

# Prevalence & Economic Burden of Adult Spinal Deformity in a Large United States Commercial Payer Population

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**Purpose:** Evaluate the prevalence and economic burden of adult spinal deformity (ASD) in a large, United States (US) commercial payer population.

**Patients and Methods:** Patients aged 21–64 having an encounter with an ASD diagnosis from the Merative™ Marketscan® Commercial Databases 2016–2022 were included to calculate prevalence. The economic burden cohort included those with an outpatient ASD encounter and no spine surgery within the prior year. Continuous health plan enrollment was required for tracking. Expenditures are tabulated from the payer and societal perspectives (2023 US\$) and rates of utilization and expenditures are reported overall and by service category.

**Results:** Annual ASD prevalence was 0.50%. 169,855 patients (46±13 years, 67.7% female) had an outpatient ASD encounter and were included in the economic burden cohort. Total spine-related payer expenditures averaged \$7,619 (95% CI; \$7,438, \$7,800) per patient within 1 year – a payer burden of \$3.8 million per 100,000 commercially-insured beneficiaries. Spine-related societal expenditures were \$8,759 (\$8,570, \$8,947) per patient within 1 year – a societal burden of \$6.2 billion among the US commercially-insured population. Nonoperative costs comprised 44% of the 1-year payer burden and 48% of the societal burden. While surgical treatment rates were low (3.5% fusions and 2.9% decompressions within 1 year), the associated economic burden was high (55% of payer burden, 51% of societal burden). The 2-year cumulative payer burden totaled \$5.4 million per 100,000 commercially-insured beneficiaries, and the US commercially-insured societal burden totaled \$8.9 billion.

**Conclusion:** The burden of both operative and nonoperative care for ASD is large. Considerable opportunity exists for development of improved nonoperative treatment modalities to increase the value of ASD care by reducing the need for continued nonoperative interventions of limited benefit and reducing the use of costly surgical interventions.

**Keywords:** adult spinal deformity, healthcare resource utilization, costs, payments, payer perspective, societal perspective, economic burden, fusion

## Introduction

Adult spinal deformity (ASD) is a highly and increasingly prevalent condition in the aging United States (US) population and carries a large physiologic burden associated with high costs and healthcare resource utilization.<sup>1–7</sup> In the movement towards value-based care, ASD is a prime target for payers and policy makers seeking to combat rising healthcare expenditures.

The management of ASD (inclusive of scoliosis, kyphosis, lordosis, and flatback) typically starts with nonoperative modalities, although the strength of evidence regarding the effectiveness of these interventions is limited. Much of the evidence regarding nonoperative modalities is derived from observational research. Randomized trials, when present,

have produced disparate results attributable to highly variable patient populations, spinal regions, diagnoses, procedure types, and procedural techniques.<sup>8–10</sup> Reported costs of nonoperative treatment range from \$1,000–\$7,000 annually, while associated improvements in health-related quality of life (HRQOL) such as back pain have so far been limited or nonexistent.<sup>2,6,11</sup> ASD surgery is a high-cost intervention, but provides more substantive improvements in several HRQOL metrics, including the Oswestry Disability Index (ODI), Short Form (SF)-6D, and Scoliosis Research Society (SRS) scores.<sup>7,12,13</sup> When successful, surgical intervention can be cost-effective; however, the relatively high rates of complications and reoperations in ASD surgery can compromise cost-effectiveness.<sup>7,12–15</sup>

Therefore, the goals of this study were to: 1) evaluate the prevalence of ASD in a large, national US commercial payer population, 2) determine the total direct economic burden from the perspectives of the US commercial payer and society, and 3) to better understand the breakdown of expenditures by service category such as inpatient admissions, physician office visits, radiology, injections, physical therapy, and pain medications.

## Materials and Methods

Cohorts were derived from the Meritive™ MarketScan® 2016–2022 Commercial Databases (DOI 10.57761/n5v8-0v21). This study was approved by the Stanford University Institutional Review Board (#40974). MarketScan® is a large, national US data resource containing deidentified payment and encounter data from approximately 350 payers and includes data from employer-based health plans of active employees, early retirees, COBRA continuees, and dependents insured by employer-sponsored health plans.<sup>16</sup>

### Estimation of ASD Prevalence

For calculation of the prevalence of ASD within the MarketScan® commercial population, all adult patients aged 21–64 years presenting with diagnoses of scoliosis, kyphosis, flatback, and/or lordosis were identified via International Classification of Diseases-10th revision (ICD-10-CM) codes ([Supplemental Table 1](#)). This included patients presenting in the inpatient (Inpatient Admissions Table) and outpatient setting (Outpatient Services Table with accompanying records from the Facility Header file). Note that the MarketScan® Outpatient Services Table contains all outpatient encounters, including those occurring at physician offices, ambulatory surgery centers, and hospital and non-hospital associated outpatient centers. The annual prevalence of ASD within the MarketScan® Commercial population was calculated as: the number of patients that had 1) an ASD diagnosis on at least one encounter during the plan year and 2) full health plan enrollment for that plan year, divided by the total number of fully-enrolled patients in MarketScan® for that plan year. The overall prevalence of ASD in the MarketScan® population was calculated by averaging the prevalence across 2016–2022. ASD can be coded either with location-specific codes or with non-location-specific codes, with these being used interchangeably. ASD is more prevalent in the thoracic, lumbar, and sacral spine than in the cervical spine; and likely most of the patients having non-specific codes are thoraco-lumbar-sacral ASD patients. We therefore calculated the annual prevalence in 2 ways: a primary analysis including both the location-specific and non-specific codes, and a sensitivity analysis using only the location-specific codes. These two prevalence estimates serve as upper and lower bounds on the true prevalence within this population.

### Economic Burden Cohort Definition

For the calculation of healthcare resource utilization and payments within the nonoperative ASD MarketScan® cohort, all adult patients aged 21–64 years having one or more outpatient encounters with an associated diagnosis of ASD were identified. The index encounter was defined as the 1st encounter for each patient where an ASD diagnosis was present. Patients were required to have continuous medical and pharmacy enrollment for at least 1 year before and after their index ASD encounter for longitudinal tracking. Patients with diagnoses of pregnancy, neoplasms, intraspinal abscesses, osteomyelitis, discitis, fracture, dislocation, vehicular accidents, and inflammatory spondyloarthropathies were excluded, as documented previously ([Supplemental Table 2](#)).<sup>17</sup> Patients having thoracic, lumbar, or sacral spine surgery within the year prior were excluded ([Supplemental Tables 3](#) and [4](#)). Patients on capitated or partially-capitated healthcare plans

were excluded, as these plans do not report complete, validated financial information. The small subset of patients on plans not reporting outpatient pharmacy data were also excluded.

## Calculation of 1-Year Total Payer and Societal Expenditures per Patient

From the index ASD diagnosis, patients were followed for 1 year to track the total spine-related net and gross payments. All payment data were converted to 2023 United States Dollars (US\$) using the medical care component of the consumer price index.<sup>18</sup> Spine-related payments were identified as payments for any healthcare encounter with a spine-related diagnosis ([Supplemental Table 5](#)). The total net payments, representing commercial payer expenditures, were calculated as the sum of all payments made by the payer. The total gross payments, representing the direct economic burden to society, were calculated as the sum of all payments for inpatient admissions, outpatient encounters, and outpatient pharmacy services made by both the payer and the patient (including deductibles, co-pays, and coordination of benefits fees). Indirect costs, such as lost productivity (work presenteeism/absenteeism) and caregiver burden, were not included in the calculation of societal burden. All services for which the total gross payments were negative or 0 were excluded from the payment calculations.

While payment data are highly skewed due to a small proportion of “super-utilizers” accounting for a large proportion of payments,<sup>19</sup> we have chosen to present our primary results as means with 95% confidence intervals (CI) expenditures, providing the payer-level expectation regarding the typical amount incurred on a per patient basis. In addition to the total spine-related net and gross payments per patient, spine-related payments were also summed for the following categories:

- Inpatient admissions
- Outpatient services
- Fusion (± decompression) surgery (primary or revision), inclusive of all costs incurred during the surgical admission (or day of outpatient surgery), eg costs for the surgery (including surgeon professional fees, anesthesia, and instrumentation), cost of the hospitalization, etc.
- Other thoraco-lumbo-sacral surgery (primary or revision), inclusive of all costs incurred during the surgical admission (or day of outpatient surgery)
- Inpatient admissions other than for spine surgery
- 18 relevant resource utilization categories (based on Medistat categories contained within Marketscan<sup>®</sup>): physical therapy (PT) (mental health and substance abuse PT categories excluded), injections, chiropractic care, radiology (X-ray, MRI, and CT), office visits, laboratory services, diagnostic services, surgical supplies and devices, nonsurgical supplies and devices, durable medical equipment, on-site pharmacy (administered at inpatient and/or outpatient facilities), home health services, skilled nursing facilities (SNF), inpatient rehabilitation facilities (IRF), emergency room services (ER), and urgent care
- Spine-related outpatient pharmacy: outpatient pharmacy data within Marketscan<sup>®</sup> does not include diagnoses, so filled prescriptions were defined as potentially spine-related if they fell into 5 drug categories commonly used for spine-related pain relief (nonsteroidal anti-inflammatory drugs [NSAIDs], opioids, analgesics/antipyretics, muscle relaxants, anticonvulsants, antidepressants, and anxiolytics).<sup>20</sup>

The number and percentage of patients using each of the above categories of services was also calculated.

## Calculation of 1-Year Commercial Payer and Societal Economic Burden

The 1-year total economic burden of ASD per 100,000 commercially-insured beneficiaries was calculated as:

$$\text{total net payments per ASD patient} \times \text{overall ASD prevalence} \times 100,000$$

The economic burden of ASD per 100,000 commercially-insured beneficiaries for each service category was calculated as the above for each category multiplied by the proportion of ASD patients using that category of service.

The 1-year total societal burden of direct healthcare costs for commercially-insured ASD patients in the United States was calculated as:

$$\text{total gross payments per ASD patient} \times \text{overall ASD prevalence} \times \text{US commercial population aged 21 to 64}$$

The size of the US commercial payer population aged 21–64 years was determined from the US census.<sup>21</sup> The societal burden for each service category was calculated as the above for each category multiplied by the proportion of ASD patients using that category of service.

## Sub-Analysis of 2-Year Payer and Societal Economic Burden

A sub-analysis was performed in the subset of patients with continuous medical and pharmacy health plan enrollment through 2 years following their index ASD diagnosis. All calculations paralleled those for the calculation of 1-year payments as outlined above.

## Statistical Analyses

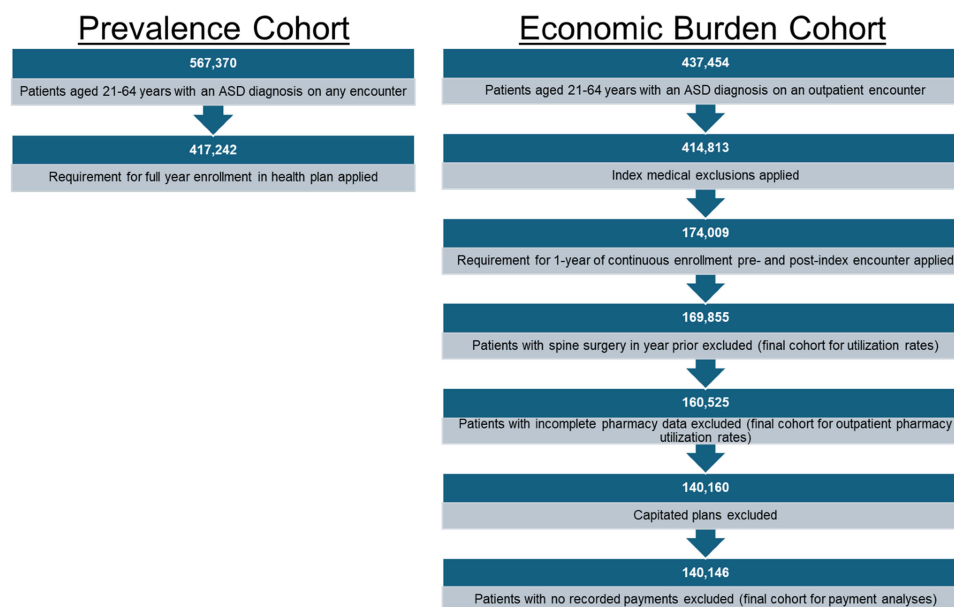
Differences in expenditures for patients with versus without surgery were assessed with Mann Whitney *U*-tests. All descriptive statistics and analysis were computed with SAS version 9.4 (Cary, NC, US).

## Results

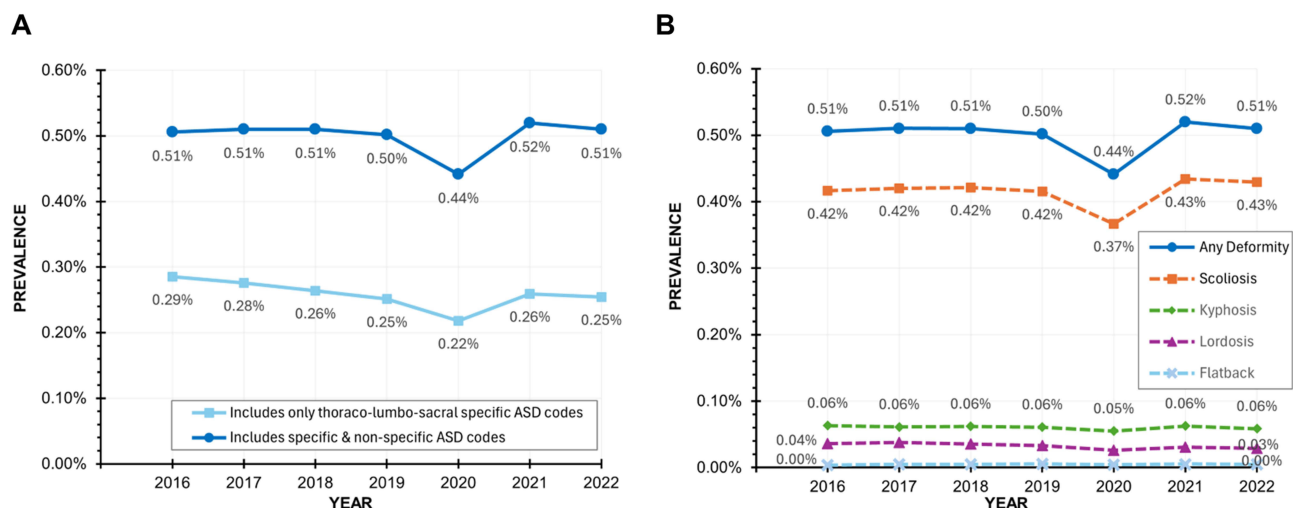
From 2016–2022, 567,370 patients with a diagnosis of ASD were identified in the MarketScan<sup>®</sup> Commercial population (Figure 1). The average annual prevalence over this time frame was 0.50% with both location-specific and non-specific codes included (Figure 2). A sensitivity analysis only including the location-specific codes resulted in a lower bound of 0.26% prevalence. The prevalence by year was relatively constant, with the exception of a slight dip in 2020 aligning with fewer patients seeking healthcare services during the coronavirus pandemic.

## Economic Burden Cohort and Medical Resource Utilization

A total of 169,855 unique patients presenting in an outpatient encounter with a diagnosis of ASD and meeting the inclusion and exclusion criteria were identified (Figure 1). Of these, 160,525 had outpatient pharmacy coverage for the year following the index encounter for tracking of outpatient pharmacy utilization, and 140,146 were enrolled in health plans providing accurate financial information and had recorded healthcare payments. The mean age of the cohort was 46 ±13 years, and 67.7% were female. Scoliosis was the most common diagnosis (81.9%), followed by kyphosis (11.4%), lordosis (7.1%), and flatback (0.8%). Commercial health plan types included preferred provider organizations



**Figure 1** Cohort flowcharts for the prevalence and economic burden cohorts.



**Figure 2 (A)** Annual prevalence of ASD among the fully-enrolled MarketScan® population when calculated from both location-specific and non-specific codes (primary analysis—upper bound) and from only location-specific codes (sensitivity analysis—lower bound). As thoraco-lumbo-sacral ASD is much more common than cervical deformity, the true prevalence is likely closest to the primary analysis. **(B)** Annual prevalence of ASD by deformity type.

(54.0%), consumer-driven (12.6%), health maintenance organizations (10.9%), high deductible (9.4%), point of service (6.5%), comprehensive (3.5%), exclusive provider organizations (0.9%), and point of service with capitation (0.8%).

Within 1 year, 3.5% of the cohort had fusion surgery (± decompression) and 2.9% had decompressive or other thoraco-lumbo-sacral surgery not involving fusion (Table 1). In the subset of patients with 2 years of continuous health plan enrollment following their index encounter (n = 101,077), 4.5% had fusion surgery and 4.0% had decompressive or other thoraco-lumbo-sacral surgery. Of those having fusion within the 1st year, 8.5% to 15.3% had another spine surgery within the 1st year, and 16.9% to 22.2% had another spine surgery within 2 years. The lower bounds on these ranges

**Table 1** % of ASD Patients Using Each Category of Service and the Number of Encounters of Each Service Type per User (Presented as Medians with 25th and 75th Percentiles)

HCRU Category	Within 1 Year				Cumulative Within 2 Years			
	% of ASD Patients Using	# Encounters/User			% of ASD Patients Using	# Encounters/User		
		Median	25th Percentile	75th Percentile		Median	25th Percentile	75th Percentile
Total Inpatient Admissions	4.2	1	1	1	5.6	1	1	1
Total Outpatient Services	100.0	5	2	13	100.0	8	2	20
Fusion Surgery (± Decompression)	3.5	1	1	1	4.5	1	1	1
Decompression Surgery	2.9	1	1	1	4.0	1	1	1
Other Admissions (Excluding Spine Surgery)	1.3	1	1	1	2.0	1	1	1
Office Visits	78.4	2	1	4	83.0	3	1	6
Urgent Care	1.7	1	1	1	2.5	1	1	1

(Continued)

**Table 1** (Continued).

HCRU Category	Within 1 Year				Cumulative Within 2 Years			
	% of ASD Patients Using	# Encounters/User			% of ASD Patients Using	# Encounters/User		
		Median	25th Percentile	75th Percentile		Median	25th Percentile	75th Percentile
ER	7.8	1	1	1	10.2	1	1	1
PT	47.7	7	3	15	53.9	9	3	19
Injections	16.6	2	1	3	20.4	2	1	3
Chiropractic	28.0	8	3	16	32.5	10	4	22
Radiology	72.5	1	1	2	75.7	1	1	3
CT	5.9	1	1	1	7.5	1	1	1
MRI	26.3	1	1	1	30.7	1	1	2
Xray	63.4	1	1	1	67.3	1	1	2
Labs	19.6	1	1	2	24.8	1	1	2
Diagnostic Services	10.4	1	1	2	13.2	1	1	2
Durable Medical Equipment	2.5	1	1	1	3.3	1	1	1
Surgical Supplies & Devices <sup>^</sup>	2.8	1	1	1	3.6	1	1	1
Other Supplies & Devices	10.2	1	1	2	12.7	1	1	2
SNF	0.2	2	1	5	0.2	3	1	5
IRF	1.6	5	2	11	1.9	6	2	11
Home Health	4.2	1	1	3	5.6	1	1	4
On-Site Pharmacy	6.5	1	1	1	8.3	1	1	2
<b>Total Outpatient Pharmacy</b>	<b>71.3</b>	<b>10</b>	<b>4</b>	<b>25</b>	<b>79.3</b>	<b>16</b>	<b>5</b>	<b>45</b>
NSAIDs	37.2	3	2	6	48.1	4	2	9
Analgesics/Antipyretics	13.2	2	2	6	18.1	2	2	7
Opioids	30.8	2	2	8	40.9	4	2	9
Muscle Relaxants	31.4	2	2	6	38.7	4	2	10
Anticonvulsants	30.8	8	4	15	36.0	15	6	28
Antidepressants	24.5	4	2	12	30.9	6	2	20
Anxiolytics	18.1	6	2	12	22.0	8	2	19

**Note:** <sup>^</sup>surgical supply and device costs were not explicitly listed as a separate line item for all surgeries.

**Abbreviations:** %, percent; #, number; HCRU, healthcare resource utilization; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

exclude surgeries within 1 week of each other to conservatively exclude the second stages of staged surgeries (planned and unplanned), while the upper bound has no such constraint. Similarly, of those having decompressive or other non-fusion surgery within the 1st year, 8.6% to 14.0% had another spine surgery within the 1st year, and 17.2% to 20.6% had another spine surgery within 2 years. Patients had a median of 7 [interquartile range (IQR): 3, 15] PT sessions, 2 [1,3] injections, and 8 [3, 16] chiropractic sessions within 1 year. Of patients with outpatient pharmacy coverage, nearly one-third (30.8%) of patients used opioids within one year after the index encounter for ASD and 40.9% used opioids within 2 years.

## Commercial Payer Economic Burden

The total spine-related payer expenditures averaged \$7,619 (95% CI; \$7,438, \$7,800) per patient within the 1st year following the index outpatient encounter for ASD (Table 2). In the subset of patients with 2-year follow up, total spine-related payer expenditures across 2 years following the index encounter averaged \$10,752 (\$10,475, \$11,029). The total expenditures for nonoperative spine care averaged \$3,338 (\$3,259, \$3,418) in the 1st year and \$5,175 (\$5,032, \$5,319) across 2 years. In those having surgery, payer expenditures per patient averaged \$100,494 (\$97,187, \$103,800) for fusion surgery and \$23,093 (\$22,238, \$23,949) for other decompressive surgery within the 1st year. Interestingly, patients who had their 1st spine surgery in the 2nd year incurred 2.5-fold higher payer expenditures for nonoperative care within the 1st year relative to those that did not go on to have surgery [\$7,177 (\$6,416, \$7,937) vs \$2,849 (\$2,777, \$2,921);  $p < 0.001$ ]. For patients who had spine surgery within the 1st year but no additional surgery in the 2nd year, payer expenditures in the 2nd year for nonoperative care remained elevated versus those that never had surgery [\$3,947 (\$3,590, \$4,305) vs \$1,743 (\$1,675, \$1,810);  $p < 0.001$ ].

Payer expenditures per 100,000 commercially-insured beneficiaries totaled over \$3.8 million for ASD patients in the 1st year following the index outpatient encounter (Table 3). Payer expenditures for nonoperative spine care totaled over \$1.7 million per 100,000 beneficiaries, 43.8% of total expenditures. While only 3.5% of patients underwent spinal fusion, fusion surgery

**Table 2** Spine-Related Payer Expenditures (2023 US\$) Per Patient Overall and Per User for Each Service Category

HCRU Category	1-Year Payer Expenditures Per Patient (2023 US\$)			Cumulative 2-Year Payer Expenditures Per Patient (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
<b>Total Spine-Related</b>	\$ 7,619	\$ 7,438	\$ 7,800	\$ 10,752	\$ 10,475	\$ 11,029
<b>Nonoperative Spine-Related</b>	\$ 3,338	\$ 3,259	\$ 3,418	\$ 5,175	\$ 5,032	\$ 5,319
<b>Expenditures per User:</b>						
<b>Total Inpatient Admissions</b>	\$ 94,699	\$ 91,763	\$ 97,635	\$ 91,475	\$ 88,313	\$ 94,637
<b>Total Outpatient Services</b>	\$ 3,003	\$ 2,948	\$ 3,058	\$ 4,283	\$ 4,178	\$ 4,389
Fusion Surgery (± Decompression)	\$ 100,494	\$ 97,187	\$ 103,800	\$ 100,487	\$ 96,805	\$ 104,169
Decompression Surgery	\$ 23,093	\$ 22,238	\$ 23,949	\$ 26,161	\$ 25,101	\$ 27,221
Other Admissions (Excluding Spine Surgery)	\$ 30,537	\$ 28,356	\$ 32,718	\$ 31,577	\$ 29,137	\$ 34,018
Office Visits	\$ 298	\$ 295	\$ 300	\$ 418	\$ 413	\$ 423
Urgent Care	\$ 298	\$ 186	\$ 409	\$ 219	\$ 182	\$ 256
ER	\$ 1,943	\$ 1,868	\$ 2,019	\$ 2,159	\$ 2,058	\$ 2,260
PT	\$ 940	\$ 919	\$ 961	\$ 1,233	\$ 1,202	\$ 1,264
Injections	\$ 601	\$ 580	\$ 623	\$ 718	\$ 688	\$ 749
Chiropractic	\$ 261	\$ 257	\$ 266	\$ 369	\$ 361	\$ 377

(Continued)

**Table 2** (Continued).

HCRU Category	1-Year Payer Expenditures Per Patient (2023 US\$)			Cumulative 2-Year Payer Expenditures Per Patient (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
Radiology	\$ 677	\$ 666	\$ 688	\$ 860	\$ 841	\$ 879
CT	\$ 839	\$ 796	\$ 882	\$ 921	\$ 849	\$ 992
MRI	\$ 1,069	\$ 1,053	\$ 1,084	\$ 1,200	\$ 1,179	\$ 1,221
Xray	\$ 212	\$ 206	\$ 217	\$ 260	\$ 251	\$ 269
Labs	\$ 546	\$ 488	\$ 605	\$ 599	\$ 550	\$ 649
Diagnostic Services	\$ 2,480	\$ 2,247	\$ 2,712	\$ 2,624	\$ 2,350	\$ 2,897
Durable Medical Equipment	\$ 1,054	\$ 978	\$ 1,129	\$ 1,211	\$ 1,105	\$ 1,318
Surgical Supplies & Devices <sup>^</sup>	\$ 73,629	\$ 70,007	\$ 77,251	\$ 77,785	\$ 73,338	\$ 82,232
Other Supplies & Devices	\$ 984	\$ 843	\$ 1,125	\$ 1,025	\$ 888	\$ 1,163
SNF	\$ 4,798	\$ 3,241	\$ 6,356	\$ 5,131	\$ 3,267	\$ 6,995
IRF	\$ 1,511	\$ 1,278	\$ 1,743	\$ 1,824	\$ 1,457	\$ 2,190
Home Health	\$ 1,570	\$ 1,370	\$ 1,770	\$ 1,953	\$ 1,467	\$ 2,440
On-Site Pharmacy	\$ 5,457	\$ 4,713	\$ 6,202	\$ 5,606	\$ 4,693	\$ 6,518
<b>Total Outpatient Pharmacy</b>	<b>\$ 944</b>	<b>\$ 884</b>	<b>\$ 1,003</b>	<b>\$ 1,752</b>	<b>\$ 1,668</b>	<b>\$ 1,836</b>
NSAIDs	\$ 351	\$ 329	\$ 373	\$ 550	\$ 511	\$ 589
Analgesics/Antipyretics	\$ 73	\$ 65	\$ 82	\$ 106	\$ 93	\$ 120
Opioids	\$ 658	\$ 536	\$ 780	\$ 941	\$ 839	\$ 1,044
Muscle Relaxants	\$ 210	\$ 198	\$ 221	\$ 362	\$ 340	\$ 384
Anticonvulsants	\$ 570	\$ 507	\$ 633	\$ 1,105	\$ 939	\$ 1,271
Antidepressants	\$ 417	\$ 398	\$ 435	\$ 744	\$ 706	\$ 781
Anxiolytics	\$ 125	\$ 105	\$ 146	\$ 227	\$ 189	\$ 265

**Note:** <sup>^</sup>surgical supply and device costs were not explicitly listed as a separate line item for all surgeries. Surgical and inpatient admission costs include all costs for services rendered during the surgical admission or day of outpatient surgery.

**Abbreviations:** HCRU, healthcare resource utilization; CI, confidence interval; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

accumulated a \$1.8 million in payer expenditures per 100,000 commercially-insured beneficiaries, 46.3% of total payer expenditures (Figure 3). For some surgeries, the surgical supply and device costs were included within the surgical payment and not explicitly as a separate line-item. In cases where these costs were explicitly enumerated, over half of the surgical costs were attributable to surgical supply and device costs. Other categories of service with high payer burdens per 100,000 beneficiaries included pharmacy (\$336,254 outpatient, \$177,997 inpatient), decompression surgery (\$333,372), radiology (\$245,278), PT (\$224,007), and hospital admissions other than those for spine surgery (\$198,492). Over 2 years total spine-related expenditures per 100,000 commercially-insured beneficiaries increased to nearly \$5.4 million, with \$2.6 million (48.1%) going to nonoperative care.

## Societal Economic Burden

The total spine-related societal burden per ASD patient averaged \$8,759 (\$8,570, \$8,947) per patient within the 1st year following the index outpatient encounter for ASD (Table 4). In the 2-year subset, the total spine-related societal burden across the 2 years following the index encounter averaged \$12,460 (\$12,168, \$12,752) per patient. The total societal

**Table 3** Spine-Related Payer Expenditures (2023 US \$) Per 100,000 Commercially-Insured Beneficiaries Overall and By Service Category

Category of Service	1-Year Payer Expenditures Per 100,000 (2023 US\$)			Cumulative 2-Year Payer Expenditures Per 100,000 (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
<b>TOTAL SPINE-RELATED</b>	\$ 3,809,525	\$ 3,719,020	\$ 3,900,030	\$ 5,376,115	\$ 5,237,490	\$ 5,514,745
<b>Nonoperative Spine-Related</b>	\$ 1,669,175	\$ 1,629,285	\$ 1,709,070	\$ 2,587,745	\$ 2,516,095	\$ 2,659,395
<b>By Service Category:</b>						
<b>Total Inpatient Admissions</b>	\$ 1,992,944	\$ 1,931,149	\$ 2,054,740	\$ 2,577,953	\$ 2,488,828	\$ 2,667,077
<b>Total Outpatient Services</b>	\$ 1,501,440	\$ 1,474,040	\$ 1,528,840	\$ 2,141,625	\$ 2,088,855	\$ 2,194,395
Fusion Surgery (± Decompression)	\$ 1,766,945	\$ 1,708,808	\$ 1,825,081	\$ 2,264,692	\$ 2,181,713	\$ 2,347,672
Decompression Surgery	\$ 333,372	\$ 321,024	\$ 345,720	\$ 518,681	\$ 497,659	\$ 539,703
Other Admissions (Excluding Spine Surgery)	\$ 198,492	\$ 184,316	\$ 212,667	\$ 315,774	\$ 291,366	\$ 340,182
Office Visits	\$ 116,678	\$ 115,681	\$ 117,675	\$ 173,457	\$ 171,374	\$ 175,540
Urgent Care	\$ 2,556	\$ 1,595	\$ 3,517	\$ 2,713	\$ 2,255	\$ 3,171
ER	\$ 75,669	\$ 72,727	\$ 78,612	\$ 109,671	\$ 104,542	\$ 114,800
PT	\$ 224,007	\$ 218,971	\$ 229,043	\$ 332,181	\$ 323,732	\$ 340,630
Injections	\$ 49,836	\$ 48,054	\$ 51,619	\$ 73,423	\$ 70,260	\$ 76,586
Chiropractic	\$ 36,623	\$ 35,988	\$ 37,259	\$ 59,895	\$ 58,622	\$ 61,167
Radiology	\$ 245,278	\$ 241,328	\$ 249,227	\$ 325,671	\$ 318,459	\$ 332,883
CT	\$ 24,666	\$ 23,403	\$ 25,929	\$ 34,310	\$ 31,632	\$ 36,987
MRI	\$ 140,278	\$ 138,188	\$ 142,368	\$ 184,190	\$ 180,950	\$ 187,428
Xray	\$ 67,018	\$ 65,336	\$ 68,701	\$ 87,552	\$ 84,485	\$ 90,619
Labs	\$ 53,428	\$ 47,696	\$ 59,160	\$ 74,288	\$ 68,142	\$ 80,434
Diagnostic Services	\$ 128,882	\$ 116,787	\$ 140,977	\$ 173,324	\$ 155,230	\$ 191,419
Durable Medical Equipment	\$ 13,277	\$ 12,325	\$ 14,229	\$ 20,106	\$ 18,343	\$ 21,868
Surgical Supplies & Devices <sup>^</sup>	\$ 1,039,827	\$ 988,673	\$ 1,090,981	\$ 1,382,604	\$ 1,303,552	\$ 1,461,656
Other Supplies & Devices	\$ 50,022	\$ 42,838	\$ 57,206	\$ 65,291	\$ 56,525	\$ 74,058
SNF	\$ 3,939	\$ 2,660	\$ 5,217	\$ 5,294	\$ 3,371	\$ 7,217
IRF	\$ 12,101	\$ 10,238	\$ 13,963	\$ 17,207	\$ 13,751	\$ 20,664
Home Health	\$ 33,141	\$ 28,923	\$ 37,360	\$ 54,388	\$ 40,855	\$ 67,920
On-Site Pharmacy	\$ 177,997	\$ 153,707	\$ 202,287	\$ 232,204	\$ 194,404	\$ 270,003
<b>Total Outpatient Pharmacy</b>	\$ 336,254	\$ 315,118	\$ 357,390	\$ 694,865	\$ 661,454	\$ 728,275
NSAIDs	\$ 65,192	\$ 61,065	\$ 69,319	\$ 132,165	\$ 122,727	\$ 141,602
Analgesics/Antipyretics	\$ 4,815	\$ 4,260	\$ 5,371	\$ 9,635	\$ 8,386	\$ 10,883
Opioids	\$ 101,437	\$ 82,633	\$ 120,241	\$ 192,529	\$ 171,577	\$ 213,480

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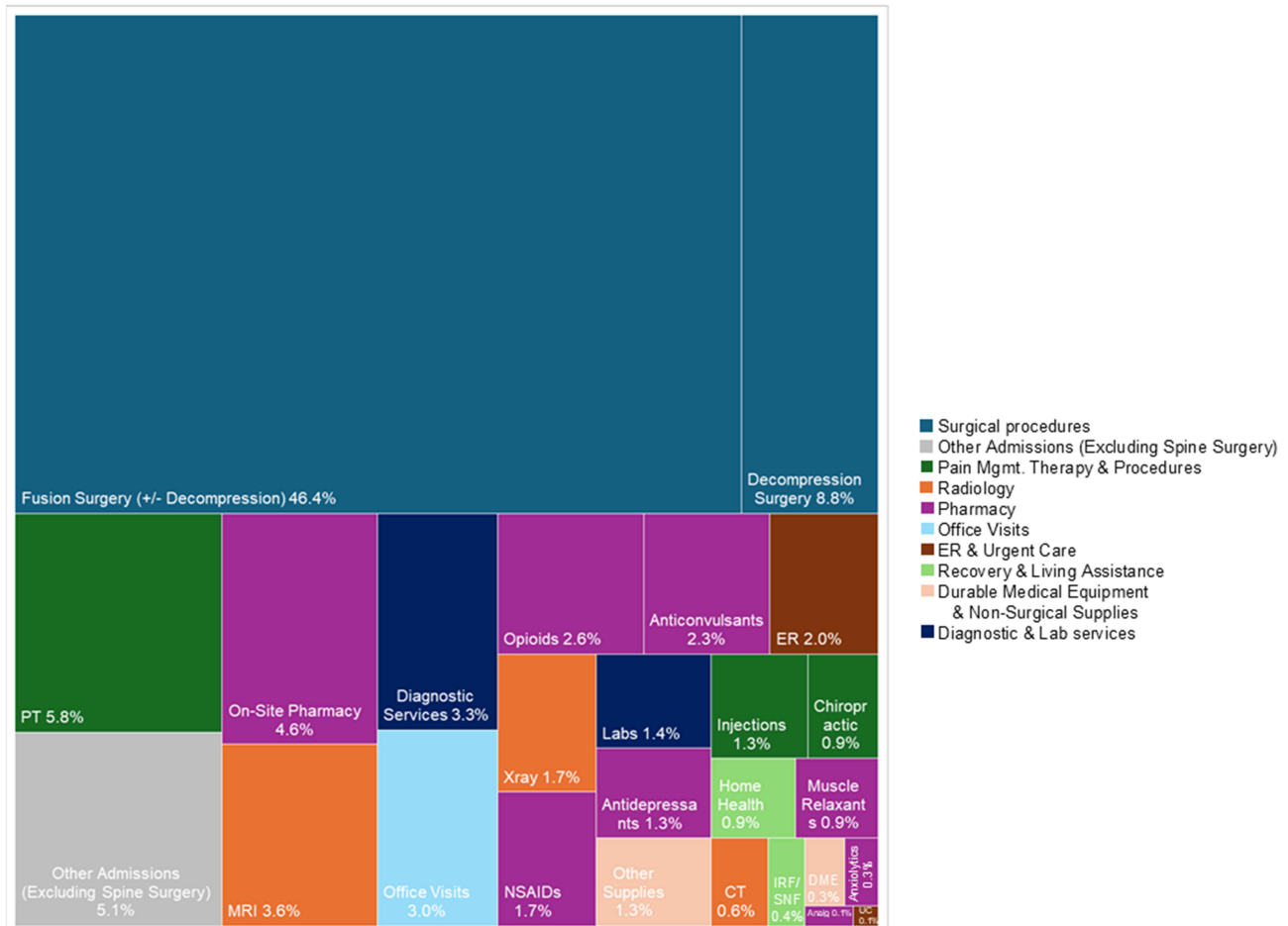
**Table 3** (Continued).

Category of Service	1-Year Payer Expenditures Per 100,000 (2023 US\$)			Cumulative 2-Year Payer Expenditures Per 100,000 (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
Muscle Relaxants	\$ 32,922	\$ 31,140	\$ 34,704	\$ 69,976	\$ 65,775	\$ 74,177
Anticonvulsants	\$ 87,875	\$ 78,187	\$ 97,563	\$ 198,859	\$ 169,042	\$ 228,678
Antidepressants	\$ 51,110	\$ 48,843	\$ 53,377	\$ 114,711	\$ 108,903	\$ 120,520
Anxiolytics	\$ 11,326	\$ 9,484	\$ 13,169	\$ 25,013	\$ 20,774	\$ 29,252

**Note:** ^surgical supply and device costs were not explicitly listed as a separate line item for all surgeries. Surgical and inpatient admission costs include all costs for services rendered during the surgical admission or day of outpatient surgery.

**Abbreviations:** HCRU, healthcare resource utilization; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

expenditures for nonoperative spine care averaged \$4,239 (\$4,115, \$4,323) in the 1st year and \$6,563 (\$6,410, 6,716) across 2 years. In those having surgery, the per patient surgical expenditures in the first year averaged \$105,224 (\$101,808, \$108,640) for fusion surgery and \$25,391 (\$24,464, \$26,318) for other decompressive surgery. Patients who had their 1st spine surgery in the 2nd year incurred nearly 2.5-fold higher societal expenditures for nonoperative



**Figure 3** Visual representation showing the percent of 1-year spine-related payer expenditures per 100,000 commercially-insured beneficiaries incurred for each category of service. Boxes are scaled to the percentage of total expenditures. Surgical cost categories include costs of surgical supplies and devices. Note that the surgical costs include all costs from the procedure and any associated admission, so there is some minor overlap with other categories.

**Abbreviations:** PT, physical therapy; MRI, magnetic resonance imaging; NSAIDs, nonsteroidal anti-inflammatory inhibitors; On-site RX, onsite pharmacy; IRF/SNF, inpatient rehabilitation facility/skilled nursing facility; Analg, analgesics/antipyretics; UC, urgent care.

**Table 4** Total Spine-Related Expenditures (2023 US \$) per Patient Overall and per User for Each Service Category from the Societal Perspective. This Includes All Payments Made by the Payer and Patient. Not Included are Indirect Costs and Any Payments Not Processed Through the Payer Such as Those for Over-the-Counter Medication

HCRU Category	1-Year Societal Expenditures Per Patient (2023 US\$)			Cumulative 2-Year Societal Expenditures Per Patient (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
<b>Total Spine-Related Per Person</b>	\$ 8,759	\$ 8,570	\$ 8,947	\$ 12,460	\$ 12,168	\$ 12,752
<b>Nonoperative Spine-Related Per Person</b>	\$ 4,239	\$ 4,155	\$ 4,323	\$ 6,563	\$ 6,410	\$ 6,716
<b>Expenditures per User:</b>						
<b>Total Inpatient Admissions</b>	\$ 99,191	\$ 96,167	\$ 102,215	\$ 95,965	\$ 92,687	\$ 99,244
<b>Total Outpatient Services</b>	\$ 3,809	\$ 3,750	\$ 3,869	\$ 5,436	\$ 5,323	\$ 5,550
Fusion Surgery (± Decompression)	\$ 105,224	\$ 101,808	\$ 108,640	\$ 105,300	\$ 101,465	\$ 109,134
Decompression Surgery	\$ 25,391	\$ 24,464	\$ 26,318	\$ 28,704	\$ 27,545	\$ 29,864
Other Admissions (Excluding Spine Surgery)	\$ 32,477	\$ 30,295	\$ 34,659	\$ 32,069	\$ 29,198	\$ 34,940
Office Visits	\$ 445	\$ 442	\$ 448	\$ 624	\$ 618	\$ 630
Urgent Care	\$ 409	\$ 284	\$ 535	\$ 307	\$ 268	\$ 346
ER	\$ 2,514	\$ 2,431	\$ 2,598	\$ 2,758	\$ 2,647	\$ 2,869
PT	\$ 1,333	\$ 1,309	\$ 1,356	\$ 1,728	\$ 1,692	\$ 1,764
Injections	\$ 771	\$ 747	\$ 796	\$ 921	\$ 886	\$ 957
Chiropractic	\$ 521	\$ 514	\$ 527	\$ 723	\$ 712	\$ 735
Radiology	\$ 924	\$ 912	\$ 937	\$ 1,158	\$ 1,138	\$ 1,179
CT	\$ 1,137	\$ 1,088	\$ 1,186	\$ 1,225	\$ 1,170	\$ 1,281
MRI	\$ 1,413	\$ 1,396	\$ 1,431	\$ 1,578	\$ 1,555	\$ 1,601
Xray	\$ 314	\$ 308	\$ 320	\$ 377	\$ 367	\$ 387
Labs	\$ 670	\$ 625	\$ 715	\$ 754	\$ 705	\$ 803
Diagnostic Services	\$ 2,794	\$ 2,598	\$ 2,989	\$ 2,949	\$ 2,723	\$ 3,174
Durable Medical Equipment	\$ 1,231	\$ 1,150	\$ 1,313	\$ 1,399	\$ 1,284	\$ 1,513
Surgical Supplies & Devices <sup>^</sup>	\$ 88,128	\$ 84,219	\$ 92,037	\$ 92,993	\$ 88,266	\$ 97,720
Other Supplies & Devices	\$ 1,305	\$ 1,140	\$ 1,471	\$ 1,392	\$ 1,217	\$ 1,566
SNF	\$ 5,244	\$ 3,648	\$ 6,839	\$ 5,850	\$ 3,888	\$ 7,811
IRF	\$ 2,073	\$ 1,647	\$ 2,498	\$ 2,257	\$ 1,868	\$ 2,645
Home Health	\$ 1,886	\$ 1,680	\$ 2,092	\$ 2,326	\$ 1,826	\$ 2,827
On-Site Pharmacy	\$ 3,845	\$ 3,534	\$ 4,156	\$ 4,346	\$ 3,635	\$ 5,058
<b>Total Outpatient Pharmacy</b>	\$ 1,148	\$ 1,087	\$ 1,209	\$ 2,137	\$ 2,047	\$ 2,227
NSAIDs	\$ 414	\$ 390	\$ 438	\$ 654	\$ 611	\$ 698
Analgesics/Antipyretics	\$ 96	\$ 87	\$ 105	\$ 140	\$ 125	\$ 155
Opioids	\$ 760	\$ 638	\$ 883	\$ 1,095	\$ 989	\$ 1,200
Muscle Relaxants	\$ 256	\$ 244	\$ 268	\$ 437	\$ 414	\$ 461

(Continued)

**Table 4** (Continued).

HCRU Category	1-Year Societal Expenditures Per Patient (2023 US\$)			Cumulative 2-Year Societal Expenditures Per Patient (2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
Anticonvulsants	\$ 701	\$ 632	\$ 769	\$ 1,340	\$ 1,162	\$ 1,517
Antidepressants	\$ 541	\$ 521	\$ 562	\$ 971	\$ 929	\$ 1,012
Anxiolytics	\$ 168	\$ 147	\$ 189	\$ 302	\$ 260	\$ 343

**Note:** ^Surgical supply and device costs were not explicitly listed as a separate line item for all surgeries. Surgical and inpatient admission costs include all costs for services rendered during the surgical admission or day of outpatient surgery.

**Abbreviations:** HCRU, healthcare resource utilization; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

care within the 1st year relative to those that did not go on to have surgery [\$8,875 (\$7,998, \$9,752) vs \$3,697 (\$3,621, \$3,774);  $p < 0.001$ ]. For patients who had spine surgery within the 1st year but no additional surgery in the 2nd year, societal expenditures for nonoperative care in the 2nd year remained elevated versus those that never had surgery [\$4,746 (\$4,361, \$5,130) vs \$2,189 (\$2,118, \$2260);  $p < 0.001$ ].

By subtracting payer from societal expenditures, the resulting average patient out-of-pocket expense for spine care totaled to \$1,141 (\$1,098, \$1,184) within 1 year and \$1,709 (\$1,639, \$1,779) within 2 years. The patient out of pocket for nonoperative spine care, alone, totaled to \$901 (\$883, \$919) within 1 year and \$1,388 (\$1,353, \$1,423) within 2 years. Among patients with spine surgery, average surgical out of pocket was \$3,834 (\$3,179, \$4,488) within 1 year and \$4,048 (\$3,262, \$4,833) within 2 years. The patient was responsible for 21.2% of the 1-year societal economic burden for nonsurgical spine care and, among those with spine surgery, 2.9% of the 1-year societal economic burden for operative spine care.

The total societal burden of spine-related care for ASD among the approximately 142 million US commercially-insured population aged 21 to 64 totaled over \$6.2 billion in the 1st year following the index ASD encounter (Table 5).

**Table 5** Societal Economic Burden of ASD Within the US Commercial Payer Population Aged 21 to 64 Overall and by Category of Service in Millions of 2023 US Dollars

Category of Service	1-Year Societal Burden (Millions of 2023 US\$)			Cumulative 2-Year Societal Burden (Millions of 2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
<b>TOTAL SPINE-RELATED</b>	\$ 6,232	\$ 6,098	\$ 6,366	\$ 8,866	\$ 8,658	\$ 9,074
<b>Nonoperative Spine-Related</b>	\$ 3,016	\$ 2,957	\$ 3,076	\$ 4,670	\$ 4,561	\$ 4,779
<b>By Service Category:</b>						
<b>Total Inpatient Admissions</b>	\$ 2,971	\$ 2,880	\$ 3,061	\$ 3,849	\$ 3,717	\$ 3,980
<b>Total Outpatient Services</b>	\$ 2,711	\$ 2,668	\$ 2,753	\$ 3,868	\$ 3,787	\$ 3,949
Fusion Surgery ( $\pm$ Decompression)	\$ 2,633	\$ 2,547	\$ 2,718	\$ 3,377	\$ 3,254	\$ 3,500
Decompression Surgery	\$ 522	\$ 503	\$ 541	\$ 810	\$ 777	\$ 843
Other Admissions (Excluding Spine Surgery)	\$ 300	\$ 280	\$ 321	\$ 456	\$ 416	\$ 497
Office Visits	\$ 248	\$ 246	\$ 250	\$ 368	\$ 365	\$ 372
Urgent Care	\$ 5	\$ 3	\$ 7	\$ 5	\$ 5	\$ 6
ER	\$ 139	\$ 135	\$ 144	\$ 199	\$ 191	\$ 207
PT	\$ 452	\$ 444	\$ 460	\$ 662	\$ 649	\$ 676

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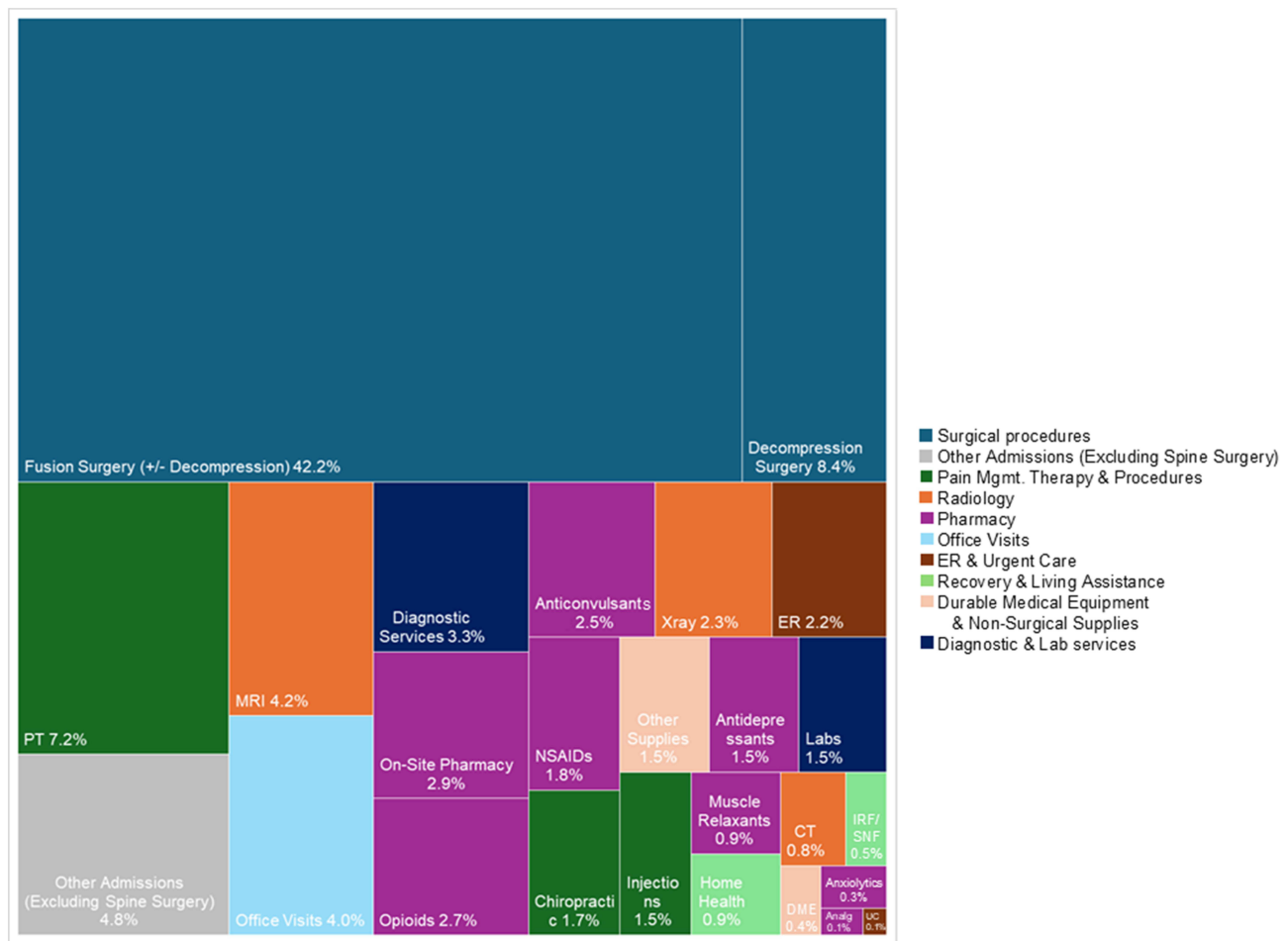
Table 5 (Continued).

Category of Service	1-Year Societal Burden (Millions of 2023 US\$)			Cumulative 2-Year Societal Burden (Millions of 2023 US\$)		
	Mean	Lower 95% CI	Upper 95% CI	Mean	Lower 95% CI	Upper 95% CI
Injections	\$ 91	\$ 88	\$ 94	\$ 134	\$ 129	\$ 139
Chiropractic	\$ 104	\$ 103	\$ 105	\$ 167	\$ 164	\$ 170
Radiology	\$ 477	\$ 470	\$ 483	\$ 624	\$ 613	\$ 635
CT	\$ 48	\$ 45	\$ 50	\$ 65	\$ 62	\$ 68
MRI	\$ 264	\$ 261	\$ 267	\$ 345	\$ 340	\$ 350
Xray	\$ 142	\$ 139	\$ 144	\$ 181	\$ 176	\$ 185
Labs	\$ 93	\$ 87	\$ 99	\$ 133	\$ 124	\$ 142
Diagnostic Services	\$ 207	\$ 192	\$ 221	\$ 277	\$ 256	\$ 298
Durable Medical Equipment	\$ 22	\$ 21	\$ 24	\$ 33	\$ 30	\$ 36
Surgical Supplies & Devices <sup>^</sup>	\$ 1,771	\$ 1,693	\$ 1,850	\$ 2,352	\$ 2,233	\$ 2,472
Other Supplies & Devices	\$ 94	\$ 82	\$ 106	\$ 126	\$ 110	\$ 142
SNF	\$ 6	\$ 4	\$ 8	\$ 9	\$ 6	\$ 11
IRF	\$ 24	\$ 19	\$ 28	\$ 30	\$ 25	\$ 36
Home Health	\$ 57	\$ 50	\$ 63	\$ 92	\$ 72	\$ 112
On-Site Pharmacy	\$ 178	\$ 164	\$ 193	\$ 256	\$ 214	\$ 298
<b>Total Outpatient Pharmacy</b>	\$ 582	\$ 551	\$ 613	\$ 1,206	\$ 1,156	\$ 1,257
NSAIDs	\$ 109	\$ 103	\$ 116	\$ 224	\$ 209	\$ 239
Analgesics/Antipyretics	\$ 9	\$ 8	\$ 10	\$ 18	\$ 16	\$ 20
Opioids	\$ 167	\$ 140	\$ 194	\$ 319	\$ 288	\$ 349
Muscle Relaxants	\$ 57	\$ 54	\$ 60	\$ 120	\$ 114	\$ 127
Anticonvulsants	\$ 154	\$ 139	\$ 169	\$ 343	\$ 298	\$ 389
Antidepressants	\$ 94	\$ 91	\$ 98	\$ 213	\$ 204	\$ 222
Anxiolytics	\$ 22	\$ 19	\$ 24	\$ 47	\$ 41	\$ 54

**Note:** <sup>^</sup>surgical supply and device costs were not explicitly listed as a separate line item for all surgeries. Surgical and inpatient admission costs include all costs for services rendered during the surgical admission or day of outpatient surgery.

**Abbreviations:** HCRU, healthcare resource utilization; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

The burden of nonoperative spine care was \$3.0 billion, 48.4% of societal expenditures. The burden of spinal fusion surgery, alone, was \$2.6 billion in the 1st year following the index outpatient encounter, or roughly 42.2% of total expenditures (Figure 4). Other high-burden categories of service included pharmacy (\$582 million outpatient, \$178 million inpatient), decompression surgery (\$522 million), radiology (\$477 million), physical therapy (\$452 million), hospital admissions other than those for spine surgery (\$300 million), and office visits (\$248 million). The burden of ER encounters, chiropractic care, and diagnostic services also totaled over \$100 million each within the 1st year. Over 2 years, the societal burden of spine care increased to nearly \$8.9 billion, \$4.7 billion of which was for nonoperative care.



**Figure 4** Visual representation showing the percent of 1-year spine-related societal expenditures projected for the US commercially-insured population aged 21–64 by category. Boxes are scaled to the percentage of total expenditures. Surgical cost categories include costs of surgical supplies and devices. Note that the surgical costs include all costs from the procedure and any associated admission, so there is some minor overlap with other categories.

**Abbreviations:** PT, physical therapy; MRI, magnetic resonance imaging; NSAIDs, nonsteroidal antiinflammatory inhibitors; On-site RX, onsite pharmacy; IRF/SNF, inpatient rehabilitation facility/skilled nursing facility; Analg, analgesics/antipyretics; UC, urgent care.

## Discussion

In a large, US national commercial payer cohort the prevalence of ASD in patients aged 21–64 was 0.50%. Extrapolating to the US commercially-insured population, this translates to 711,558 patients. During the 1st year following the index ASD encounter, the associated commercial payer burden of ASD per 100,000 beneficiaries was \$3.8 million. An Accountable Care Organization with 500,000 adult beneficiaries can expect \$19.0 million in spine-related expenditures from patients receiving an ASD diagnosis within the 1st year, alone, and \$26.9 million within 2 years.

Our calculated 0.50% prevalence rate in the MarketScan<sup>®</sup> commercial population is slightly lower than the 0.74% reported previously from analyses of administrative data by the Orthopaedic Research Society US Bone & Joint Initiative who counted multiple ASD diagnoses per patient separately.<sup>22</sup> Prior analyses showing higher prevalence rates have used a lower curve severity threshold (Cobb angle of  $\geq 10$  degrees versus  $\geq 20$  degrees) for defining scoliosis, included asymptomatic patients, and/or included older adults or those being referred to specialty clinics, among which prevalence rates are higher.<sup>4,23</sup> Further, between 20% and 50% of adults with ASD seek treatment.<sup>22,24</sup> Our claims-based prevalence calculations represent a national “community-based” cohort of adults who are symptomatic seeking medical services for ASD. This is likely an underestimation of the true burden of ASD in this population, as ASD is under-coded in claims data. In fusion surgery, claims coding of scoliosis demonstrated a sensitivity of 94% and a specificity of 97% when compared against the medical record.<sup>25</sup> However, the sensitivity of ASD diagnoses is likely lower in the non-surgical and

outpatient setting. Indeed, in the current study, summed payments for services with an ASD diagnosis listed on the claim were vastly lower than expected and, therefore, we opted to present spine-related payments for the defined ASD cohort, which are likely a more accurate reflection of the burden of ASD-associated treatment. An illustrative scenario is as follows: An ASD patient receives an injection for stenosis caused by their ASD. On the submitted claim, the stenosis diagnosis is most important to receiving reimbursement from the payer, while the ASD that caused the stenosis is not required for reimbursement and therefore is less likely to be coded. Despite limitations in sensitivity, the coding of spine diagnoses in claims data tends to be highly specific, meaning that when the ASD code is present, it is highly likely that the patient has ASD.<sup>25,26</sup>

Our study demonstrated that 3.5% of patients underwent fusion surgery and 2.9% underwent other decompressive surgery within one year of the index ASD encounter. By comparison, Passias et al reported a conversion rate of 12.7% (24/189) from nonoperative to operative treatment within one year among patients considering surgical correction depending on the success of nonoperative treatment.<sup>27</sup> Compared to our community-based cohort that initially sought outpatient care, the Passias study included patients with more severe spinal deformity who sought initial treatment at a surgical clinic. As such, our results would be generalizable to commercially-insured ASD patients aged 21–64 years who sought care initially on an outpatient basis. Among these patients, from a payer perspective, fusion and other decompressive surgery costs totaled to \$2.1 million per 100,000 commercially-insured beneficiaries in the 1st year, increasing to \$2.8 million within 2 years. From the societal perspective, this equates to \$3.2 billion in direct healthcare expenditures for the US commercially-insured population within 1 year and \$4.2 billion within 2 years. In cases where the surgical supply and device costs were explicitly enumerated, more than half of the surgical expenditures were attributable to payments for surgical supplies and devices.

The management of ASD typically starts with nonoperative modalities. Nonoperative payer expenditures per patient averaged \$3,338 (\$3,259, \$3,418) within the 1st year following the index outpatient ASD diagnosis, and the total societal nonoperative expenditures averaged \$4,239 (\$4,115, \$4,323). This is in line with prior reports of nonoperative treatment ranging from \$1,000–\$7,000 annually.<sup>2,6,11</sup> In the current study, nonoperative care constituted a payer burden of \$1.7 million per 100,000 commercially-insured beneficiaries within 1 year and \$2.6 million within 2 years. The US commercially-insured societal burden in patients aged 21–64 totaled to \$3.0 billion within 1 year and \$4.7 billion within 2 years. Patients were responsible for 21% of the nonoperative 1-year societal economic burden. Patients that had spine surgery incurred more than twice the payer and societal expenditures for nonoperative care in the year preceding and the year following surgery relative to those who did not undergo surgery. It is possible that the patients progressing to surgery have more severe deformity and/or symptoms, but surgical patients may also be required to try more nonoperative treatments as a prerequisite to surgery and have required PT during their surgical recovery. Further study is warranted to determine whether the increased expenditures for nonoperative care correlate with disease and symptom severity and whether we can use this information to better optimize these patients to surgery sooner rather than spending additional nonoperative resources with limited benefit. Despite the large amount of healthcare dollars being allocated to continued use of nonoperative therapies, the strength of evidence regarding the effectiveness of these interventions is limited.<sup>8–10</sup> Much of the evidence regarding nonoperative modalities is derived from observational research. Randomized trials, when present, have produced disparate results attributable to highly variable patient populations, spinal regions, diagnoses, procedure types, and procedural techniques. In contrast, surgical intervention offers substantive improvements in several health-related quality of life HRQOL domains, including back pain, and can be highly cost-effective when successful.<sup>7,12–15</sup> However, surgery is a costly intervention and the cost-effectiveness can be further compromised by the relatively high rates of complications and reoperations. Thus, there is a critical need for extensive research into appropriate patient indications and procedural approaches or nonoperative management. Furthermore, considerable opportunity exists for the development of new and improved nonoperative interventions to increase the value of nonoperative ASD management.

Claims data present inherent strengths and limitations. Of note, MarketScan<sup>®</sup> is one of few claims resources providing true payment rather than charge data. The MarketScan<sup>®</sup> financial data captures the vast majority of direct medical payments, including out of pocket costs paid by the patient (copayments, deductibles, and coordination of benefits fees) in addition to all payments made by the payer.<sup>16</sup> Nonetheless, there are some out of pocket expenses that

are not captured, such as those for over-the-counter pain medication and complementary/alternative medicine. Quality-of-life and indirect cost data will also be essential for examining the value derived from these ASD healthcare expenditures. The present study demonstrated that the total societal direct cost burden from the US commercially-insured population was \$6.2 billion in the 1st year following the index ASD encounter, which does not consider indirect costs. Indirect costs related to absenteeism, loss of productivity, and caretaker time are substantial in commercially-insured, working-age ASD patients and are not well documented due to the considerable challenges in collecting this type of data.<sup>28–30</sup> In the context of degenerative spine conditions, indirect costs over 1–2 years ranged from \$3,540 to \$8,852 (2023 US\$) per patient.<sup>31</sup>

Claims data contain relatively limited clinical information. Our analysis is inclusive of multiple types of ASD, including kyphotic and hyper- and hypo-lordotic deformities, which are rare in comparison to scoliosis (Figure 2B). Future studies with more detailed information regarding deformity type and severity, and pain and symptom duration and severity will be important to understanding variations within the ASD population and how these factors influence costs. Additional study of variations in outcomes by the timing and type of surgical intervention are also warranted. With regards to the outpatient pharmacy data, MarketScan<sup>®</sup> includes no associated diagnosis information. While the omission of over-the-counter medications from claims data will cause an underestimation of total drug costs, the lack of associated diagnoses will conversely cause some overestimation of total drug costs. We opted to more inclusively capture all filled prescriptions falling into the 5 drug categories commonly used for spine-related pain relief; however, each of these categories of drugs may be used to treat other pain generators or physical/mental pathologies. Next, claims data are subject to coding inaccuracies and we have removed payments that were recorded as  $\leq$  \$0. Another limitation inherent to claims data is the constrained timeline available to scan pre and post the index encounter due to drop off in patient numbers resulting from the continuous enrollment window required for longitudinal tracking. An estimated 5–22% of patients change health plans annually.<sup>32–34</sup> In our experience with spine cohorts derived from MarketScan<sup>®</sup>, patients meeting the continuous enrollment requirements did not differ in any of the available demographic (age, sex, region of the US, rural/urban) or comorbidity measures more than would be expected by chance (standardized differences <10%) relative to those without continuous enrollment.<sup>20,35</sup> However, MarketScan<sup>®</sup> does not include information on race, ethnicity, or socio-demographics, and therefore we cannot rule out potential biases with regards to these factors. Nearly 70% of plan changes are involuntary due to changing employers or employers changing health plan offerings; however, near-elderly patients, blacks, Hispanics, and patients in fair or poor health are more likely to change health plans.<sup>32</sup> These factors are known sources of cost variation and further study is warranted to identify their impact on healthcare costs and resource utilization.<sup>36,37</sup>

## Conclusions

The prevalence of ASD in a large, US national commercial payer cohort aged 21–64 was 0.50%. The associated payer and societal economic burden of both operative and nonoperative care for ASD is substantial. There is considerable opportunity for the development of improved nonoperative treatment modalities to increase the value of ASD care by reducing the need for continued nonoperative interventions of limited benefit and reducing the use of costly operative care.

## Abbreviations

ASD, adult spinal deformity; US, United States; US\$, United States Dollars; HRQOL, health-related quality of life; ODI, Oswestry Disability Index; SF, Short Form; SRS, scoliosis research society; COBRA, Consolidated Omnibus Budget Reconciliation Act; ICD-10-CM, International Classification of Diseases-10th revision; HCRU, healthcare resource utilization; CI, confidence interval; SNF, skilled nursing facility; IRF, inpatient rehabilitation facility; ER, emergency room; PT, physical therapy; NSAID, nonsteroidal anti-inflammatory drug.

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## Disclosure

SJA declares consulting for NSite Medical, SI Bone, ATEC, Carlsmed, and Mainstay Medical. MB declares consulting for NSite Medical. MJG owns stock of NSite Medical. SSH declares consulting for Medtronic and Surgistep, speaker fees from Globus, scientific advisory board membership for Medcura, board membership for Scoliosis Research Society, journal review board for Spine Deformity and Global Spine Journal. DWP Jr declares consulting for SI Bone, Medtronic, and Globus, royalties from SI Bone and Springer, and institutional research support from Mizuho OSI, SI Bone, Medtronic and AO Spine. The authors report no other conflicts of interest in this work.

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