Any reoperation	−1.33%	0.2211
Major complications	−0.82%	0.1435
HRQOL		
SF-36 PCS 2Y difference	+0.2526	0.3985
ODI 2Y difference	−0.3687	0.3683
National average cost data		
2Y cost	−$3,194	0.6602
2Y utility gained	+0.0041	0.57
2Y QALYs gained	+0.008	0.57
2Y cost per QALY	−$39,953	0.6778
Individual DRG cost data		
2Y cost	−$793	0.0483
2Y cost per QALY	−$19,903	0.3181

DRG indicates diagnosis-related group; HRQOL, health-related quality of life; ODI, Oswestry Disability Index; QALY, quality adjusted life years; SF-36 PCS, SF-36 Physical Component Score; 2Y, two years.

cost-effectiveness appear to be driven primarily by reductions in postsurgical complications, the need for reoperation and improvements in HRQL.[41,42] To the extent that future innovations in operative technique, surgical instrumentation, or recovery pathways can lead to further improvements in these arenas, additional improvements in cost-effectiveness could be appreciated. These areas should serve as foci of additional capital investment and research going forward.

We acknowledge several potential shortcomings associated with this effort. Although we accrued many patients over the course of 10 years from different centers and surgeons, there remains the potential for selection and expertise bias, as well as patient clustering, to confound results. Because this multi-center study follows specific inclusion criteria, we understand there is inherent selection bias as not all ASD patients were consented and enrolled in the study. Given the tedious checks for data at each follow-up timepoint, the number of patients enrolled at each site is limited to properly maintain the quality of information gathered. This can limit the generalizability of this study to single centers nationwide as the breadth of cases may not be fully representative of the ASD population. Further, given the study design is limited to 2Y postoperatively, there is also the prospect of a surveillance bias, and we cannot ensure that all possible outcomes and events during postsurgical care for ASD are adequately represented in this cohort. Although derived from the experience across 13 centers, we cannot be certain that the outcomes and trends presented here are fully translatable and the findings may not be uniformly applicable to all healthcare contexts, especially those that are dramatically different from the contributing members of the ISSG. Finally, improvements in surgical outcomes, changes in complication rates and healthcare costs and not likely to be linear, so the trend lines established here may not hold true in the future. This is an area of future investigation that should be observed closely going forward.

CONCLUSION

In this multicenter investigation, encompassing the experience of over 1200 patients treated for ASD, we found that the rates of complications and reoperations decreased between 2008 and 2019, with concurrent improvements in patient-reported outcomes. The combination of these phenomena resulted in improved cost-effectiveness for ASD procedures. The value of ASD surgery, as measured by costs per QALY, appeared to have improved substantially over the course of the last decade.

➢ Key points

- ❑ In a cohort of 1236 patients there was an overall decrease in rates of any complication, any reoperation, and minor complication between 2009 and 2018.
- ❑ BL to 2Y difference in SF-36 PCS had the greatest improvement (0.2526 increase per year), while ODI improved by 0.3687 per year.
- ❑ National average 2Y cost decreased at an annual rate of $3194, 2Y QALYs gained increased annually by 0.008, and 2Y cost per QALY decreased per year by $39,953.
- ❑ Between 2008 and 2019, the value of ASD surgery has improved substantially over the course of the last decade.

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