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| **Supplementary Table 1a.** ICD-9 and ICD-10 codes used for to identify patients with index back or lower extremity pain. | |
| **ICD** | **Description** |
| 7213 | Lumbosacral spondylosis without myelopathy |
| 7214 | Thoracic or lumbar spondylosis with myelopathy |
| 7242 | Lumbago (low back pain) |
| 7243 | Sciatica |
| 7244 | Thoracic or lumbosacral neuritis or radiculitis, unspecified |
| 7245 | Backache, unspecified |
| 7384 | Acquired spondylolisthesis |
| 72141 | Spondylosis with myelopathy, thoracic region |
| 72142 | Spondylosis with myelopathy, lumbar region |
| 72210 | Displacement of lumbar intervertebral disc without myelopathy |
| 72252 | Degeneration of lumbar or lumbosacral intervertebral disc |
| M4300 | Spondylolysis, site unspecified |
| M4310 | Spondylolisthesis, site unspecified |
| M4714 | Other spondylosis with myelopathy, thoracic region |
| M4716 | Other spondylosis with myelopathy, lumbar region |
| M47817 | Spondylosis without myelopathy or radiculopathy, lumbosacral region |
| M5126 | Other intervertebral disc displacement, lumbar region |
| M5127 | Other intervertebral disc displacement, lumbosacral region |
| M5136 | Other intervertebral disc degeneration, lumbar region |
| M5137 | Other intervertebral disc degeneration, lumbosacral region |
| M5414 | Radiculopathy, thoracic region |
| M5415 | Radiculopathy, thoracolumbar region |
| M5416 | Radiculopathy, lumbar region |
| M5417 | Radiculopathy, lumbosacral region |
| M5430 | Sciatica, unspecified side |
| M545 | Low back pain |
| M5489 | Other dorsalgia (backache) |
| M549 | Dorsalgia (backache) |

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| **Supplementary Table 1b.** Comprehensive list of opioid-containing medications included in the study. | |
| A.P.C. W/Codeine | Butorphanol Tartrate |
| Acetaminophen/Butalbital/Codeine Phosphate | Codeine Phosphate |
| Acetaminophen/Caffeine/Dihydrocodeine Bitartrate | Codeine Sulfate |
| Acetaminophen/Codeine Phosphate | Dihydrocodeine/Apap/Caffeine |
| Acetaminophen/Hydrocodone Bitartrate | Fentanyl |
| Acetaminophen/Meperidine Hydrochloride | Fentanyl Citrate |
| Acetaminophen/Oxycodone Hydrochloride | Hydrocodone Bitartrate |
| Acetaminophen/Pentazocine Hydrochloride | Hydrocodone Bitartrate/Ibuprofen |
| Acetaminophen/Propoxyphene Hydrochloride | Hydromorphone Hydrochloride |
| Acetaminophen/Propoxyphene Napsylate | Ibuprofen/Oxycodone Hydrochloride |
| APAP/Butabarbital Na/Codeine Phos | Levomethadyl Acetate Hydrochloride |
| APAP/Butalbital/Caff/Codeine Phos | Levorphanol Tartrate |
| ASA/Oxycodone HCl/Oxycodone Terephthalate | Meperidine Hydrochloride |
| Aspirin (Buffered)/Codeine Phosphate | Methadone Hydrochloride |
| Aspirin/Butalbital/Caffeine/Codeine Phosphate | Morphine Sulfate |
| Aspirin/Caffeine/Dihydrocodeine Bitartrate | Morphine Sulfate/Naltrexone Hydrochloride |
| Aspirin/Caffeine/Propoxyphene Hydrochloride | Naloxone Hydrochloride/Pentazocine Hydrochloride |
| Aspirin/Carisoprodol/Codeine Phosphate | Oxycodone |
| Aspirin/Codeine Phosphate | Oxycodone Hydrochloride |
| Aspirin/Hydrocodone Bitartrate | Oxymorphone Hydrochloride |
| Aspirin/Oxycodone Hydrochloride | Propoxyphene Hydrochloride |
| Aspirin/Pentazocine Hydrochloride | Propoxyphene Napsylate |
| Belladonna Alkaloids/Opium Alkaloids | Tapentadol Hydrochloride |

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| **Supplementary table 1c.** Primary CPT codes used to identify study cohort. | | |
| **CPT** | | **Description** |
| Fusion with or without decompression | | |
|  | 0171T | posterior interspinous distraction device, lumbar, single level |
|  | 22532 | arthrodesis, lateral, minimal discectomy, thoracic |
|  | 22533 | arthrodesis, lateral extracavitary, minimal discectomy, lumbar |
|  | 22556 | arthrodesis, anterior, thoracic |
|  | 22558 | arthrodesis, anterior, lumbar |
|  | 22610 | arthrodesis, posterior, thoracic, single level |
|  | 22612 | arthrodesis, posterior, lumbar, single level |
|  | 22630 | arthrodesis, posterior, laminectomy discectomy, single level, lumbar |
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| Decompression without fusion | | |
|  | 22206 | osteotomy, posterior, 3 columns, 1 vertebral segment, thoracic |
|  | 22207 | osteotomy, posterior, 3 columns, 1 vertebral segment, lumbar |
|  | 22212 | osteotomy, posterior, 1 vertebral segment, thoracic |
|  | 22214 | osteotomy, posterior, 1 vertebral segment, lumbar |
|  | 22222 | osteotomy, discectomy, anterior, single level, thoracic |
|  | 22224 | osteotomy, discectomy, anterior, single level, lumbar |
|  | 22862 | revision total disc arthroplasty, anterior, lumbar, single level |
|  | 22865 | removal total disc arthroplasty, anterior, lumbar, single level |
|  | 63003 | laminectomy decompression, 1-2 levels, thoracic |
|  | 63005 | laminectomy decompression, 1-2 levels, lumbar, except spondylolisthesis |
|  | 63011 | laminectomy, decompression, 1-2 levels, sacral |
|  | 63012 | laminectomy, removal of abnormal facets and pars for decompression, spondylolisthesis, lumbar |
|  | 63016 | laminectomy with decompression, more than 2 levels, thoracic |
|  | 63017 | laminectomy, more than 2 vertebral segments, lumbar |
|  | 63030 | laminotomy with decompression, herniated disc, 1 level, lumbar |
|  | 63042 | laminotomy with decompression, herniated disc, 1 level, re-exploration, lumbar |
|  | 63046 | laminectomy with facetectomy and foraminotomy, single level, thoracic |
|  | 63047 | laminectomy with facetectomy and foraminotomy, single level, lumbar |
|  | 63055 | decompression, transpedicular, single level, thoracic |
|  | 63056 | decompression, transpedicular, single level, lumbar |
|  | 63064 | decompression, costovertebral, single level, thoracic |
|  | 63077 | one level anterior thoracic discectomy |
|  | 63085 | corpectomy, transthoracic / anterior, thoracic, single level |
|  | 63087 | corpectomy, for decompression, lower thoracic or lumbar, single level |
|  | 63090 | corpectomy, anterior, for decompression, lower thoracic lumbar or sacral, single level |
|  | 63101 | corpectomy, partial or complete, lateral extracavitary, decompression, single level, thoracic |
|  | 63102 | corpectomy, partial or complete, lateral extracavitary, decompression, single level, lumbar |

**Supplementary Table 2.** Probability of high-frequency opioid use by state.



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| **Supplementary Table 3.** Opioid prescription patterns in patients newly diagnosed with back or lower extremity pain and opioid-naïve for at least 6 months prior to diagnosis, who undergo thoracic or lumbosacral spine surgery within one year following diagnosis. | | | |
| **Post-operative opioid-use characteristics** | **Postoperative high-frequency opioid use patients** | **Postoperative low-frequency opioid use patients** | **p-value** |
| (N= 2,952) | (N= 22,554) |
| Days from index surgery to first outpatient opioid prescription - no. ± SD | 6.9 ± 19.9 | 12.3 ± 46.6 | < 0.001 |
| Days from index surgery to discontinuation of opioid prescription - no. ± SD | 276.8 ± 93.0 | 73.0 ± 109.6 | < 0.001 |
| Average number of days each prescription covered - no. ± SD | 14.2 ± 7.3 | 9.2 ± 6.3 | < 0.001 |
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| **Supplementary Table 4.** Healthcare utilization in patients newly diagnosed with back or lower extremity pain and opioid-naïve for at least 6 months prior to diagnosis, who undergo thoracic or lumbosacral spine surgery within one year following diagnosis. | | | | |
| **Healthcare utilization** | | **Post-operative high-frequency opioid use patients** | **Postoperative low-frequency opioid use patients** | **p-value** |
| (N= 2,952) | (N= 22,554) |
| 12 months after index surgery | |  |  |  |
|  | Total payment - US dollars ± SD | $36,883 ± 39,342 | $19,756 ± 26,588 | < 0.001 |
|  | Inpatient & outpatient visits - no. ± SD | 12.1 ± 11.4 | 6.3 ± 8.1 | < 0.001 |
|  | Inpatient & outpatient services - no. ± SD | 56.7 ± 45.6 | 33.2 ± 29.9 | < 0.001 |
|  |  |  |  |  |
| 6 months after index surgery | |  |  |  |
|  | Total payment - US dollars ± SD | $33,106 ± 36,751 | $19,114 ± 25,692 | < 0.001 |
|  | Inpatient & outpatient visits - no. ± SD | 8.7 ± 8.4 | 5.3 ± 6.7 | < 0.001 |
|  | Inpatient & outpatient services - no. ± SD | 30.5 ± 26.3 | 46.1 ± 35.5 | < 0.001 |
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| Days of follow-up after index surgery - no. ± SD | | 1,369 ± 757 | 1,366 ± 772 | 0.845 |

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| **Supplementary Table 5.** Specific services that added excess costs amongst different frequency of postoperative opioid use patients | | | |
| **Most common healthcare encounters within 1-year after surgery** | **Postoperative low-frequency opioid use patients** | **Post-operative high-frequency opioid use patients** | **p-value** |
| (N= 22,554) | (N= 2,952) |
| Imaging | 8,125 (36.0%) | 2,161 (73.2%) | < 0.001 |
| Physical therapy | 7,053 (31.3%) | 1,178 (39.9%) | < 0.001 |
| Visit with ortho provider | 4,084 (18.1%) | 977 (33.1%) | < 0.001 |
| Visit with neurosurgery or neurology provider | 3,755 (16.6%) | 971 (32.9%) | < 0.001 |
| Visit with PMR provider | 925 ( 4.1%) | 341 (11.6%) | < 0.001 |
| Visit with pain management provider | 350 ( 1.6%) | 205 ( 6.9%) | < 0.001 |
| Visit with chiropractic provider | 332 ( 1.5%) | 58 ( 2.0%) | 0.049 |
| Visit with emergency or urgent care provider | 353 ( 1.6%) | 168 ( 5.7%) | < 0.001 |
| Repeat spine surgery | 1,487 ( 6.6%) | 547 (18.5%) | < 0.001 |