A New Method of Assessing the Impact of Evidence-Based Medicine on Claim Outcomes

Dan L. Hunt, DO, Jack Tower, MS, Ryan D. Artuso, PhD, Jeffrey A. White, MS, Craig Bilinski, MS, James Rademacher, BA, Xuguang Tao, MD, PhD, and Edward J. Bernacki, MD, MPH

Objective: The objective of this study is to develop a method of quantifying compliance with Evidence-Based Medicine (EBM) guidelines as a means of assessing the relationship between the use of EBM guidelines and illness absence and costs in workers' compensation. **Methods:** A total of 45,951 indemnity claims with two years of development filed between 2008 and 2013 were utilized to develop the methodology. **Results:** The newly developed methodology adequately assessed the relationship between claim outcomes (duration and medical incurred) and adherence to EBM guidelines, controlling for medical complexity, distinct number of International Classification of Diseases (ICD)-9 codes, and other confounding factors. **Conclusions:** The compliance score described in this paper may be a useful tool for determining the impact of worker's compensation treatment guidelines on claim outcomes.

More states are adopting legislation in support of Evidence-Based Medicine (EBM)[1–3] guidelines and protocols to improve consensus around the definition of "necessary and appropriate" treatment for workers' compensation injuries. For a given diagnosis code and procedure combination, the EBM guidelines typically provide references to clinical research and peer-reviewed treatment plans aimed at improving outcomes and return-to-work results. The goal of EBM guidelines in workers' compensation is to improve the quality of care for injured workers by using an objective standard for treatment. The philosophy is that properly constituted guidelines

1. Achieve better and more predictable results for the majority of patients;
2. Establish a standard of care with projected disability durations;
3. Define necessity and appropriateness of medical treatments;
4. Provide expectations for recovery, cost, and risks for complications.

The most widely adopted guideline in workers' compensation is the Official Disability Guidelines (ODGs) maintained by the Work Loss Data Institute.[4] These guidelines are based on a comprehensive analysis of the medical literature with preference given to high-quality, systematic reviews, meta-analyses, and clinical trials. The guidelines are available in digital form for use with medical bill and utilization review systems. These treatment guidelines were designed to ensure injured workers receive appropriate medical care, while limiting ineffective and unproven medical interventions in workers' compensation. They are based on a combination of evidence-based analysis and workers' compensation claims analytics, representing over three million claims and $20 billion dollars of incurred costs.[4] For practical applications, the ODG maps Common Procedural Terminology (CPT) to International Classification of Diseases (ICD) codes in workers' compensation claims, providing normative utilization data on incidence, frequency, number of visits, and cost.

Previous work investigating EBM[5,6] has focused on adoption of these guidelines in both general practice[7,8] and in workers compensation (CWCI), integration of EBM into the decision making process,[9,10] methods to evaluate the harm versus benefit of treatment choices,[11] and criticisms of EBM.[12,13] To date, there has not been a comprehensive study to evaluate the impact of adherence to EBM guidelines on medical costs and the duration of patient treatment.

In this paper, we introduce a methodology to measure adherence to the EBM guidelines over the course of treatment for a cohort of workers' compensation claims. The study does not advocate for any particular public policy position but rather demonstrates a methodology and algorithm for testing the effectiveness of an EBM guideline. Decisions whether or not to use the EBM guidelines should be left to the individual state and should be determined by public policy with regulators, employers, employee groups, and physicians participating in the discussions.

To measure adherence, we calculated a compliance score and compared the outcomes for different case mix adjusted, claims populations. The question this investigation assesses is "If injured workers are managed under EBM guidelines as defined by ODG, do they have better outcomes in terms of absence from work and total medical care cost?" Although this would seem intuitively to be true, this project was designed to test this hypothesis.

METHODS

Cohort Selection

The claims population consisted of all indemnity claims from Accident Fund, United Heartland, Third Coast Underwriters, and CompWest, reported between 2008 and 2013, meeting the following criteria: at least two years of development, at least one day of Temporary Total Disability Benefits, and noncatastrophic claims (less than $1million expected total incurred). All claims were evaluated two years after the date reported.

Compliance Score Calculation

For the purpose of this study, the ODGs,[4] published by the Work Loss Data Institute (WLDI), were used as the EBM rules. The ODG guidelines are a list containing one service code (CPT code)[14] and one diagnosis code (ICD9 code)[15] and a corresponding payment flag that indicates whether the service should be approved for that diagnosis, based on EBM. The flags are color-coded indicating how strongly the medical evidence supports that service as the best treatment for the given diagnosis code. Green flags indicate that the service should be approved on the basis of consensus in the EBM literature, whereas black flags indicate that it should be denied on

From the Corporate Claims (Dr Hunt), Medical Center of Excellence (Mr Tower, Dr Artuso, Mr Rademacher), Corporate Administration office, AF Group, Lansing, Michigan (Mr White and Mr Bilinski), Division of Environmental and Occupational Medicine, Department of Medicine, Johns Hopkins School of Medicine, Baltimore, Maryland (Drs Tao and Bernacki).
The study received partial funding from AF Group.
The authors have no conflicts of interest.
Address correspondence to: Edward J. Bernacki, MD, MPH, Professor and Executive Director of Healthcare Solutions, Dell Medical School, The University of Texas at Austin, Concurrently Professor of Medicine, Johns Hopkins University School of Medicine, Baltimore, MD 21205. (ed.bernacki@austin.utexas.edu).

DOI: 10.1097/JOM.0000000000000718

that same criteria. Yellow flags are assigned to services in which statistical analysis suggests that the procedure is a common treatment for that diagnosis and should be allowed on a limited basis with restriction on the number of times it should be performed. Red flags point to a service that is less commonly utilized than a yellow flag service and these procedures require review according to ODG guidelines.

This information was provided for this study by WLDI using ODG's UR Advisor solution. In order to leverage the ODG guidelines as a measure of adherence to EBM, it must first be determined whether each service performed on a patient during the course of their treatment was approved or denied according to the ODG rules. For any given medical service that is performed, there can, in general, be many diagnosis codes associated with that service.

Each of these diagnosis codes can be mapped to an ODG flag indicating whether the service should be allowed based solely on that diagnosis code. When all of the payment flags associated with a particular service are examined, the most important flag is the one that indicates most strongly that the services should be approved. Thus, if a service has at least one green flag associated with it, that service is labeled as a green flag service. If the service does not have any green flags, but does have at least one yellow, then it is labeled as a yellow flag service, similarly for red flags and then finally for black flags. Red flags indicate services that may be allowed, but should be reviewed. Due to the infrequent nature of these relatively uncommon services, services that have a red flag as their strongest flag are not included in the analysis.

To identify which medical services performed on a claim were approved by the ODG guidelines, this analysis considers the service approved if the most compliant flag is green or yellow, or not approved if the only payment flags associated with the service are black. Once each service on a claim has been identified as approved, not approved, or is removed as a red flag service, the dollar-weighted percentage of services performed on a claimant during the course of their treatment that met ODG guidelines for approval is calculated.

When the cohort of claimants is analyzed, the ratio of green/yellow flags to black flags is not evenly distributed over common service categories and diagnosis groupings. To control for this, one particular diagnosis code is identified as the principal diagnosis code with each service. To do so, the analysis first looks at the most compliant flag associated with the service and all of the diagnosis codes associated with that procedure for that claimant. This is the predominant flag conforming to the ODG guidelines. For example (Table 1), if the diagnosis codes in the table are present on a medical bill for an open repair of a rotator cuff (CPT code 23410), then according to the ODG guidelines, there are three payment flags associated with this surgery, namely green, red, and black. The presence of a green flag indicates that the service should be approved, and both ICD9 codes 840.4 and 726.2 correspond to green flags. In general, there could be many diagnosis codes that all correspond to the most compliant flag. In order to select a single diagnosis as the principal diagnosis in the case wherein there is a tie, the one that is most frequently co-occurring with the procedure in the medical billing database was chosen. In the example above, the ICD9 code 840.4 was the principal diagnosis because it was the most common diagnosis code to occur with CPT 23410 in the medical records.

In an attempt to remove any bias, the unequal distribution of nonapproved services might cause, all services were grouped according to the principal diagnosis and the percentage of allowed services to total services (not including red services) within the group was calculated by the paid amounts of each service. Principal diagnosis codes that were sparsely represented in the data were grouped together into ICD9 subcategories, specified by a range of similar ICD9 codes. The percentage of approved medical incurred was then compared with the average for that principal diagnosis, for all claims in the population. This ratio then represents a normalized score (in which 1.0 is average) on the compliance of a claim for a particular principal diagnosis. Taking a weighted average of these scores across all principal diagnoses on a particular claim then yields an overall claim level compliance score.

TABLE 1. Diagnosis Codes for Repair of Musculotendinous Cuff Open, Acute (CPT 23410)

Diagnosis (ICD9 Code)	ODG Flag
Diabetes, uncomplicated type II (250.00)	Black
Arthropathy, unspecified shoulder (716.91)	Red
Shoulder region disease other (726.2)	Green
Sprain rotator cuff (840.4)	Green

ODG: Official Disability Guidelines

Summary of steps used to calculate the compliance score:

1. Identify all procedures (CPT codes) performed on claimant;
2. Map all diagnosis codes associated with each procedure to those that appear in the ODG table (720.41 –> 720.4 for example);
3. Given the CPT code and the set of associated diagnosis codes, identify the ODG flags associated with those CPT-ICD9 pairs;
4. Select the best flag associated with each procedure as the overall flag for that procedure;
5. Label procedures with an overall flag of "green" or "yellow" as "allowed" and those with an overall flag of "black" as "not allowed" and drop all procedures where overall flag is red.
6. For each procedure, identify all diagnosis codes that give the overall flag and choose the most common (from entire dataset for that CPT code) as the primary diagnosis for that procedure.
7. Group all procedures on the claim by their primary diagnosis, and calculate the percentage of allowed procedures to all nonred procedures for each primary diagnosis.
8. Divide the percentage of allowed procedures by the average on that primary diagnosis code over the entire dataset to arrive at a normalized score for each primary diagnosis.
9. Calculate the dollar-weighted average of these normalized scores over all primary diagnosis codes appearing on a claim, which is the claim compliance score.

Medical Complexity Score Calculation

Although compliance scores were normalized by diagnosis code, when measuring the effect of compliance, it is important to still control for other known risk factors associated with high severity claims.[16,17] For this reason, it was necessary to introduce an additional metric that scores claims according to expected medical severity. This metric, referred to as the medical complexity score, uses a mix of elastic net regression[18] and stochastic gradient boosting.[19] The predictive model targets claim duration and incorporates the following independent variables: age at accident, nature of injury, primary body part injured, cause of injury, claimant's benefit state, claimant's class code, and claimant's ICD9 codes. On a randomly chosen, 30% held-out validation set, the Spearman correlation between predicted and actual values was 0.6424632. The final score is calculated by mapping each prediction to a 1 to 100 scale by way of one percentile groupings, whereby 1 represents the lowest medical complexity and 100 represents the highest. Claims are then grouped together in ventiles (or buckets each containing 5% of the population) to make the final medical complexity groupings. This allows for comparison of claims within each complexity group.

Data Analysis

Descriptive analysis methods were used to present general information about the study population.

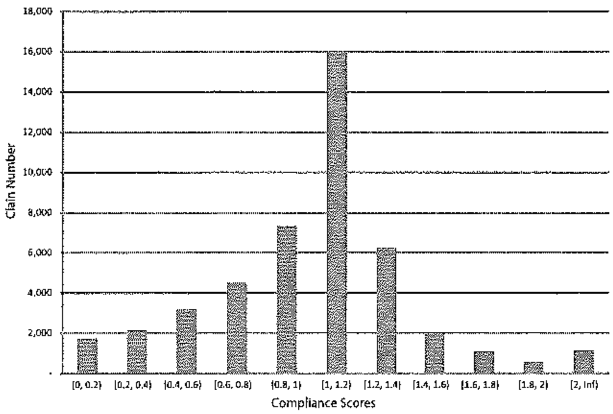

FIGURE 1. Distribution of compliance scores.

Claim duration and medical incurred cost were used as two outcome variables to be associated with newly developed compliance scores.

When the population is divided into groups of similar medical complexity, the compliance scores within a particular group were compared with each other. Claims that have a compliance score in the top 50% of their medical complexity group were labeled as "high compliance," and similarly the bottom 50% were labeled as "low compliance." In Fig. 2, the number of flags indicating approved services (green and yellow flags) are notably similar for compliant and noncompliant claims, whereas the number of black flags may differ greatly between the two shown in Fig. 3.

In addition, statistical analysis was performed to evaluate the impact of the compliance score. Two separate regressions were performed using log-transformed claim duration and medical incurred as dependent variables. Medical complexity, the distinct number of ICD9 codes, and the number of nonred flagged medical services were used as controlling independent variables. An additional independent indicator variable was included denoting upper 50% compliance.

The estimated percentage effect for compliant claims is then calculated as $\exp^{(\text{Regression Estimate for Upper 50\% Compliance})} - 1$.

RESULTS

There exists a fairly equal distribution of claims across all report years ranging between 17% and 21% of the claims falling in each bucket. This analysis considered all body parts as summarized in Table 2, with the top three body parts comprising 83% of the population reported as upper extremities, lower extremities, and trunk having a relative distribution of 34%, 26%, and 23%, respectively. This can be further subdivided into constituent body parts with the top five effected areas comprising 51% of the population reported as lower back, multiple parts, knee, shoulders, and fingers having a relative distribution of 12%, 12%, 11%, 11%, and 5%, respectively.

Table 3 provides the distribution of both age and gender for the claims population. The ages of 41 to 60 represent approximately 50% of the injured workers, with males representing 62.8% and females 36.5%.

Adherence to ODG guidelines was measured by the use of the compliance score. The compliance score assigns a quantitative value to the claim indicating roughly how many of the treatments were consistent with the recommendations from the guidelines as outlined above. Scores closer to zero have the lowest adherence, while scores closer to 2 had the highest adherence to the guidelines. Scoring all claims in the dataset reveals that 64% of the scores ranged between 0.8 and 1.4 represented by the three center bands in frequency distribution graph of Fig. 1. The lower adherence group to the left of center comprises roughly 25% of the claims, while the highest compliance group to the right represented only 10%.

Case mix adjustment of claims was accomplished using predictive modeling to output a medical complexity score. Inspection of the features of the predictive model used to generate the medical complexity score reveals the strong dependence of the model on the ICD9 or diagnosis codes with lesser influence related to class code, cause of injury, body part, nature of injury, and age at accident.

For each ventile of medical complexity scores, claims are further subdivided by the median compliance score within that ventile so that one can make direct comparisons of claim outcomes based on adherence to the ODG guidelines. For the purposes of this study, the lower 50% compliance group is compared with the upper 50% compliance group.

Figure 3 indicates the number of black flag procedures that are present in each claim by medical complexity ventile and

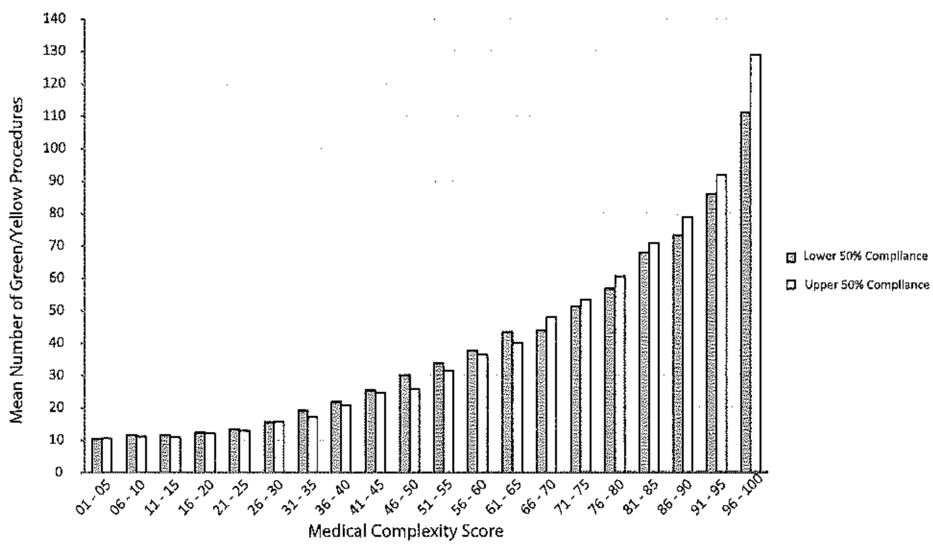

FIGURE 2. Mean number of green/yellow procedures by medical complexity score and compliance score category.

TABLE 2. Distribution of Body Parts

Body Part	Claims	% Claims
Upper extremities	15,631	34.0%
Lower extremities	11,864	25.8%
Trunk	10,654	23.2%
Multiple body parts	5556	12.1%
Head	1550	3.4%
Neck	683	1.5%
Not reported	8	0.0%
Not assigned	5	0.0%
Total	45,951	100.0%

TABLE 3. Distribution of Age Group and Gender

Age Group	Male	Female	Unknown	Total	%
<15	9	2	0	11	0.0
15–20	878	531	7	1416	3.1
21–30	5237	2819	55	8111	17.7
31–40	6523	3222	59	9804	21.3
41–50	7824	4508	71	12,403	27.0
51–60	6351	4156	80	10,587	23.0
61–70	1754	1299	25	3078	6.7
More than 71	270	249	5	524	1.1
NA	15	2	0	17	0.0
Total	28,861	16,788	302	45,951	100.0
%	62.8%	36.5%	0.7%	100.0%	

compliance quantile. As a point of reference, the green flags in the ODG treatment guidelines indicate that the procedure is evidence-based, meaning that it is recommended on the basis of current medical research for the specific diagnosis in question. The yellow flags however are not driven by clinical studies, but instead by the claims data from member companies of the Work Loss Data Institute. The black flags generally identify inappropriate care and a strong candidate for denial if a utilization review program is employed.[4]

The number of black flags in the low compliance group in Fig. 3 always exceeds that of the high compliance group across all ventiles. On average, there are eight more black flag procedures in the low compliance group than the high compliance group per ventile. Overall, the low compliance group has 3.5 times the total number of black flag procedures than the high compliance group.

Using the same methodology as above, but instead looking at the number of green and yellow treatments, Fig. 2 demonstrates that the number of green and yellow flags is roughly equivalent across all Medical Complexity ventiles. However, the high compliance group does have a consistently higher number of green and yellow flags per claim when the medical complexity exceeds the 61 to 65 range. For a medical complexity score below 66, both the low and high compliance groups have a relatively similar number of green and yellow procedures with a negligible difference between the compliance groups for medical complexity under 31. These results appear to indicate that the amount of compliant treatments is generally equivalent in the lower complexity injuries with divergent behavior occurring consistently with claims having a higher medical complexity.

The mean medical incurred per claim indicates a large statistically significant difference between the low and high compliance groups. Linear regression analysis results from Table 4 indicate that the estimated impact of low compliance is an increase of 37.9% to medical incurred across all ventiles for medical complexity. These results demonstrate a major difference in the outcomes of claims on the basis of the adherence of medical treatments to the ODG guidelines for workers' compensation across all case mixes, body parts, and injury types. Figure 4 presents the mean medical incurred expenses for the low compliance group always exceed that of the high compliance group across all ventiles of medical complexity.

The mean claim duration also shows a statistically significant difference between the low and high compliance groups. Linear regression analysis results from Table 5 indicate that the estimated impact of low compliance is an increase of 13.2% to claim duration across all ventiles for medical complexity. These results also indicate major differences in the outcomes of claims on the basis of the adherence of medical treatments to the ODG guidelines for workers' compensation across all cases mixes, body parts, and injury types. Figure 5 indicates that the mean claim duration for the low compliance group always exceeds that of the high compliance group across all ventiles of medical complexity.

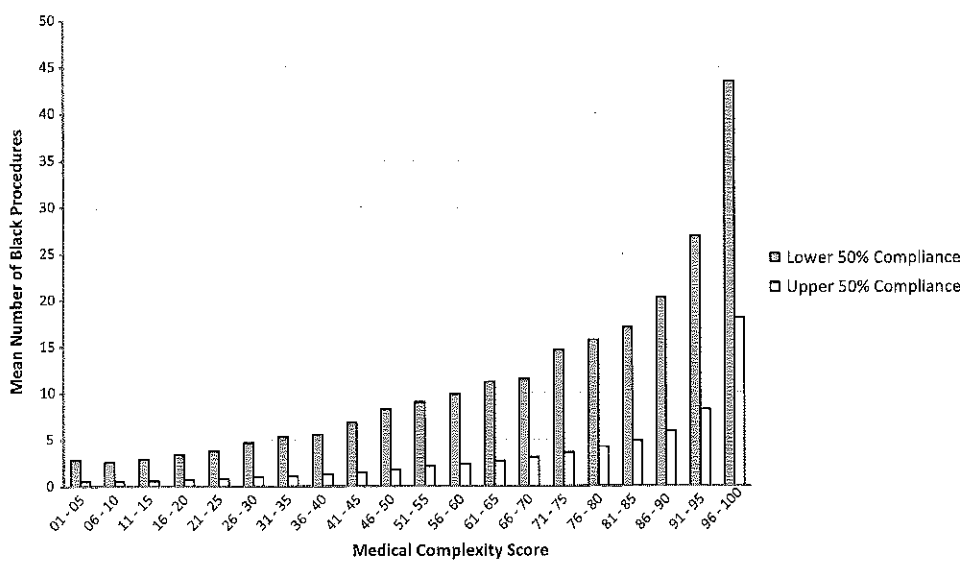

FIGURE 3. Mean number of black procedures by medical complexity score and compliance score category.

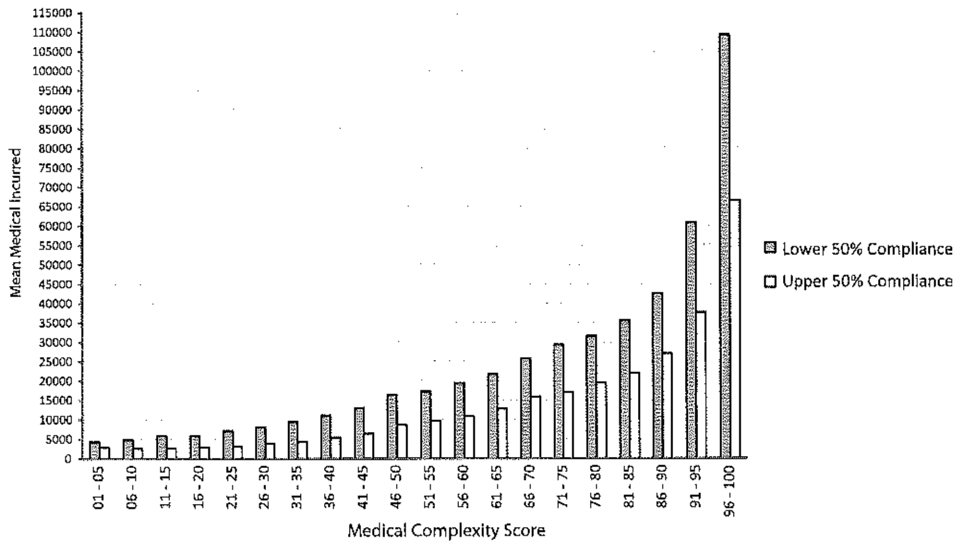

FIGURE 4. Mean medical incurred by medical complexity score and compliance score category.

TABLE 4. Factors Associated With Log (Medical Incurred): Upper 50% Compliance

Independent Variables	Estimate	Std. Error	t value	P	Effect
(Intercept)	7.2503	0.0108	673.0	0.000000	
Medical complexity	0.0188	0.0002	83.2	0.000000	
Distinct ICD9 codes	0.1071	0.0017	62.5	0.000000	
Medical Services_No Red	0.0059	0.0001	57.2	0.000000	
Upper 50% compliance	−0.4764	0.0095	−50.2	0.000000	−37.9%

Controlling for benefit state, the industry class code of the injured worker, the part, nature and cause of the injury, the age at accident, as well as the diagnosis codes, and CPT codes present in the billing history.

DISCUSSION

A review of the current medical literature reveals a paucity of research related to the use of EBM in workers' compensation. However, notable exceptions include the works of Fisher and Wood,[5] Sackett et al,[3,6] Djulbegovic et al,[11] and Harris and Swedlow,[20] who provide a background for EBM investigation in workers' compensation. Even without a scientific underpinning, many states are adopting legislation in support of EBM guidelines in the workers' compensation industry. The lack of research regarding the impact of EBM guidelines on injured worker outcomes presents many questions related to the proper use and continued expansion.

TABLE 5. Factors Associated With Log (Duration)—Upper 50% Compliance

Independent Variables	Estimate	Std. Error	t	P	Effect
(Intercept)	2.0899	0.0120	174.5	0.000000	
Medical complexity	0.0252	0.0003	100.6	0.000000	
Distinct ICD9 codes	0.0226	0.0019	11.8	0.000000	
Medical services_NoRed	0.0045	0.0001	39.6	0.000000	
Upper 50% compliance	−0.1411	0.0106	−13.4	0.000000	−13.2%

Controlling for benefit state, the industry class code of the injured worker, the part, nature and cause of the injury, the age at accident, as well as the diagnosis codes, and CPT codes present in the billing history.

The intention of the EBM guidelines is to combine best practice protocols and optimal care pathways with caution to avoid potentially harmful, inappropriate care to the injured worker. This study was designed to investigate this principal and to develop a first of its kind algorithm to quantify the impact of EBM guideline on claims outcomes. To this aim, we describe a generalizable method of assigning a compliance score to a claim, based on the primary diagnosis and treatments provided to injured workers, considering all body parts and injury types. The compliance score makes it possible to quantify adherence to EBM guidelines, so that the impact of EBM-supported treatments on duration of time off work and medical cost can be assessed.

One of the unique aspects of workers compensation insurance is that both the injured worker and the workers compensation insurance company share a similar goal—returning the injured worker back to work in a timely fashion. This path to recovery is frequently convoluted. Clinical decision-making is based on an individual providers training, experience, and regional differences. EBM is a resource that distills the current medical research into appropriate treatment guidelines for a wide variety of clinical problems. We wanted to investigate whether utilizing EBM in the care of injured workers meets the goal of shortened duration off work and decreased medical cost of the claim.

The development of two separate analytical techniques was needed to test the hypotheses, one to stratify each claim for medical complexity and a second to determine the compliance/adherence to EBM guidelines as defined by ODG. The claims were divided into 10 levels of medical complexity and then scored on the basis of their adherence to the ODG guidelines. The comparison of the claims in the high compliance group (or the top 50% of compliance) to the low compliance group (or the bottom 50% of compliance) of the claims is the foundation of our findings.

When all levels of medical complexity are considered, those claims in the low compliance group had a 13.2% increase in claim duration and a 37.9% increase in medical incurred when compared with claims in the high compliance group.

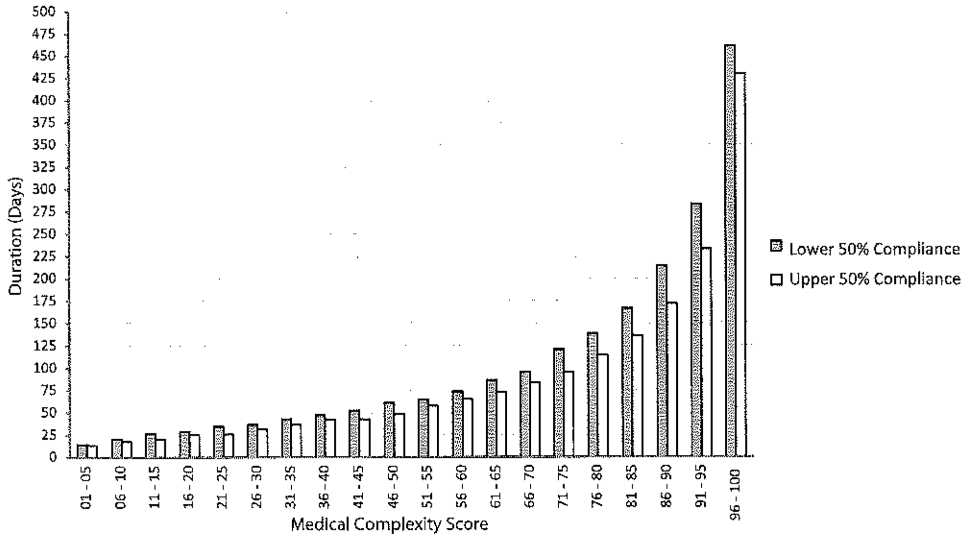

FIGURE 5. Mean claim duration by medical complexity score and compliance score category.

As the medical complexity of the claim increases, so does the difference in duration and medical spend between the low and high compliance groups. In the top 10% of claims for medical complexity, the difference in duration of the claim and medical spend between the low and high compliance groups is 18% and 38%, respectively.

Across all levels of medical complexity, the mean number of appropriate procedures for the high compliance and low compliance groups was similar. When we evaluated the mean number of inappropriate procedures, as represented by black flags in Fig. 3, we found a striking difference between the low and high compliance groups. The study demonstrated a steadily increase in the number of inappropriate procedures performed per claim in the low compliance group across all medical complexities. This finding suggests that the primary driver of increasing duration and medical spend in the low compliance group (or the bottom 50% of the population) is the addition of inappropriate care to the injured worker.

CONCLUSIONS

Currently, most state workers' compensation rules and regulations, specifically regarding the payment of medical treatments or drugs, do not favor an objective standard for treatment. However, more states are creating their own guidelines or considering the adoption of published workers' compensation guidelines. The hope, assuming the guidelines are well written and the dispute resolution process is clear, is that limiting overutilization of treatments and inappropriate care will lead to a reduction in system cost and an improvement in injured worker outcomes.

Our research demonstrates the possibility of using claims and medical billing data to assess the impact of EBM guidelines on injured worker outcomes. Using the ODGs, we were able to demonstrate a significant difference in claims outcomes resulting from "compliant" versus "noncompliant" care.

REFERENCES

1. Davidoff F, Haynes B, Sackett D, Smith R. Evidence based medicine. *BMJ.* 1995;310:1085–1086.
2. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. *BMJ.* 1996;13: 1996;312:71–72.
3. Sackett DL, Rosenberg WM. The need for evidence-based medicine. *J R Soc Med.* 1995;88:620–624.
4. WLDI. *Official Disability Guidelines.* George West, TX: Work Loss Data Institute; 2015.
5. Fisher CG, Wood KB. Introduction to and techniques of evidence-based medicine. *Spine (Phila Pa 1976).* 2007;12007;32(19 Suppl):S66–S72.
6. Sackett DL, Rosenberg WM. On the need for evidence-based medicine. *J Public Health Med.* 1995;17:330–334.
7. Zwolsman SE, van Dijk N, de Waard MW. Observations of evidence-based medicine in general practice. *Perspect Med Educ.* 2013;2:196–208.
8. Zwolsman SE, van Dijk N, Te Pas E, Wieringa-de Waard M. Barriers to the use of evidence-based medicine: knowledge and skills, attitude, and external factors. *Perspect Med Educ.* 2013;2:4–13.
9. Bates DW, Kuperman GJ, Wang S, et al. Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *J Am Med Inform Assoc.* 2003;10:523–530.
10. Craig JC, Irwig LM, Stockler MR. Evidence-based medicine: useful tools for decision making. *Med J Aust.* 2001;174:248–253.
11. Djulbegovic B, Hozo I, Lyman GH. Linking evidence-based medicine therapeutic summary measures to clinical decision analysis. *Med Gen Med.* 2000;2:E6.
12. Cohen AM, Hersh WR. Criticisms of evidence-based medicine. *Evid Based Cardiovasc Med.* 2004;8:197–198.
13. Haynes RB, Devereaux PJ, Guyatt GH. Clinical expertise in the era of evidence-based medicine and patient choice. *ACP J Club.* 2002;136:A11–A14.
14. AMA. Current Procedural Terminology. Chicago, IL: American Medical Association; 2015.
15. NCHS. International Classification of Diseases, 9th Revision. Hyattsville, MD: National Center for Health Statistics; 1977.
16. White JA, Tao X, Artuso RD, Bilinski C, Rademacher J, Bernacki EJ. Effect of physician-dispensed medication on workers' compensation claim outcomes in the state of Illinois. *J Occup Environ Med.* 2014;56:459–464.
17. White JA, Tao X, Talreja M, Tower J, Bernacki E. The effect of opioid use on workers' compensation claim cost in the State of Michigan. *J Occup Environ Med.* 2012;54:948–953.
18. Friedman J, Hastie T, Tibshirani R. Regularization paths for generalized linear models via coordinate descent. *J Stat Softw.* 2010;33:1–22.
19. Friedman JH. Stochastic gradient boosting. *Computational Statistics & Data Analysis.* 2002;38:367–378.
20. Harris J, Swedlow A. Evidence-Based Medicine & The California Workers' Compensation System. Oakland, CA: California Workers' Compensation Institute; 2004.