Background: Many patients are affected by concurrent disease of the hip and spine, undergoing both total hip arthroplasty (THA) and lumbar spinal fusion (LSF). Recent literature demonstrates increased prosthetic dislocation rates in patients with THA done after LSF. Evidence is lacking on which surgery to do first to minimize complications. The purpose of this study was to evaluate the effect of timing between the two procedures on postoperative outcomes.

Methods: We queried the Medicare standard analytics files between 2005 and 2014. Four groups were identified and matched by age and sex: THA with previous LSF, LSF with previous THA, THA with spine pathology without fusion, and THA without spine pathology. Revision THA or LSF and bilateral THA were excluded. Comorbidities and Charlson Comorbidity Index were identified. Postoperative complications at 90 days and 2 years were calculated after the most recent surgery. Four-way chi-squared and standard descriptive statistics were calculated.

Results: Thirteen thousand one hundred two patients had THA after LSF, 10,482 patients had LSF after THA, 104,820 had THA with spine pathology, and 492,654 had THA without spine pathology. There was no difference in the Charlson Comorbidity Index score between the THA after LSF and LSF after THA groups. There was a statistically significant difference in THA dislocation rate, with LSF after THA at 1.7%, THA without spine pathology at 2.3%, THA with spine pathology at 3.3%, and THA after LSF at 4.6%. There was a statistically significant difference in THA revision rate, with THA without spine pathology at 3.3%, LSF after THA at 3.7%, THA with spine pathology at 4.2%, and THA after LSF at 5.7%.

Conclusion: LSF after THA is associated with a reduced dislocation rate compared with THA after LSF. Reasons may include decreasing pelvic mobility in a stable, well-healed THA or early postoperative spine precautions after LSF restricting positions of dislocation.
Hip-spine syndrome, the concurrent existence of degenerative conditions of both the hip joint and the spine, can have overlapping symptoms making specific identification and treatment of pathology difficult.\textsuperscript{1,2} Both total hip arthroplasty (THA) and lumbar spinal fusion (LSF) done for degenerative disease can provide pain relief and improve functional outcomes in many patients, and, correspondingly, the utilization of both procedures continues to increase rapidly.\textsuperscript{3,4}

When switching from the standing to the sitting position, a balanced and flexible spine allows for pelvic retroversion, which leads to increased functional anteversion of the acetabulum.\textsuperscript{5-7} This allows for adequate coverage of the femoral head in the sitting position as the hip goes into flexion. Degenerative conditions of the lumbar spine can lead to a stiff spine which limits the mobility necessary for changes in functional version of the acetabulum. This can put a patient at risk of intra-articular impingement and instability.\textsuperscript{7-10} Approximately two percent of Medicare patients who undergo THA have had previous LSF, with between 18\% and 25\% having seen a spine surgeon before proceeding with arthroplasty.\textsuperscript{11-14} With spinal deformity, degenerative disease, and LSF now known as risk factors for alteration of functional acetabular position, even with cup placement in the traditional “safe zone,” it is no surprise that there are many emerging data demonstrating higher dislocation rates of THA after previous spinal fusion.\textsuperscript{9,11,15,16}

A recent meta-analysis by An et al. found that previous LSF increases the relative risk of THA dislocation twofold.\textsuperscript{17} As such, it is a known complication that surgeons should routinely counsel patients who present for evaluation of primary THA in the setting of previous LSF. What remains unclear in both practice and in the literature, however, is the appropriate sequence by which to treat patients who have concurrent surgical hip and spine pathology to minimize these risks. The purpose of this study was to evaluate whether timing of LSF, either before or after THA, affects prosthetic dislocation and other postoperative complications.

### Methods

The study used completely de-identified patient information and was exempt from Institutional Review Board approval. We queried the entire Medicare database from 2005 to 2014 containing 100\% of administrative records on more than 51 million patients using Pearl Diver International Classification of Diseases-9 procedure code 81.51 and Current Procedural Terminology code 27130. Next, we selected for patients who only had a single primary THA done and with a minimum of 2-year follow-up per patient after surgery.

We then identified all patients who had primary LSF done using International Classification of Diseases-9 procedure code 81.51 and Current Procedural Terminology code 27130. Next, we selected for patients who only had a single primary THA done and with a minimum of 2-year follow-up per patient after surgery.

We identified and matched 13,102 patients who had THA done after LSF. Group two included patients who had LSF done after THA. Group three included patients who had known lumbar spine pathology who underwent THA, never having LSF at any time point in their record. Group four, our true control, was the group of patients who underwent THA without any LSF or diagnosis of spine pathology. Each group had a minimum of 2 years of follow-up from the latest procedure. Using a stepwise algorithm, all four study groups were matched by age and sex.

Surgical complications were assessed at both 90 days and 2 years. To prevent confounding from codes previously on patients’ records, the “first_instance” command was used on all complications of interest, allowing us to identify the first time the complication occurred to prevent any pre-existing diagnoses from skewing the results. Complications were tracked from the latest procedure. Demographics were identified, comorbidities were found using the standardized Elixhauser measure, and the Charlson comorbidity index (CCI) for each group was calculated.\textsuperscript{19,20} Four-way chi-squared and associated P values were calculated to compare all four groups at once. Additional subgroup analysis with standard descriptive statistics was done between the THA after LSF and the LSF after THA groups. Significance was set at an alpha of <0.05.

We identified and matched 13,102 patients who had THA after LSF (group 1), 10,482 patients who had LSF after THA (group 2), 104,820 patients with spine pathology without LSF who underwent THA (group 3), and 492,654 patients who had THA done without any spine pathology or LSF (group 4). With the use of the matching system, there were no differences in age and sex proportions among the four groups (Table 1).
Results

There were differences in Elixhauser medical comorbidities ($P < 0.001$), with those having THA without spine pathology with the lowest proportions, indicating the healthiest cohort (Table 2). Using a four-way analysis of variance test, we found differences in the CCI score ($P < 0.001$), with THA after LSF at 5.3 (SD 2.1), LSF after THA at 5.4 (SD 2.2), THA with spine pathology without LSF at 5.4 (SD 2.2), and THA without spine pathology at 4.8 (SD 1.9). However, when specifically comparing our two main groups of interest, THA after LSF and LSF after THA, a $t$-test demonstrated no difference in the CCI score ($P = 0.287$), indicating similar health status.

THA after LSF had the highest rate of dislocation at 90 days (2.8%), followed by THA with spine pathology (1.9%) and THA without spine pathology (1.2%). LSF after THA had the lowest 90-day dislocation rate of 0.2% ($P < 0.001$) (Table 3). The odds of an early dislocation were increased by 16.6-fold (95% confidence interval [CI] 10.3 to 26.7, $P < 0.001$) when THA was done after LSF in comparison with LSF done after THA. That is an absolute risk reduction of 2.6% in the rate of early dislocation if LSF is done after THA rather than before THA. Hence, doing LSF after THA in 39 cases prevents one early dislocation caused by THA after LSF.

THA after LSF had the highest rate of dislocation at 2 years (4.6%), followed by THA with spine pathology (3.2%) and THA without spine pathology (2.3%). LSF after THA had the lowest 2-year dislocation rate of 1.7% ($P < 0.001$) (Table 4). The odds of a late dislocation were increased by 2.8-fold (95% CI, 2.4 to 3.4, $P < 0.001$) when THA was done after LSF in comparison with LSF done after THA. That is an absolute risk reduction of 2.9% in the rate of late dislocation if LSF is done after THA rather than before THA. Hence, doing LSF after THA in 56 cases prevents one early THA revision caused by THA after LSF.
dislocation caused by THA after LSF. THA revision rates at 2 years followed a similar trend, with THA after LSF at 5.7%, THA with spine pathology at 4.2%, THA without spine pathology at 3.3%, and LSF after THA at 3.7% (P < 0.001). The odds of a late revision were increased by 1.6-fold (95% CI, 1.4 to 1.8, P < 0.001) when THA was done after LSF in comparison with LSF done after THA. That is an absolute risk reduction of 2.0% in the rate of late THA revision if LSF is done after THA rather than

| Table 2 |
| --- |
| **Comorbidities** | THA After LSF | LSF After THA | THA, Spine Path, No LSF | THA, No Spine Path | P Value |
| n | 13,102 | 10,482 | 104,820 | 492,654 |
| **Comorbidity** | | | | |
| Congestive heart failure | 1562 (12%) | 1288 (12%) | 13,268 (13%) | 35,493 (7%) | <0.001 |
| Valvular disease | 1969 (15%) | 1595 (15%) | 15,404 (15%) | 38,374 (8%) | <0.001 |
| Pulmonary circulation disorders | 727 (6%) | 602 (6%) | 5644 (5%) | 13,094 (3%) | <0.001 |
| Peripheral vascular disease | 2763 (21%) | 2193 (21%) | 22,218 (21%) | 42,816 (9%) | <0.001 |
| HTN (uncomplicated) | 10,945 (84%) | 8941 (85%) | 78,231 (75%) | 245,620 (50%) | <0.001 |
| HTN (complicated) | 1797 (14%) | 1597 (15%) | 13,816 (13%) | 33,723 (7%) | <0.001 |
| HTN (uncomplicated and complicated) | 10,999 (84%) | 8991 (86%) | 78,881 (75%) | 250,089 (51%) | <0.001 |
| Paralysis | 480 (4%) | 217 (2%) | 1995 (2%) | 4928 (1%) | <0.001 |
| Other neurological disorders | 1662 (13%) | 1419 (14%) | 12,326 (12%) | 27,047 (5%) | <0.001 |
| Chronic pulmonary disease | 4196 (32%) | 3433 (33%) | 31,290 (30%) | 77,702 (16%) | <0.001 |
| Diabetes without chronic complications | 3796 (29%) | 3101 (30%) | 27,491 (26%) | 79,674 (16%) | <0.001 |
| Diabetes with chronic complications | 886 (7%) | 770 (7%) | 6639 (6%) | 14,747 (3%) | <0.001 |
| Hypothyroidism | 3501 (27%) | 2857 (27%) | 24,600 (23%) | 67,746 (14%) | <0.001 |
| Renal failure | 1307 (10%) | 1109 (11%) | 9721 (9%) | 25,912 (5%) | <0.001 |
| Liver disease | 520 (4%) | 444 (4%) | 4848 (5%) | 9497 (2%) | <0.001 |
| Chronic peptic ulcer disease | 47 (0%) | 24 (0%) | 301 (0%) | 648 (0%) | <0.001 |
| HIV/AIDS | 21 (0%) | 17 (0%) | 353 (0%) | 1309 (0%) | <0.001 |
| Lymphoma | 187 (1%) | 149 (1%) | 1814 (2%) | 4627 (1%) | <0.001 |
| Metastatic cancer | 196 (1%) | 169 (2%) | 2353 (2%) | 6071 (1%) | <0.001 |
| Solid tumor without metastasis | 1518 (12%) | 1258 (12%) | 15,169 (14%) | 44,233 (9%) | <0.001 |
| Rheumatoid arthritis/collagen vascular diseases | 2046 (16%) | 1730 (17%) | 14,491 (14%) | 28,413 (6%) | <0.001 |
| Coagulation deficiency | 1038 (8%) | 978 (9%) | 6457 (6%) | 17,073 (3%) | <0.001 |
| Obesity | 2850 (22%) | 2439 (23%) | 16,189 (15%) | 34,765 (7%) | <0.001 |
| Weight loss | 998 (8%) | 704 (7%) | 7947 (8%) | 17,727 (4%) | <0.001 |
| Fluid and electrolyte disorders | 4317 (33%) | 3435 (33%) | 26,827 (26%) | 69,409 (14%) | <0.001 |
| Blood loss anemia | 614 (5%) | 580 (6%) | 3014 (3%) | 8305 (2%) | <0.001 |
| Deficiency anemias | 4896 (37%) | 4606 (44%) | 29,178 (28%) | 79,446 (16%) | <0.001 |
| Alcohol abuse | 392 (3%) | 365 (3%) | 3167 (3%) | 8606 (2%) | <0.001 |
| Drug abuse | 469 (4%) | 332 (3%) | 3162 (3%) | 5168 (1%) | <0.001 |
| Psychoses | 977 (7%) | 756 (7%) | 7544 (7%) | 15,884 (3%) | <0.001 |
| Depression | 3178 (24%) | 2739 (26%) | 19,354 (18%) | 38,734 (8%) | <0.001 |
| Average CCI score | 5.33 | 5.36 | 5.43 | 4.75 | <0.001 |
| Median CCI score | 5 | 5 | 5 | 4 |
| SD for CCI score | 2.14 | 2.17 | 2.32 | 1.93 |

CCI = Charlson Comorbidity Index, HTN = hypertension, LSF = lumbar spinal fusion, THA = total hip arthroplasty
before THA. Hence, doing LSF after THA in 50 cases prevents one late THA revision caused by THA after LSF.

**Discussion**

As the utilization of THA and LSF increases and the general population ages, the cohort of patients who present with concurrent degenerative hip and spine disease who benefit from both interventions will also increase. As our understanding of spinopelvic mobility and its effect on the mechanics of the hip joint continues to improve, so has the literature solidifying both previous LSF and degenerative lumbar disease as risk factors for THA dislocation. We sought to answer the question of which surgery should be done first to minimize complications. Our data suggest that LSF should be done after THA to minimize dislocation and revision risk.

Our results of increased dislocation, revision, and overall surgical complications for THA done after LSF align with the established literature. Buckland et al found dislocation rates for THA after LSF between 3% and 4%, similar to those seen in our study. Sing et al found 2-year revision rates for THA after LSF between 5% and 7%, again reflecting our findings. In addition, our data also corroborate the literature which demonstrates that lumbar spine disease in the absence of LSF also places patients at risk of dislocation and revision after THA. As there are no similar studies examining LSF after THA, we cannot directly compare our results for this group.

Decreased dislocation risk with LSF done after THA in comparison with THA after LSF can be explained from multiple angles. From a biomechanical perspective, a patient who has LSF done after THA may have a stable well-performing THA with a well-positioned acetabular implant in an already stiff and immobile spine. Therefore, the subsequent correction of lumbar lordosis with added...
stability and stiffness after LSF is insufficient to alter functional anteverision, and the risk of dislocation does not substantially increase. From a patient selection perspective, patients who have chronic THA instability may not be considered safe surgical candidates, and surgeons may inherently select against doing LSF in patients with a known history of recurrent surgical complications. Although literature to support this explanation is lacking, careful preoperative planning before spine fusion in a value-based health care environment is becoming increasingly important, and thus, such exclusion criteria may be relevant. Finally, early postoperative spine restrictions limiting bending, lifting, and twisting in the setting of newly altered spinopelvic mobility may prevent patients from engaging in positions predisposing to THA dislocation. This concept, however, requires additional validation.

The capsule, short external rotators, and abductors all contribute to THA stability. Hip instability is multifactorial with patients falling into early (<3 months) and late (>3 months) instability. Early dislocation is caused by surgical issues related to soft-tissue tension and component position. Late dislocation is due to deteriorating neuromuscular function, polyethylene wear, component migration, or infection. In this case, a patient with a stable well-performing THA which has had sufficient time for bone ingrowth (if cementless), soft-tissue healing and scarring, and adequate time for surrounding muscular strengthening may be better suited to handle the changes in spinopelvic mobility imposed by an LSF. This is in contrast to having THA done after pre-existing LSF, in which case a new hip prosthesis is placed into an unfavorable mobility

Table 4

| Factors                        | THA After LSF | LSF After THA | THA, Spine Path, No LSF | THA, No Spine Path | 4-Way X² P | THA After LSF Versus LSF After THA Only (OR, 95% CI) | P value |
|-------------------------------|--------------|--------------|-------------------------|-------------------|-----------|--------------------------------------------------|---------|
| n                             | 13,102       | 10,482       | 104,820                 | 492,654           |           |                                                  |         |
| Complication                  |              |              |                         |                   |           |                                                  |         |
| Wound complication            | 132 (1.0%)   | 214 (2.0%)   | 909 (0.9%)              | 2988 (0.6%)       | <0.001    | 0.488 (0.392-0.608)                              | <0.001  |
| Vascular injury               | 49 (0.4%)    | 41 (0.4%)    | 386 (0.4%)              | 1703 (0.3%)       | 0.578     | 0.956 (0.631-1.449)                              | 0.832   |
| PJL                           | 352 (2.7%)   | 174 (1.7%)   | 2470 (2.4%)             | 8531 (1.7%)       | <0.001    | 1.636 (1.361-1.965)                              | <0.001  |
| Periprosthetic fracture       | 179 (1.4%)   | 52 (0.5%)    | 1174 (1.1%)             | 4236 (0.9%)       | <0.001    | 2.778 (2.038-3.787)                              | <0.001  |
| Implant dislocation           | 608 (4.6%)   | 174 (1.7%)   | 3329 (3.2%)             | 11,229 (2.3%)     | <0.001    | 2.883 (2.431-3.419)                              | <0.001  |
| Bearing surface wear          | 25 (0.2%)    | 26 (0.2%)    | 141 (0.1%)              | 573 (0.1%)        | <0.001    | 0.769 (0.444-1.332)                              | 0.347   |
| Osteolysis                    | 22 (0.2%)    | 29 (0.3%)    | 98 (0.1%)               | 517 (0.1%)        | <0.001    | 0.606 (0.348-1.056)                              | 0.074   |
| Implant loosening             | 220 (1.7%)   | 200 (1.9%)   | 1267 (1.2%)             | 4243 (0.9%)       | <0.001    | 0.878 (0.724-1.065)                              | 0.187   |
| Broken implant                | 70 (0.5%)    | 50 (0.5%)    | 526 (0.5%)              | 2102 (0.4%)       | 0.003     | 1.121 (0.779-1.612)                              | 0.539   |
| Cellulitis                    | 680 (5.2%)   | 383 (3.7%)   | 5528 (5.3%)             | 19,844 (4.0%)     | <0.001    | 1.443 (1.270-1.640)                              | <0.001  |
| Other postoperative infection | 431 (3.3%)   | 553 (5.3%)   | 3308 (3.2%)             | 12,153 (2.5%)     | <0.001    | 0.611 (0.537-0.695)                              | <0.001  |
| Heterotopic ossification      | 33 (0.3%)    | 15 (0.1%)    | 414 (0.4%)              | 1014 (0.2%)       | <0.001    | 1.762 (0.957-3.246)                              | 0.066   |
| Cup-liner dissociation        | 221 (1.7%)   | 151 (1.4%)   | 1167 (1.1%)             | 3653 (0.7%)       | <0.001    | 1.174 (0.953-1.446)                              | 0.132   |
| THA revision                  | 745 (5.7%)   | 384 (3.7%)   | 4387 (4.2%)             | 16,198 (3.3%)     | <0.001    | 1.585 (1.398-1.798)                              | <0.001  |
| THA arthroscopy/I&D           | 207 (1.6%)   | 106 (1.0%)   | 1757 (1.7%)             | 6232 (1.3%)       | <0.001    | 1.571 (1.242-1.989)                              | <0.001  |

CI = confidence interval, I&D = irrigation and débridement, LSF = lumbar spinal fusion, OR = odds ratio, PJI = periprosthetic joint infection, THA = total hip arthroplasty
environment and does not have a sufficiently healed soft-tissue envelope to protect against instability. This idea fits conceptually with the timing of the dislocations identified in our study, where THA after LSF had a comparatively higher proportion of early dislocations (2.8% by 90 days and 4.6% by 2 years, a 2-fold increase), while most of the dislocations identified for the LSF after THA group were late (0.2% by 90 days and 1.7% by 2 years, an 8.5-fold increase). Although there is evidence that early soft-tissue healing is seen after THA, it can take multiple years until complete scar maturity.26 During this interval, patients with a new primary THA with a previous LSF may be at increased risk until sufficient capsule healing, scar formation, and muscle strengthening are achieved. This concept is not well studied in the THA literature; however, it is observed with modern radial head replacements. In this case, soft-tissue healing and scar formation around the radio capitellar joint, rather than the mechanical properties and position of the implant, help the elbow joint achieve stability and account for the excellent functional outcomes of nonpress fit, cementless radial head replacements.27 Studies involving administrative claims have inherent limitations which are important to discuss in this study. Evidence in both the arthroplasty and spine literature is mixed on the accuracy and validity of administrative claims in identifying postoperative complications.28-31 Moreover, we do not have patient-specific identifiers or direct clinical information that allows for more complex multivariate regression analysis. Although we were able to match patients by age and sex, there were still differences in comorbidities among the groups which may confound our surgical outcomes. However, the fact that our two main groups of interest (THA after LSF, and LSF after THA) had no difference in the CCI score, and a very similar Elixhauser comorbidity profile is reassuring that our question of timing of fusion versus arthroplasty is not confounded by differences in baseline health status. We were also not able to examine surgical approach for the THA as this is not coded in the database, which may have an effect on dislocation based on spinopelvic position. Finally, we were not able to specifically delineate the amount of correction nor specific involvement of sacroiliac fusion, which may also affect our results. However, we hope that our results serve as a springboard for future study in more specific groups which may be able to answer these questions. As the utilization of both THA and LSF increase, there will be a larger cohort of patients who will benefit from both interventions. Our results suggest that for patients indicated to undergo both procedures, doing THA first with LSF to follow at a later date is associated with a lower risk of instability and revision THA. Reasons may include minimal adjustment in spinopelvic parameters, patient selection, and improved stability from a well-healed soft-tissue envelope. Additional investigation is certainly warranted; yet, we believe these results will help surgeons in counseling patients and in preoperative planning.

References

1. Devin CJ, McCullough KA, Morris BJ, Yates AJ, Kang JD: Hip-spine syndrome. J Am Acad Orthop Surg 2012;20:434-442.
2. Offierski CM, MacNab I: Hip-spine syndrome. Spine 1983;8:316-321.
3. Kurtz S, Ong K, Lau E, Mowat F, Halpern M: Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am Vol 2007;89:780-785.
4. Yoshihara H, Yoneoka D: National trends in the surgical treatment for lumbar degenerative disc disease: United States, 2000 to 2009. Spine J 2015;15:263-271.
5. Esposito CI, Carroll KM, Sculco PK, Padgett DE, Jerabek SA, Mayman DJ: Total hip arthroplasty patients with fixed spinopelvic alignment are at higher risk of hip dislocation. J Arthroplasty 2018;33:1449-1454.
6. Stefl M, Lundergan W, Heckmann N, et al: Spinopelvic mobility and acetabular component position for total hip arthroplasty. Bone Joint J 2017;99-b(1 supp A):37-45.
7. Lum ZC, Coury JG, Cohen JL, Dorr LD: The current knowledge on spinopelvic mobility. J Arthroplasty 2018;33:291-296.
8. Jackson RP, McManus AG: Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine 1994;19:1611-1618.
9. Barry JJ, Yucekul A, Theologis AA, Hansen EN, Ames C, Deviren V: Spinal realignment for adult deformity: Three-column osteotomies alter total hip acetabular component positioning. J Am Acad Orthop Surg 2017;25:125-132.
10. Esposito CI, Miller TT, Kim HJ, et al: Does degenerative lumbar spine disease influence femoroacetabular flexion in patients undergoing total hip arthroplasty? Clin Ortoph Relat Res 2016;474:1788-1797.
11. Sing DC, Barry JJ, Aguilar TU, et al: Prior lumbar spinal arthrodesis increases risk of prosthetic-related complication in total hip arthroplasty. J Arthroplasty 2016;31(9 suppl):227-232.e1.
12. Staihano P, Winemaker M, Petruccelli D, de Beer J: Total joint arthroplasty and prooperative low back pain. J Arthroplasty 2014;29:867-871.
13. Parviz I, Pour AE, Hillibrand A, Goldberg G, Sharkey PF, Rothman RH: Back pain and total hip arthroplasty: A prospective natural history study. Clin Ortoph Relat Res 2010;468:1325-1330.
14. Hsieh PH, Chang Y, Chen DW, Lee MS, Shih HN, Ueng SW: Pain distribution and response to total hip arthroplasty: A prospective observational study in 113 patients with end-stage hip disease. J Orthop Sci 2012;17:213-218.
15. DelSole EM, Vigdorich JM, Schwarzkopf R, Errico TJ, Buckland AJ: Total hip arthroplasty in the spinal deformity population: Does degree of sagittal deformity affect rates of safe zone placement, instability, or revision? J Arthroplasty 2017;32:1910-1917.
16. Buckland AJ, Puvanesarajah V, Vigdorich J, et al: Dislocation of a primary total hip arthroplasty is more common in patients with a lumbar spinal fusion. Bone Joint J 2017;99-b:585-591.
17. An VVG, Phan K, Sivakumar BS, Mobbs RJ, Bruce WJ: Prior lumbar spinal fusion is associated with an increased risk of dislocation and revision in total hip arthroplasty: A meta-analysis. *J Arthroplasty* 2018;33:297-300.

18. Blizzard DJ, Sheets CZ, Seyler TM, et al: The impact of lumbar spine disease and deformity on total hip arthroplasty outcomes. *Orthopedics* 2017;40:e520-e525.

19. Elixhauser A, Steiner C, Harris DR, Coffey RM: Comorbidity measures for use with administrative data. *Med Care* 1998;36:8-27.

20. Gordon M, Stark A, Skoldenberg OG, Karrholm J, Garellick G. The influence of comorbidity scores on re-operations following primary total hip replacement: Comparison and validation of three comorbidity measures. *Bone Joint J* 2013;95-b:1184-1191.

21. Axelsson P, Karlsson BS: Intervertebral mobility in the progressive degenerative process. A radiostereometric analysis. *Eur Spine J* 2004;13:567-572.

22. Buchlak QD, Yanamadala V, Leveque JC, Sethi R: Complication avoidance with pre-operative screening: Insights from the seattle spine team. *Carr Rev Musculoskelet Med* 2016;9:316-326.

23. Brooks PJ. Dislocation following total hip replacement: Causes and cures. *Bone Joint J* 2013;95-b[11 suppl A]:67-69.

24. Parvizi J, Wade FA, Rapuri V, Springer BD, Berry DJ, Hozack WJ: Revision hip arthroplasty for late instability secondary to polyethylene wear. *Clin Orthop Relat Res* 2006;447:66-69.

25. von Knoch M, Berry DJ, Harmsen WS, Morrey BF: Late dislocation after total hip arthroplasty. *J Bone Joint Surg Am* Vol 2002;84-a:1949-1953.

26. McLawhorn AS, Potter HG, Cross MB, et al: Posterior soft tissue repair after primary THA is durable at mid-term followup: A prospective MRI study. *Clin Orthop Relat Res* 2015;473:3183-3189.

27. Acevedo DC, Paxton ES, Kukelyansky I, Abboud J, Ramsey M: Radial head arthroplasty: State of the art. *J Am Acad Orthop Surg* 2014;22:633-642.

28. Bozic KJ, Bashyal RK, Anthony SG, Chiu V, Shulman B, Rubash HE: Is administratively coded comorbidity and complication data in total joint arthroplasty valid? *Clin Orthop Relat Res* 2013;471:201-205.

29. Clair AJ, Innehi IA, Iorio R, et al: Can administrative data be used to analyze complications following total joint arthroplasty? *J Arthroplasty* 2015;30:17-20.

30. Patel NK, Moses RA, Martin BI, Lurie JD, Mirza SK: Validation of using claims data to measure safety of lumbar fusion surgery. *Spine* 2017;42:682-691.

31. Kazberouk A, Martin BI, Stevens JP, McGuire KJ: Validation of an administrative coding algorithm for classifying surgical indication and operative features of spine surgery. *Spine* 2015;40:114-120.

### Appendix 1

#### List of ICD-9 and CPT codes used in this study

| Code Type | Description |
|-----------|-------------|
| **THA** | CPT: 27130, ICD-9: 81.51 |
| **LSF** | ICD-9: 81.06-81.08, 81.62, 81.63 |
| **LSF revision** | ICD-9: 813-813.9, CPT: 22849, 22850, 22852, 22855 |
| **Wound complication** | ICD-9: 998.32 |
| **Neural deficit** | ICD-9: 997.00, 965.0-956.9 |
| **Vascular injury** | ICD-9: 997.2 |
| **PJI** | ICD-9: 996.66 |
| **Periprosthetic fracture** | ICD-9: 996.44 |
| **Implant dislocation** | ICD-9: 996.42 |
| **Bearing surface wear** | ICD-9: 996.46 |
| **Osteolysis** | ICD-9: 996.45 |
| **Implant loosening** | ICD-9: 996.41 |
| **Broken implant** | ICD-9: 996.43 |
| **Cellulitis** | ICD-9: 682.6, 682.9 |
| **Other postoperative infection** | ICD-9: 998.59 |
| **Heterotopic ossification** | ICD-9: 728.13 |
| **Cup-liner dissociation** | ICD-9: 996.47 |
| **THA revision** | CPT: 27090, 27091, 27134, 27137, 27138, ICD-9: 81.53, 00.70, 00.71, 00.72, 00.73 |
| **THA arthrotomy/I&D** | ICD-9: 80.00, 80.05, 80.10, 80.15, 80.75, CPT: 26990, 26992, 27030, 27033, 27052, 27054, 10140, 27036, 27301, 27303 |