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Health Policy

Cost Utility Analysis of Lumbar Interlaminar Epidural Injections in the Treatment of Lumbar Disc Herniation, Central Spinal Stenosis, and Axial or Discogenic Low Back Pain

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Conflict of Interest: Dr. Manchikanti has provided limited consulting services to Semnur Pharmaceuticals, Incorporated, which is developing nonparticulate steroids. Dr. Benyamin is a consultant for Medtronic. Dr. Hirsch is a consultant for Medtronic.

Background: Cost utility or cost effective analysis continues to take center stage in the United States for defining and measuring the value of treatments in interventional pain management. Appropriate cost utility analysis has been performed for caudal epidural injections, percutaneous adhesiolysis, and spinal cord stimulation. However, the literature pertaining to lumbar interlaminar epidural injections is lacking, specifically in reference to cost utility analysis derived from randomized controlled trials (RCTs) with a pragmatic approach in a practical setting.

Objectives: To assess the cost utility of lumbar interlaminar epidural injections in managing chronic low back and/or lower extremity pain secondary to lumbar disc herniation, spinal stenosis, and axial or discogenic low back pain.

Study Design: Analysis based on 3 previously published randomized trials of effectiveness of lumbar interlaminar epidural injections assessing their role in disc herniation, spinal stenosis, and axial or discogenic pain.

Setting: A contemporary, private, specialty referral interventional pain management center in the United States.

Methods: Cost utility of lumbar interlaminar epidural injections with or without steroids in managing lumbar disc herniation, central spinal stenosis, and discogenic or axial low back pain was conducted with data derived from 3 RCTs that included a 2-year follow-up, with inclusion of 360 patients. The primary outcome was significant improvement defined as at least a 50% in pain reduction and disability status. Direct payment data from 2016 was utilized for assessment of procedural costs. Overall costs, including drug costs, were determined by multiplication of direct procedural payment data by a factor of 1.67 to accommodate for indirect payments respectively for disc herniation, spinal stenosis, discogenic pain.

Results: The results of 3 RCTs showed direct cost utility for one year of quality-adjusted life year (QALY) of $2,050.87 for disc herniation, $2,112.25 for axial or discogenic pain without disc herniation, and $1,773.28 for spinal stenosis, with an average cost per one year QALY of $1,976.58, with total estimated costs of $3,425, $3,527, $2,961, and $3,301 respectively.

Limitations: The limitation of this cost utility analysis includes that it is a single center evaluation, even though 360 patients were included in this analysis. Further, only the costs of interventional procedures and physician visits were assessed based on the data, with extrapolation of indirect costs presenting the overall total costs. The benefits of returning to work were not assessed.

Conclusion: This cost utility analysis of lumbar interlaminar epidural injections in patients nonresponsive to conservative management in the treatment of disc herniation, central spinal stenosis, and axial or discogenic low back pain in the lumbar spine shows the clinical effectiveness and cost utility of these injections of $1,976.58 for direct costs with a total cost of $3,301 per QALY.

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Key words: Lumbar interlaminar epidural injections, chronic low back pain, lumbar disc herniation, lumbar discogenic pain, cost utility analysis, cost effectiveness analysis, quality-adjusted life years

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With the passage and implementation of the Affordable Health Care Act (ACA) (1-3), focused on quality (4-10) and reduction in cost of care (1-3,11). Increasing attention has been focused on defining and measuring the value of interventions in general, and interventional techniques in particular (12-38). The increasing prevalence of chronic low back with or without lower extremity pain and health care costs, which have been described as escalating at an unsustainable rate, are continuing problems in managing spinal pain (39-53). In addition to escalating use of surgical interventions (42,43,52,53), various non-surgical interventions are extensively utilized with variable and often discordant conclusions of safety and effectiveness (12,13,46-51,54-74). Among these modalities, lumbar epidural injections are a commonly used modality in disc herniation, discogenic pain, and spinal stenosis prior to surgical intervention, after the failure of surgical intervention, in patients with or without indications or contraindications for surgical intervention (12,13,54-58,63,64,71-78).

Lumbar epidural access with an interlaminar approach is one of the commonly used approaches in managing low back and lower extremity pain apart from caudal epidural injections and transforaminal epidural injections (12,13,54-58,63,64,71-78). Consequently, the use of these procedures has been increasing significantly (46,47,49). The studies of the Medicare population showed that while all interventional techniques for chronic pain increased 153% per 100,000 Medicare beneficiaries from 2000 to 2014 (46,47), overall lumbar epidural injections increased 99%, and lumbar transforaminal epidurals increased 609%, whereas lumbar epidurals including interlaminar and caudal decreased 2% (49).

Martin et al (39), in the assessment of health care expenditures in managing back and neck problems, found that expenditures totaled approximately $86 billion. These expenditures showed that there was an increase of 49% in the number of patients seeking spine-related care while the expenses increased 65%. Gaskin and Richard (45) showed costs of chronic pain of approximately $100 billion per year. More recently, Dieleman et al (40), in evaluating US spending on personal health care and public health from 1996 to 2013, showed that low back and neck pain accounted for the third highest amount, with estimated health care spending of $87.6 billion in 2013. Further, they also showed that spending on low back and neck pain and on diabetes increased the most over the 18 years, by an estimated $57.2 billion and $64.4 billion, respectively.

Due to continued escalating health care costs and debate on the effectiveness of multiple interventions, cost effectiveness or cost utility analysis has become a cornerstone in health policy including for epidural injections (16-28). The cost utility has been described to estimate the ratio between the cost of a health-related intervention and the benefit it produces in terms of the number of years lived in full health by the patient receiving the intervention. As such, it can be considered as a special type of cost effectiveness analysis. Thus, cost effectiveness and cost utility are sometimes mistakenly used interchangeably. In a scenario of cost utility analysis, cost is measured in monetary units, unlike a cost-benefit analysis in which the benefit does not have to be expressed in monetary terms. Numerous interventions conducted in assessing the cost utility analysis have resulted in highly variable conclusions. Two well publicized cost effectiveness analysis studies of surgical versus non-operative treatment for lumbar disc herniation and spinal stenosis with and without degenerative spondylolisthesis showed $69,403 per quality-adjusted life year (QALY) in managing lumbar disc herniation, $77,600 in managing spinal stenosis without degenerative spondylolisthesis, and $115,600 in managing spinal stenosis with degenerative spondylolisthesis (23,24). Similarly, Taylor et al (27) showed cost effectiveness of spinal cord stimulation at £5,624 per QALY. Cost utility analysis was performed for interventional techniques utilizing RCTs by Manchikanti et al (25,26) and showed cost utility of caudal epidural injections at $2,172.50 in 480 patients suffering with various conditions and $2,650 in percutaneous adhesiolysis in the United States. However, Manchikanti et al provided the data only on direct procedural costs without inclusion of indirect costs or drug therapy. Tosteson et al (23,24), in their landmark cost utility analysis, showed direct costs of 60% in spinal stenosis, 68% in disc herniation, and 71% in spinal stenosis with degenerative spondylolisthesis, with highest indirect costs for spinal stenosis of 40%. Thus, utilizing direct medical costs at 60%, the data from Manchikanti et al (24-26) was multiplied by 1.67, deriving cost utility of caudal epidural injections of $3,628 per QALY (25) and $4,426 for percutaneous adhesiolysis per QALY (26).

We sought to derive a reliable and valid overall assessment of cost utility data with assessment of direct costs and addition of drug and indirect costs, utilizing 3 lumbar interlaminar epidural injections RCTs in disc herniation, central spinal stenosis, and discogenic pain with low back and lower extremity pain with a 2-year follow-up (76-78).

Methods

Study Design

The cost utility analysis for this assessment was performed based on 3 double-blind RCTs, which assessed effectiveness of lumbar interlaminar epidural injections in managing low back and lower extremity pain secondary to disc herniation (78), discogenic or axial pain without disc herniation (76)¸ and lumbosacral central spinal stenosis (77). The methodology utilized in performing these studies has been described in their respective manuscripts (76-78). Appropriate diagnosis was established in all patients with disc herniation, axial or discogenic pain, and central spinal stenosis based on a multitude of investigations including diagnostic facet joint nerve blocks in patients with discogenic pain. Further, all the patients have failed conservative management with structured exercise program, physical therapy or occupational therapy, and drug therapy.

Outcome Measures

Outcome measures included pain rating and disability status. Pain rating was determined on an 11-point Numeric Rating Scale (NRS) and disability and functional status were assessed based on a 50-point Oswestry Disability Index (ODI). Intermittent post treatment outcomes were assessed for 2 years. Primary outcome was determined as significant improvement of 50% reduction in pain and increase in function.

Analysis

Each trial consisted of 120 patients assigned to either a control group receiving 6 mL of 0.5% local anesthetic only or an intervention group receiving 5 mL of 0.5% local anesthetic mixed with 6 mg of 1 mL of Celestone.

Detailed analysis is provided in the manuscripts (76-78). For analysis of the direct procedural cost utility, reimbursement rates were utilized from 2016 for calculating costs for physician services and the facility costs based on each patient's payer status. Overall costs were estimated by multiplying direct procedural costs by a factor of 1.67 based on previous studies (23,24).

Results

Patient Flow

Figure 1 shows the patient flow diagram of the RCTs of 3 lumbar interlaminar epidural injection trials.

Outcomes

Table 1 shows baseline demographic characteristics of patients enrolled in 3 trials. Table 2 shows characteristics of pain relief and functional status improvement as evaluated by NRS and ODI. Figure 2 shows the proportion of patients with significant reduction in pain scores and improvement in ODI scores.

Adverse Events

No additional costs were incurred due to adverse events occurring in any of the 360 patients during the study period.

Cost Utility Analysis

Cost utility analysis was based on the quality of life improvement and cost for procedure per QALY based on the primary outcomes of pain relief and improvement in functional status. As shown in Table 3, direct cost utility for one-year improvement in QALY was $2,050.87 for disc herniation, $2,112.25 for discogenic pain, and $1,773.28 for spinal stenosis. Overall direct procedural cost utility for one year of improvement in quality of life was $1,976.58. Average total direct cost per patient in 2 years was $2,496.17. Total costs for one-year improvement of quality of life with multiplication of direct cost by a factor of 1.67 showed cost utility of $3,425 for disc herniation per QALY, $3,527 for discogenic pain per QALY, $2,961 for spinal stenosis per QALY, and $3,301 on average for all epidural injections per QALY.

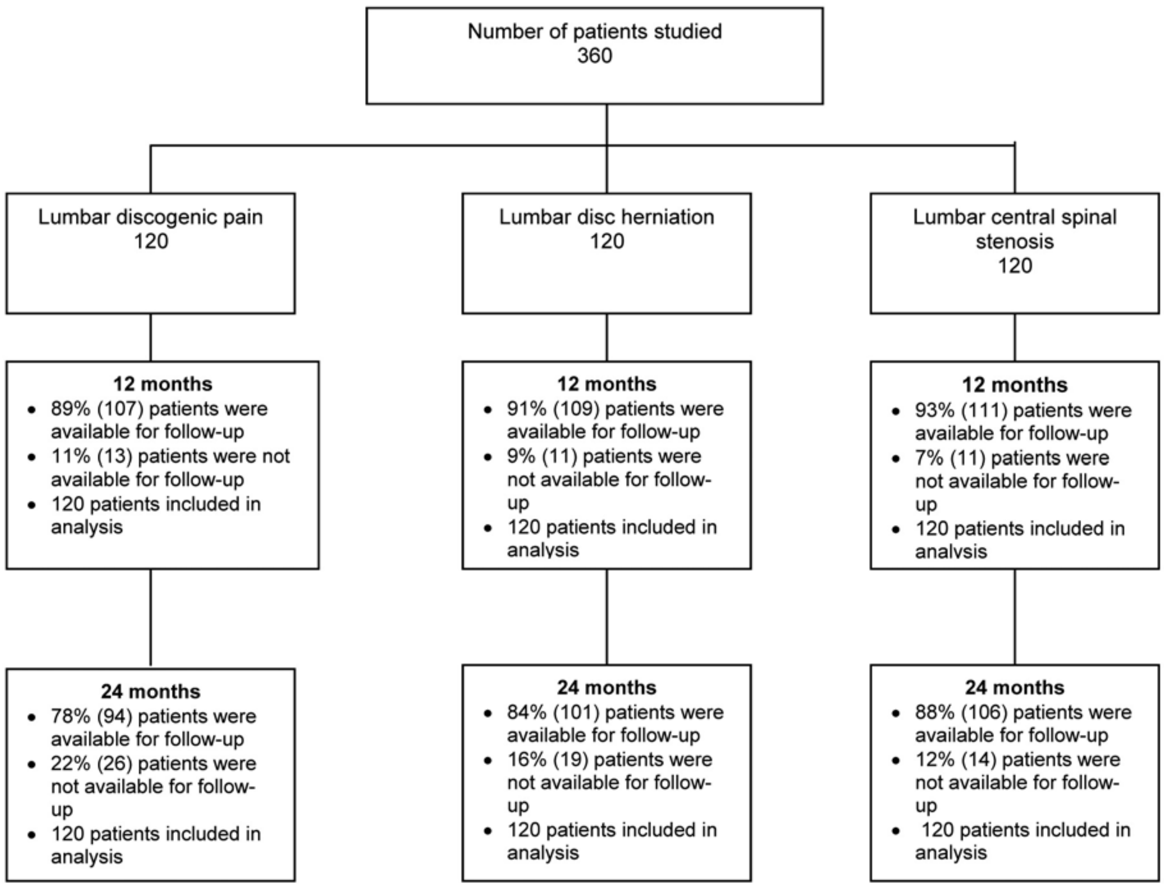

Fig. 1. *Patient flow diagram of randomized controlled trials of lumbar interlaminar epidural injections (76-78).*

Table 1. *Baseline demographic characteristics of patients of lumbar interlaminar epidural injections trials of disc herniation, discogenic pain, and spinal stenosis (76-78).*

	Discogenic Pain	Disc Herniation	Spinal Stenosis	Pooled	*P* value
Number of patients	120	120	120	360	
Age	42 ± 11.6	45 ± 13.9	52* ± 14.6	46 ± 14.1	0.001
Gender (M/F)	32% / 68%	50% / 50%	43% / 57%	43% / 57%	0.014
Duration of Pain (months)	116 ± 99.4	134 ± 114.9	115 ± 92.7	122 ± 102.6	0.227
Mode of Onset of the Pain (Gradual)	68%	67%	80%*	72%	0.044

Discussion

The cost utility analysis was derived from 3 RCTs with a 2-year follow-up with data from 360 patients, nonresponsive to conservative management, undergoing lumbar interlaminar epidural injections with outcomes data. The results showed overall 74% of the patients met the primary outcome criteria of significant improvement with 50% pain relief and improvement in functional status with 69% at the end of 2 years. The total costs for one-year improvement in QALY were $3,425 for disc herniation, $3,527 for discogenic pain, and $2,961 for central spinal stenosis, with an average of $3,301 for interlaminar epidural treatment with local

Table 2. *Pain relief and functional status improvement evaluated by Numeric Rating Scale (NRS) and Oswestry Disability Index (ODI) (76-78).*

Numeric Rating Scores	Disc Herniation	Discogenic Pain	Central Spinal Stenosis	Pooled
Baseline	8.1 ± 0.9	7.8 ± 0.9	8.0 ± 0.9	8.0 ± 0.9
6 months	3.8* ± 1.4 (79%)	3.7* ± 1.1 (79%)	3.8* ± 1.7 (78%)	3.8* ± 1.4 (79%)
12 months	3.7* ± 1.4 (78%)	3.7* ± 1.2 (74%)	3.7* ± 1.8 (75%)	3.7* ± 1.5 (76%)
24 months	3.9* ± 1.5 (67%)	3.7* ± 1.4 (73%)	3.7* ± 1.8 (73%)	3.8* ± 1.6 (71%)
Oswestry Disability Index Scores				
Baseline	30.0 ± 4.8	29.9 ± 4.9	30.7* ± 7.4	30.2* ± 5.8
6 months	14.8* ± 5.7 (76%)	14.9* ± 5.0 (75%)	14.9* ± 6.1 (76%)	14.9* ± 5.6 (76%)
12 months	14.4* ± 5.8 (78%)	15.0* ± 5.7 (73%)	14.7* ± 6.4 (75%)	14.7* ± 6.0 (75%)
24 months	14.8* ± 6.0 (68%)	14.7* ± 5.6 (71%)	14.4* ± 6.9 (75%)	14.7* ± 6.2 (71%)

(____) illustrates proportion with significant pain relief (≥ 50%) from baseline
* significant difference with baseline values ($P < 0.001$)

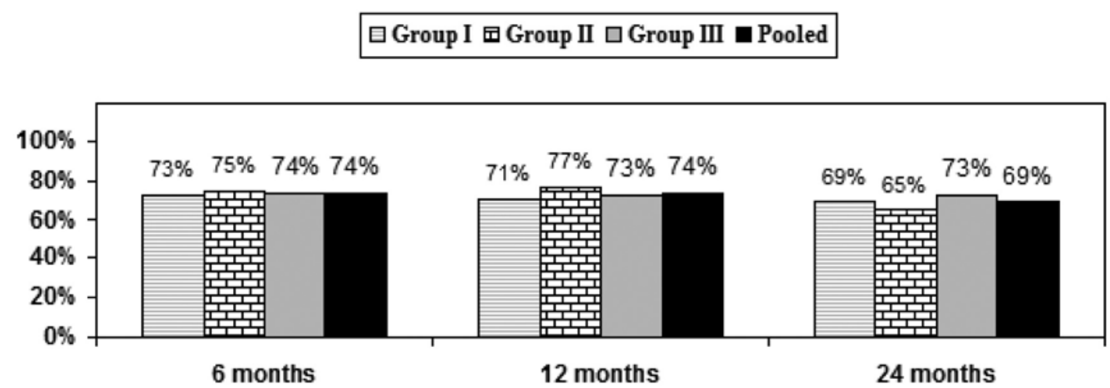

Fig. 2. *Proportion of patients with significant reduction in Numeric Rating Scale (NRS) and Oswestry Disability Index (ODI) scores (≥ 50% reduction from baseline) (76-78).*

anesthetics with or without steroids. A lower cost for spinal stenosis of $2,961 compared to $3,527 for discogenic pain appears to show a non-significant difference based on somewhat higher significant improvement per procedure of 13.2 ± 12.7 weeks compared to the average improvement of 11.5 ± 8.8 weeks. Consequently, the number of procedures performed in the spinal stenosis group were also less compared to the disc herniation and discogenic pain groups.

The results of the present assessment are similar to previously published cost utility analysis of caudal epidural injections utilizing similar methodology performed in the same clinical setting with a pragmatic approach at an average cost of $3,628 per QALY (25). However, the cost utility of lumbar interlaminar epidural injections compared to the previous analysis, based on RCTs of percutaneous adhesiolysis, is lower than $4,426 per QALY (26). In addition, the cost utility analysis also shows lower cost compared to spinal cord stimulation in post lumbar surgery syndrome of CAN $9,293 per QALY (30) and £5,624 per QALY (27). These results are also superior to the results by Whynes et al (79) reporting the cost effectiveness of lumbar interlaminar epidural injections at £8,975 per QALY, which was rather more expensive than spinal cord stimulation.

In global analysis of various modalities of interventions utilized in spine treatment in a systematic review, Kepler et al (19) analyzed 33 studies with only 45% of the cost utility assessments showing costs less than $100,000 per QALY, whereas around 23% showed costs greater than $100,000 per QALY. Similarly, Indrakanti et al (20), assessing cost utility analysis of value-based care in 27 studies, showed that studies of nonoperative treatments demonstrated greater value. Dagenais et

Table 3. *Cost utility analysis of lumbar interlaminar epidural injections in managing pain and disability of disc herniation, discogenic pain, and spinal stenosis.*

	Disc Herniation	Discogenic Pain	Spinal Stenosis	Total
Number of patients	120	120	120	360
Total number of procedures for 2 years	682	714	644	2040
Number of treatments for 2 years per patient (mean) ± SD	5.7 ± 2.5	6.0 ± 2.5	5.4 ± 2.6	5.7 ± 2.6
Number of weeks with significant improvement for all patients in the study in weeks	7667	7900	8074	23641
Significant improvement in weeks per procedure (mean) ± SD	10.8 ± 5.7	10.5 ± 5.9	13.2 ± 12.7	11.5 ± 8.8
Direct procedural costs without drug costs ($)				
Physician	$85,443	$93,250	$66,342	$245,036
Facility	$216,942	$227,649	$208,994	$653,585
Total	$302,385	$320,899	$275,336	$898,620
Direct costs per procedure ($)				
Physician	$125.28	$130.60	$103.02	$120.12
Facility	$318.10	$318.84	$324.52	$320.38
Total	$443.38	$449.44	$427.54	$440.50
Average total direct costs per patient in 2 years	$2,519.88	$2,674.16	$2,294.47	$2496.17
Direct procedural improvement in quality of life ($)	$2,050.87	$2,112.25	$1,773.28	$1,976.58
Indirect costs including drug costs for 1-year improvement in quality of life ($)	$1,374.08	$1,791.68	$1,188.10	$1,324.31
Total estimated costs including procedural costs, costs of medicine and other indirect costs for 1-year improvement in quality of life ($)	$3,425	$3,527	$2,961	$3,301

Total costs ($) for one-year improvement of quality of life

al (16) also showed cost utility to range from $304 to $579,527, with a median cost of $13,015 per QALY.

Thus, lumbar interlaminar epidural injections are also superior in terms of quality adjusted life years to non-interventional conservative management treatments. As an example, an exercise program and education were found to be superior to education alone, for patients with low back pain for more than 3 months, resulting in a QALY of $8,650 (80). Fritz et al (38) conducted a cost effectiveness study of primary care management for acute low back pain and showed early physical therapy resulted in better quality of life with an incremental cost effectiveness ratio of $32,058 per QALY. They emphasized the importance of simultaneously conducting clinical effectiveness and cost effectiveness, since for a condition such as low back pain, nearly all interventions are characterized by small treatment effects.

Multiple surgical interventions have been assessed for cost utility and cost effectiveness analysis in conjunction with the clinical effectiveness. Tosteson et al (23,24) assessed the clinical effectiveness data from the SPORT trials for surgical treatment for disc herniation relative to nonoperative care and found cost effectiveness was $69,403 per QALY gained in the general population and $34,355 in the Medicare population. They also showed cost effectiveness in patients with stenosis with decompressive laminectomy was $77,600 per QALY compared to stenosis with degenerative spondylolisthesis, undergoing fusion and instrumentation at a cost of $115,600 per QALY.

This cost analysis is limited to the total cost of medical care given and does not include any monetary benefits that ensued from treatment, including return to work. At baseline, of 112 patients in this analysis, eligible for employment, 75 were employed, with 95 employed at end of 2 years, an increase in employment from 67% to 85%.

NICE -- the National Institute for Health and Clinical Excellence (81) in the United Kingdom is well known for assessment of the cost effectiveness of potential expenditures within the National Health Services. NICE assesses the cost effectiveness of treatments by analyzing the cost and benefit of the proposed treatment relative to the next best treatment. NICE accepts as cost effective those interventions with an incremental cost effectiveness ratio of less than £20,000 per QALY and an incremental cost effectiveness ratio or threshold of £30,000 per QALY in extenuating circumstances. In the United States, there is no organization such as NICE to calculate cost effectiveness. In fact, many of the regulations derived from ACA, including PCORI state that cost effectiveness is not to be taken into consideration, but to the contrary, cost utility is being used frequently in practice (1-11,82-84).

Multiple limitations of this analysis include consideration of current procedural costs and extrapolation of indirect costs at 40% or multiplication by a factor of 1.67 of direct procedural costs. However, there was no benefit analyzed for return of work even though there was a significant proportion of patients returning to work. Further, the study is derived from a single center assessment of 360 patients, even though this included a large population of chronic pain patients recalcitrant to conservative management incorporating 3 RCTs and assessing long-term improvement. However, these limitations may be considered as advantages. In addition, the cost of provision of epidural injections have decreased in 2017 compared to 2016, which in fact may lower the cost utility with use of 2017 data (85,86).

The costs estimated here are only applicable in a practical pragmatic setting such as described here in private practice with performance of these procedures in an ambulatory surgery setting with reasonable charges (85,86). Consequently, the results of this analysis may not be generalizable to all settings and all populations. Further, it is estimated that cost utility may be 30% to 70% higher in a hospital setting and approximately 20% to 30% lower in an office setting (85,86).

Conclusion

The present analysis of 3 RCTs of lumbar interlaminar epidural injections in a private practice setting in patients after failure of conservative management shows cost utility of epidural injections at $3,301 per QALY. The results also showed cost effectiveness at $3,425 for managing disc herniation, $3,527 for managing discogenic pain, and $2,961 for managing central spinal stenosis with or without steroids with no significant differences observed among the groups or those receiving steroids or those receiving local anesthetic only.

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Appendix Table 1. Employment characteristics of patients in each randomized trial at baseline and at end of 24-month period.

Employment status	Disc Herniation		Discogenic Pain		Spinal Stenosis		Pooled	
	Baseline	24 months	Baseline	24 months	Baseline	24 months	Baseline	24 months
Employed part-time	7	5	10	10	4	2	21	17
Employed full-time	22	31	16	21	16	26	54	78
Unemployed	9	6	6	5	10	5	25	16
Off the work due pain	8	6	4	1	0	0	12	7
Eligible for employment	46	46	36	36	30	30	112	112
Total Employed	29	36	26	31	20	28	75 (67%)	95 (85%*)
Housewife	10	8	10	10	12	10	32	28
Disabled	54	54	71	70	57	56	182	180
Over 65 year of age	10	10	3	3	21	21	34	34
Total Number of Patients	120	120	120	120	120	120	360	360

* significant difference with baseline values ($P < 0.001$)

References

1. Public Law No: 111-148: H.R. 3590. Patient Protection and Affordable Care Act. March 23, 2010.
2. Hirsch JA, Barr R, McGinty G, Nicola GN, Silva E 3rd, Schaefer P, Manchikanti L. Affordable Care 2014: A tale of two boards. *J Neurointerv Surg* 2014; 6:718-720.
3. Manchikanti L, Helm S 2nd, Benyamin RM, Hirsch JA. A critical analysis of Obamacare: Affordable care or insurance for many and coverage for few? *Pain Physician* 2017; 20:111-138.
4. Manchikanti L, Helm II S, Benyamin RM, Hirsch JA. Merit-Based Incentive Payment System (MIPS): Harsh choices for interventional pain management physicians. *Pain Physician* 2016; 19:E917-E934.
5. Manchikanti L, Helm II S, Calodney AK, Hirsch JA. Merit-based incentive payment system: Meaningful changes in the final rule brings cautious optimism. *Pain Physician* 2017; 20:E1-E12.
6. Hirsch JA, Leslie-Mazwi TM, Nicola GN, Bhargavan-Chatfield M, Seidenwurm DJ, Silva E, Manchikanti L. PQRS and the MACRA: Value-based payments have moved from concept to reality. *AJNR Am J Neuroradiol* 2016; 37:2195-2200.
7. Manchikanti L, Hammer M, Benyamin RM, Hirsch JA. Physician Quality Reporting System (PQRS) for interventional pain management practices: Challenges and opportunities. *Pain Physician* 2016; 19:E15-E32.
8. Manchikanti L, Staats PS, Boswell MV, Hirsch JA. Analysis of the carrot and stick policy of repeal of the sustainable growth rate formula: The good, the bad, and the ugly. *Pain Physician* 2015; 18:E273-E292.
9. Hirsch JA, Leslie-Mazwi TM, Patel AB, Rabinov JD, Gonzalex RG, Barr RM, Nicola GN, Klucznik RP, Prestigiacomo CJ, Manchikanti L. MACRA: Background, opportunities and challenges for the neurointerventional specialist. *J Neurointerv Surg* 2016; 8:868-874.
10. Hirsch JA, Leslie-Mazwi TM, Barr RM, McGinty G, Nicola GN, Patel AB, Manchikanti L. The Burwell roadmap. *J Neurointerv Surg* 2016; 8:544-546.
11. Obama B. United States health care reform: Progress to date and next steps. *JAMA* 2016 Jul 11 [Epub ahead of print].
12. Chou R, Hashimoto R, Friedly J, Fu Rochelle, Dana T, Sullivan S, Bougatsos C, Jarvik J. Pain Management Injection Therapies for Low Back Pain. Technology Assessment Report ESIB0813. (Prepared by the Pacific Northwest Evidence-based Practice Center under Contract No. HHSA 290-2012-00014-I.) Rockville, MD: Agency for Healthcare Research and Quality; July 10, 2015.

    www.cms.gov/medicare/coverage/determinationprocess/downloads/id98ta.pdf
13. Manchikanti L, Knezevic NN, Boswell MV, Kaye AD, Hirsch JA. Epidural injections for lumbar radiculopathy and spinal stenosis: A comparative systematic review and meta-analysis. *Pain Physician* 2016; 19:E365-E410.
14. Manchikanti L, Helm II S, Singh V, Hirsch JA. Accountable interventional pain management: A collaboration among practitioners, patients, payers, and government. *Pain Physician* 2013; 16:E635-E670.
15. Fritz JM, Magel JS, McFadden M, Asche C, Thackeray A, Meier W, Grennan G. Early physical therapy vs usual care in patients with recent-onset low back pain: A randomized clinical trial. *JAMA* 2015; 314:1459-1467.
16. Dagenais S, Haldeman S, Polatin PB. It is time for physicians to embrace cost-effectiveness and cost utility analysis research in the treatment of spinal pain. *Spine J* 2005; 5:357-360.
17. Dagenais S, Roffey DM, Wai EK, Haldeman S, Caro J. Can cost utility evaluations inform decision making about interventions for low back pain? *Spine J* 2009; 9:944-957.
18. Dagenais S, Caro J, Haldeman S. A systematic review of low back pain cost of illness studies in the United States and internationally. *Spine J* 2008; 8:8-20.
19. Kepler CK, Wilkinson SM, Radcliff KE, Vaccaro AR, Anderson DG, Hilibrand AS, Albert TJ, Rihn JA. Cost-utility analysis in spine care: A systematic review. *Spine J* 2012; 12:676-690.
20. Indrakanti SS, Weber MH, Takemoto SK, Hu SS, Polly D, Berven SH. Value-based care in the management of spinal disorders: A systematic review of cost-utility analysis. *Clin Orthop Relat Res* 2012; 470:1106-1023.
21. Rampersaud YR, Tso P, Walker KR, Lewis SJ, Davey JR, Mahomed NN, Coyte PC. Comparative outcomes and cost-utility following surgical treatment of focal lumbar spinal stenosis compared with osteoarthritis of the hip or knee: Part 2 -- estimated lifetime incremental cost-utility ratios. *Spine J* 2014; 14:244-254.
22. Furlan AD, Yazdi F, Tsertsvadze A, Gross A, van Tulder M, Santaguida L, Gagnier J, Ammendolia C, Dryden T, Doucette S, Skidmore B, Daniel R, Ostermann T, Tsouros S. A systematic review and meta-analysis of efficacy, cost-effectiveness, and safety of selected complementary and alternative medicine for neck and low-back pain. *Evid Based Complement Alternat Med* 2012; 2012:953139.
23. Tosteson AN, Skinner JS, Tosteson TD, Lurie JD, Andersson GB, Berven S, Grove MR, Hanscom B, Blood EA, Weinstein JN. The cost effectiveness of surgical versus nonoperative treatment for lumbar disc herniation over two years: Evidence from the Spine Patient Outcomes Research Trial (SPORT). *Spine (Phila Pa 1976)* 2008; 33:2108-2115.
24. Tosteson AN, Lurie JD, Tosteson TD, Skinner JS, Herkowitz H, Albert T, Boden SD, Bridwell K, Longley M, Andersson GB, Blood EA, Grove MR, Weinstein JN; SPORT Investigators. Surgical treatment of spinal stenosis with and without degenerative spondylolisthesis: Cost-effectiveness after 2 years. *Ann Intern Med* 2008; 149:845-853.
25. Manchikanti L, Falco FJE, Pampati V, Cash KA, Benyamin RM, Hirsch JA. Cost utility analysis of caudal epidural injections in the treatment of lumbar disc herniation, axial or discogenic low back pain, central spinal stenosis, and post lumbar surgery syndrome. *Pain Physician* 2013; 16:E129-E143.
26. Manchikanti L, Helm S 2nd, Pampati V, Racz GB. Cost utility analysis of percutaneous adhesiolysis in managing pain of post-lumbar surgery syndrome and lumbar central spinal stenosis. *Pain Pract* 2015; 15:414-422.
27. Taylor RS, Ryan J, O'Donnelll R, Eldabe S, Kumar K, North RB. The cost-effectiveness of spinal cord stimulation in the treatment of failed back surgery syndrome. *Clin J Pain* 2010; 26:463-469.
28. Kumar K, Rizvi S, Bishop S, tang W. Cost impact of intrathecal polyanalgesia. *Pain Med* 2013; 14:1569-1584.
29. Gannon B, Finn DP, O'Gorman D, Ruane N, McGuire BE. The cost of chronic pain: An analysis of a regional pain management service in Ireland. *Pain Med* 2013; 14:1518-1528.
30. Kumar K, Rizvi S. Cost-effectiveness of spinal cord stimulation therapy in management of chronic pain. *Pain Med* 2013; 14:1631-1649.
31. Critchley DJ, Ratcliffe J, Noonan S, Jones RH, Hurley MV. Effectiveness and cost-effectiveness of three types of physiotherapy used to reduce chronic low back pain disability: A pragmatic randomized trial with economic evaluation. *Spine (Phila Pa 1976)* 2007; 32:1474-1481.
32. Rivero-Arias O, Gray A, Frost H, Lamb SE, Stewart-Brown S. Cost-utility analysis of

physiotherapy treatment compared with physiotherapy advice in low back pain. *Spine (Phila Pa 1976)* 2006; 31:1381-1387.

33. Malter AD, Larson EB, Urban N, Deyo RA. Cost-effectiveness of lumbar discectomy for the treatment of herniated intervertebral disc. *Spine (Phila Pa 1976)* 1996; 21:1048-1054; discussion 1055.
34. Burnett MG, Stein SC, Bartels RH. Cost-effectiveness of current treatment strategies for lumbar spinal stenosis: Nonsurgical care, laminectomy, and X-STOP. *J Neurosurg Spine* 2010; 13:39-46.
35. Rivero-Arias O, Campbell H, Gray A, Fairbank J, Frost H, Wilson-MacDonald J. Surgical stabilization of the spine compared with a programme of intensive rehabilitation for the management of patients with chronic low back pain: Cost utility analysis based on a randomised controlled trial. *BMJ* 2005; 330:1239.
36. Soegaard R, Bünger CE, Christiansen T, Høy K, Eiskjaer SP, Christensen FB. Circumferential fusion is dominant over posterolateral fusion in a long-term perspective: Cost-utility evaluation of a randomized controlled trial in severe, chronic low back pain. *Spine (Phila Pa 1976)* 2007; 32:2405-2414.
37. Parker SL, Fulchiero EC, Davis BJ, Adogwa O, Aaronson OS, Cheng JS, Devin CJ, McGirt MJ. Cost-effectiveness of multi-level hemilaminectomy for lumbar stenosis-associated radiculopathy. *Spine J* 2011; 11:705-711.
38. Fritz JM, Kim M, Magel JS, Asche CV. Cost-effectiveness of primary care management with or without early physical therapy for acute low back pain: Economic evaluation of a randomized clinical trial. *Spine (Phila Pa 1976)* 2017; 42:285-290.
39. Martin BI, Turner JA, Mirza SK, Lee MJ, Comstock BA, Deyo RA. Trends in health care expenditures, utilization, and health status among US adults with spine problems, 1997-2006. *Spine (Phila Pa 1976)* 2009; 34:2077-2084.
40. Dieleman JL, Baral R, Birger M, Bui AL, Bulchis A, Chapin A, Hamavid H, Horst C, Johnson EK, Joseph J, Lavado R, Lomsadze L, Reynolds A, Squires E, Campbell M, DeCenso B, Dicker D, Flaxman AD, Gabert R, Highfill T, Naghavi M, Nightingale N, Templin T, Tobias MI, Vos T, Murray CJ. US spending on personal health care and public health, 1996-2013. *JAMA* 2016; 316:2627-2646.
41. Ivanova JI, Birnbaum HG, Schiller M, Kantor E, Johnstone BM, Swindle RW. Real-world practice patterns, health-care utilization, and costs in patients with low back pain: The long road to guideline-concordant care. *Spine J* 2011; 11:622-632.
42. Rajaee SS, Bae HW, Kanim LE, Delamarter RB. Spinal fusion in the United States: Analysis of trends from 1998 to 2008. *Spine (Phila Pa 1976)* 2012; 37:67-76.
43. Bae HW, Rajaee SS, Kanim LE. Nationwide trends in the surgical management of lumbar spinal stenosis. *Spine (Phila Pa 1976)* 2013; 38:916-926.
44. Manchikanti L, Kaye AM, Knezevic NN, McAnally H, Trescot AM, Blank S, Pampati V, Abdi S, Grider JS, Kaye AD, Manchikanti KN, Cordner HJ, Gharibo CG, Harned ME, Albers SL, Atluri S, Aydin SM, Bakshi S, Barkin R, Benyamin RM, Boswell MV, Buenaventura RM, Calodney AK, Cedeno DL, Datta S, Deer TR, Fellows B, Galan V, Grami V, Hansen H, Helm S 2nd, Justiz R, Koyyalagunta D, Malla Y, Navani A, Nouri K, Pasupuleti R, Sehgal N, Silverman SM, Simopoulos TT, Singh V, Slavin KV, Solanki DR, Staats PS, Vallejo R, Wargo BW, Watanabe A, Hirsch JA. Responsible, safe, and effective prescription of opioids for chronic non-cancer pain: American Society of Interventional Pain Physicians (ASIPP) guidelines. *Pain Physician* 2017: 20:S3-S92.
45. Gaskin DJ, Richard P. The economic costs of pain in the United States. *J Pain* 2012; 13:715-724.
46. Manchikanti L, Pampati V, Falco FJE, Hirsch JA. An updated assessment of utilization of interventional pain management techniques in the Medicare population: 2000 – 2013. *Pain Physician* 2015; 18:E115-E127.
47. Manchikanti L, Pampati V, Hirsch JA. Utilization of interventional techniques in managing chronic pain in Medicare population from 2000 to 2014: An analysis of patterns of utilization. *Pain Physician* 2016; 19:E531-E546.
48. Manchikanti L, Hirsch JA, Pampati V, Boswell MV. Utilization of facet joint and sacroiliac joint interventions in Medicare population from 2000 to 2014: Explosive growth continues! *Curr Pain Headache Rep* 2016; 20:58.
49. Manchikanti L, Pampati V, Hirsch JA. Retrospective cohort study of usage patterns of epidural injections for spinal pain in the US fee-for-service Medicare population from 2000 to 2014. *BMJ Open* 2016; 6:e013042.
50. Hirsch JA, Chandra RV, Pampati V, Barr JD, Brook AL, Manchikanti L. Analysis of vertebral augmentation practice patterns: A 2016 update. *J Neurosurg Sci* 2016 Oct 31. [Epub ahead of print].
51. Manchikanti L, Hirsch JA. Neurological complications associated with epidural steroid injections. *Curr Pain Headache Rep* 2015; 19:482.
52. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. *JAMA* 2010; 303:1259-1265.
53. Deyo RA, Martin BI, Kreuter W, Jarvik JG, Angier H, Mirza SK. Revision surgery following operations for lumbar stenosis. *J Bone Joint Surg Am* 2011; 93:1979-1986.
54. Manchikanti L, Benyamin RM, Falco FJ, Kaye AD, Hirsch JA. Do epidural injections provide short- and long-term relief for lumbar disc herniation? A systematic review. *Clin Orthop Relat Res* 2015; 473:1940-1956.
55. Manchikanti L, Nampiaparampil DE, Manchikanti KN, Falco FJE, Singh V, Benyamin RM, Kaye AD, Sehgal N, Soin A, Simopoulos TT, Bakshi S, Gharibo CG, Gilligan CJ, Hirsch JA. Comparison of the efficacy of saline, local anesthetics, and steroids in epidural and facet joint injections for the management of spinal pain: A systematic review of randomized controlled trials. *Surg Neurol Int* 2015; 6:S194-S235.
56. Manchikanti L, Kaye AD, Manchikanti KN, Boswell MV, Pampati V, Hirsch JA. Efficacy of epidural injections in the treatment of lumbar central spinal stenosis: A systematic review. *Anesth Pain Med* 2015; 5:e23139.
57. Manchikanti L, Manchikanti KN, Gharibo CG, Kaye AD. Efficacy of percutaneous adhesiolysis in the treatment of lumbar post surgery syndrome. *Anesth Pain Med* 2016; 6:e26172.
58. Kaye AD, Manchikanti L, Abdi S, Atluri S, Bakshi S, Benyamin R, Boswell MV, Buenaventura R, Candido KD, Cordner HJ, Datta S, Doulatram G, Gharibo CG, Grami V, Gupta S, Jha S, Kaplan ED, Malla Y, Mann DP, Nampiaparampil DE, Racz G, Raj P, Rana MV, Sharma ML, Singh V, Soin A, Staats PS, Vallejo R, Wargo BW, Hirsch JA. Efficacy of epidural injections in managing chronic spinal pain: A best evidence synthesis. *Pain Physician* 2015; 18:E939-E1004.
59. Boswell MV, Manchikanti L, Kaye AD, Bakshi S, Gharibo CG, Gupta S, Jha S, Nampiaparampil DE, Simopoulos TT, Hirsch JA. A best-evidence systematic appraisal of the diagnostic accuracy and utility of facet (zygapophysial) joint injections in chronic spinal pain. *Pain Physi-*

cian 2015; 18:E497-E533.

60. Manchikanti L, Kaye AD, Boswell MV, Bakshi S, Gharibo CG, Grami V, Grider JS, Gupta S, Jha S, Mann DP, Nampiaparampil DE, Sharma ML, Shroyer LN, Singh V, Soin A, Vallejo R, Wargo BW, Hirsch JA. A systematic review and best evidence synthesis of the effectiveness of therapeutic facet joint interventions in managing chronic spinal pain. *Pain Physician* 2015; 18:E535-E582.
61. Manchikanti L, Hirsch JA, Falco FJ, Boswell MV. Management of lumbar zygapophysial (facet) joint pain. *World J Orthop* 2016; 7:315-337.
62. Manchikanti L, Hirsch JA, Kaye AD, Boswell MV. Cervical zygapophysial (facet) joint pain: Effectiveness of interventional management strategies. *Postgrad Med* 2016; 128:54-68.
63. Chang Chien GC, Knezevic NN, McCormick Z, Chu SK, Trescot Am, Candido KD. Transforaminal versus interlaminar approaches to epidural steroid injections: A systematic review of comparative studies for lumbosacral radicular pain. *Pain Physician* 2014; 17:E509-E524.
64. Manchikanti L, Nampiaparampil DE, Candido KD, Bakshi S, Grider JS, Falco FJE, Sehgal N, Hirsch JA. Do cervical epidural injections provide long-term relief in neck and upper extremity pain? A systematic review. *Pain Physician* 2015; 18:39-60.
65. Grider JS, Manchikanti L, Carayannopoulos A, Sharma ML, Balog CC, Harned ME, Grami V, Justiz R, Nouri KH, Hayek SM, Vallejo R, Christo PJ. Effectiveness of spinal cord stimulation in chronic spinal pain: A systematic review. *Pain Physician* 2016; 19:E33-E54.
66. Simopoulos TT, Manchikanti L, Gupta S, Aydin SM, Kim CH, Solanki D, Nampiaparampil DE, Singh V, Staats PS, Hirsch JA. Systematic review of the diagnostic accuracy and therapeutic effectiveness of sacroiliac joint interventions. *Pain Physician* 2015; 18:E713-E756.
67. Helm II S, Racz GB, Gerdesmeyer L, Justiz L, Hayek SM, Kaplan ED, El Terany MA, Knezevic NN. Percutaneous and endoscopic adhesiolysis in managing low back and lower extremity pain: A systematic review and meta-analysis. *Pain Physician* 2016; 19:E245-E282.
68. Manchikanti L, Kaye AD, Hirsch JA. Comment RE: Chou R, Hashimoto R, Friedly J, et al RE: Epidural corticosteroid injections for radiculopathy and spinal stenosis: A systematic review and meta-analysis. *Ann Intern Med* 2015; 163:373-381; *Ann Intern Med* 2016; 164:633.
69. Boswell MV, Manchikanti L. Appropriate design and methodologic quality assessment, clinically relevant outcomes are essential to determine the role of epidural corticosteroid injections. Commentary RE: Chou R, Hashimoto R, Friedly J, Fu R, Bougatsos C, Dana T, Sullivan SD, Jarvik J. Epidural corticosteroid injections for radiculopathy and spinal stenosis: A systematic review and meta-analysis. *Ann Intern Med* 2015; 163:373-381. *Evid Based Med* 2016; 21:89.
70. Manchikanti L, Staats PS, Nampiaparampil DE, Hirsch JA. What is the role of epidural injections in the treatment of lumbar discogenic pain: A systematic review of comparative analysis with fusion and disc arthroplasty. *Korean J Pain* 2015; 28:75-87.
71. Manchikanti L, Singh V, Pampati V, Falco FJE, Hirsch JA. Comparison of the efficacy of caudal, interlaminar, and transforaminal epidural injections in managing lumbar disc herniation: Is one method superior to the other? *Korean J Pain* 2015; 28:11-21.
72. Manchikanti L, Pampati V, Benyamin RM, Boswell MV. Analysis of efficacy differences between caudal and lumbar interlaminar epidural injections in chronic lumbar axial discogenic pain: Local anesthetic alone vs. local combined with steroids. *Int J Med Sci* 2015; 12:214-222.
73. Manchikanti L, Benyamin RM. Key safety considerations when administering epidural steroid injections. *Pain Manag* 2015; 5: 261-72.
74. Manchikanti L, Falco FJE. Safeguards to prevent neurologic complications after epidural steroid injections: Analysis of evidence and lack of applicability of controversial policies. *Pain Physician* 2015; 18: E129-38.
75. Manchikanti L, Falco FJE, Pampati V, Hirsch JA. Lumbar interlaminar epidural injections are superior to caudal epidural injections in managing lumbar central spinal stenosis. *Pain Physician* 2014; 17:E691-E702.
76. Manchikanti L, Cash KA, McManus CD, Pampati V, Benyamin RM. A randomized, double-blind, active-controlled trial of fluoroscopic lumbar interlaminar epidural injections in chronic axial or discogenic low back pain: Results of a 2-year follow-up. *Pain Physician* 2013; 16:E491-E504.
77. Manchikanti L, Cash KA, McManus CD, Damron KS, Pampati V, Falco FJE. A randomized, double-blind controlled trial of lumbar interlaminar epidural injections in central spinal stenosis: 2-year follow-up. *Pain Physician* 2015; 18:79-92.
78. Manchikanti L, Singh V, Cash KA, Pampati V, Falco FJE. A randomized, double-blind, active-control trial of the effectiveness of lumbar interlaminar epidural injections in disc herniation. *Pain Physician* 2014; 17:E61-E74.
79. Whynes DK, McCahon RA, Ravenscroft A, Hardman J. Cost effectiveness of epidural steroid injections to manage chronic lower back pain. *BMC Anesthesiol* 2012; 12:26.
80. Johnson RE, Jones GT, Wiles NJ, Chaddock C, Potter RG, Roberts C, Symmons DP, Watson PJ, Torgerson DJ, Macfarlane GJ. Active exercise, education, and cognitive behavioral therapy for persistent disabling low back pain: A randomized controlled trial. *Spine (Phila Pa 1976)* 2007; 32:1578-1585.
81. National Institute for Health and Clinical Excellence. *Guide to the Methods of Technology Appraisal*. NICE, London, 2008.
82. Manchikanti L, Falco FJ, Benyamin RM, Helm S 2nd, Parr AT, Hirsch JA. The impact of comparative effectiveness research on interventional pain management: Evolution from Medicare Modernization Act to Patient Protection and Affordable Care Act and the Patient-Centered Outcomes Research Institute. *Pain Physician* 2011; 14:E249-E282.
83. Manchikanti L, Falco FJE, Boswell MV, Hirsch JA. Facts, fallacies, and politics of comparative effectiveness research: Part 1. Basic considerations. *Pain Physician* 2010; 13:E23-E54.
84. Manchikanti L, Falco FJE, Boswell MV, Hirsch JA. Facts, fallacies, and politics of comparative effectiveness research: Part 2. Implications for interventional pain management. *Pain Physician* 2010; 13:E55-E79.
85. Manchikanti L, Singh V, Hirsch JA. Facility payments for interventional pain management procedures: Impact of proposed rules. *Pain Physician* 2016; 19 E957-E984.
86. Manchikanti L, Kaye AD, Hirsch JA. Proposed Medicare physician payment schedule for 2017: Impact on interventional pain management practices. *Pain Physician* 2016; 19:E935-E955.