10-1-2021

Expected Organizational Costs for Inserting Prevalence Information Into Lumbar Spine Imaging Reports

Brian W. Bresnahan

Jeffrey G. Jarvik

Eric N. Meier

Kathryn T. James

Laura S. Gold

See next page for additional authors

Authors

Brian W. Bresnahan, Jeffrey G. Jarvik, Eric N. Meier, Kathryn T. James, Laura S. Gold, Sean D. Rundell, Judith A. Turner, Pradeep Suri, Patrick H. Luetmer, Janna L. Friedly, Karen J. Sherman, Patrick J. Heagerty, David F. Kallmes, Andrew L. Avins, Brent D. Griffith, and Larry G. Kessler

Expected Organizational Costs for Inserting Prevalence Information Into Lumbar Spine Imaging Reports

VISUAL ABSTRACT

Brian W. Bresnahan, PhD[a,c,d], Jeffrey G. Jarvik, MD, MPH[a,b,c,d], Eric N. Meier, MS[e], Kathryn T. James, MPH[a,d], Laura S. Gold, PhD[a,d], Sean D. Rundell, DPT, PhD[d,h], Judith A. Turner, PhD[d,f,h], Pradeep Suri, MD, MS[g,h], Patrick H. Luetmer, MD[i], Janna L. Friedly, MD, MPH[d,h], Karen J. Sherman, PhD, MPH[j], Patrick J. Heagerty, PhD[e], David F. Kallmes, MD[i], Andrew L. Avins, MD, MPH[k], Brent D. Griffith, MD[l], Larry G. Kessler, ScD[c]

Abstract

Background: Modifying physician behavior to more closely align with guideline-based care can be challenging. Few effective strategies resulting in appropriate spine-related health care have been reported. The Lumbar Imaging With Reporting of Epidemiology (LIRE) intervention did not result in reductions in spine care but did in opioid prescriptions written.

Objectives: To estimate organizational resource needs and costs associated with implementing a pragmatic, decision support-type intervention that inserted age- and modality-matched prevalence information for common lumbar spine imaging findings, using site-based resource use data from the LIRE trial.

Research design: Time and cost estimation associated with implementing the LIRE intervention in a health organization.

Subjects: Providers and patients assessed in the LIRE trial.

Measures: Expected personnel costs required to implement the LIRE intervention.

Results: Annual salaries were converted to daily average per person costs, ranging from $400 to $2,200 per day (base case) for personnel (range: $300-$2,600). Estimated total average cost for implementing LIRE was $5,009 (range: $2,651-$12,020), including conducting pilot testing with providers. Costs associated with a small amount of time for a radiologist (6-12 hours) and imaging-ordering providers (1-8 hours each) account for approximately 75% of the estimated total cost.

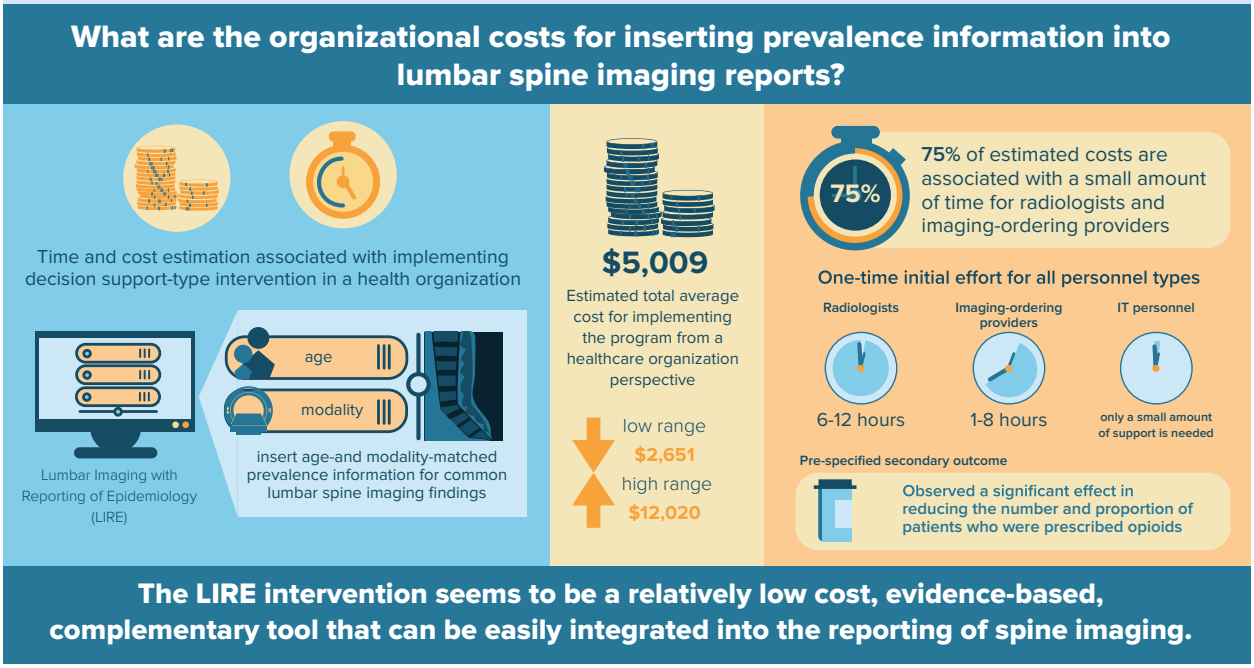
[a]Department of Radiology, University of Washington, Seattle, Washington.
[b]Department of Neurological Surgery, University of Washington, Seattle, Washington.
[c]Department of Health Services, University of Washington, Seattle, Washington.
[d]Comparative Effectiveness, Cost, and Outcomes Research Center, University of Washington, Seattle, Washington.
[e]Department of Biostatistics, University of Washington, Seattle, Washington.
[f]Department of Psychiatry and Behavioral Sciences, University of Washington, Seattle, Washington.
[g]Rehabilitation Care Services, VA Puget Sound Health Care System, Seattle, Washington.
[h]Department of Rehabilitation Medicine, University of Washington, Seattle, Washington.
[i]Department of Radiology, Mayo Clinic, Rochester, Minnesota.
[j]Kaiser Permanente Washington, Seattle, Washington.
[k]Division of Research, Kaiser Permanente Northern California, Oakland, California.
[l]Diagnostic Radiology, Henry Ford Hospital, Henry Ford Health System, Detroit, Michigan.

Corresponding author and reprints: Brian W. Bresnahan, PhD, University of Washington School of Medicine, Department of Radiology, 325 Ninth Avenue, Seattle, WA 98104-2499; email: bres@uw.edu.

Dr Bresnahan, Dr Jarvik, Mr Meier, Ms James, Dr Gold, Dr Rundell, Dr Turner, Dr Suri, Dr Luetmer, Dr Friedly, Dr Sherman, Dr Heagerty, Dr Kallmes, Dr Avins, Dr Griffith, and Dr Kessler report grants from the United States of America's National Institutes of Health, during the conduct of the study. In addition, Dr Kallmes has a patent Spine Augmentation licensed to Kypheze Medical, LLC. Dr Jarvik reports Springer Publishing: royalties as a book co-editor; GE-Association of University Radiologists Radiology Research Academic Fellowship (GERRAF): Travel reimbursement for Faculty Board of Review; Wolters Kluwer/UpToDate: Royalties as a chapter author. Dr Friedly reports grants from United States of America Department of Defense, and other support from the American Academy of Physical Medicine and Rehabilitation, outside the submitted work. Dr. Bresnahan, Dr Jarvik, Mr Meier, Dr Gold, Dr Rundell, Dr Turner, Dr Suri, Dr Luetmer, Dr Friedly, Dr Sherman, Dr Heagerty, Dr Kallmes, Dr Griffith, and Dr Kessler are nonpartner, non–partnership track employees. Ms James was a nonpartner, non–partnership track employee, but is no longer an employee of the University of Washington, and is not an employee of a health care organization. Dr Avins is a partner in The Permanente Medical Group.

1546-1440/21/$36.00 ■ https://doi.org/10.1016/j.jacr.2021.06.010

Visual Abstract



JACR VISUAL ABSTRACT

Conclusions: The process of implementing an intervention for lumbar spine imaging reports containing age- and modality-appropriate epidemiological benchmarks for common imaging findings required radiologists, imaging-ordering providers, information technology specialists, and limited testing and monitoring. The LIRE intervention seems to be a relatively low-cost, evidence-based, complementary tool that can be easily integrated into the reporting of spine imaging.

Key Words: Costs, imaging, implementation, opioids, spine

J Am Coll Radiol 2021;18:1415-1422.

INTRODUCTION

Modifying physician behavior to more closely align with guideline-based care can be challenging. Systematic reviews have concluded that interventions associated with desired changes in physician behaviors aligned with guideline-based recommendations were often educational in nature and multifaceted [1]. In the United States, multiple strategies were used in response to the opioid crisis of dramatic opioid prescribing [2]. Opioid-related guideline developers and expert panels have focused on reducing associated risks and encouraging appropriate prescribing, including for patients with low back pain [3-5]. There has been some success with initiatives imposing greater restrictions on opioid prescribing and using education approaches for providers and patients [2]. Despite progress in slowing increases in the rate of US deaths attributed to opioid prescribing, a substantial burden remains, because deaths remained consistent at approximately 17,000 per year between 2011 and 2015 [2]. Non-guideline-based inappropriate use of opioids and potential adverse events, in general and with low back pain, continue to be concerning [2,3]. Total 2017 estimated expenses for outpatient opioid prescriptions for payers and patients were greater than $7 billion [6]. Despite these trends, and despite published guidelines for low back pain [5], few effective strategies to encourage appropriate spine-related health care have been reported. General practitioners in the United States are high-volume prescribers of opioids and often an early point of contact for patients presenting with back issues who may have imaging ordered to assess their condition [7].

We recently conducted a large, pragmatic, cluster-randomized trial in multiple sites in the United States to study the effect of an intervention that incorporates standardized prevalence estimates of commonly encountered spine imaging findings (ie, the Lumbar Imaging With Reporting of Epidemiology [LIRE] trial) [8]. Although we found no evidence of intervention effects in our primary outcome of a reduction of spine-related relative value units, among patients whose providers received the intervention, we observed a significant effect of the intervention

in reducing the number and proportion of patients who were prescribed opioids, a prespecified secondary outcome [9]. The current article estimates average expected health care organization costs for implementing the LIRE intervention in clinics. Our research on implementing the LIRE intervention will inform health systems and other stakeholders about resource needs and expected average costs.

METHODS

Data Sources and Overview of LIRE Trial

The LIRE trial was a pragmatic, multicenter, stepped-wedge, cluster-randomized controlled trial assigning primary care clinics at four large US health systems to receive lumbar spine imaging reports containing age- and modality-appropriate epidemiological benchmarks for common imaging findings in people without back pain. We previously published the study protocol [8] and reported study findings [9]. For this article, we estimated implementation costs using personnel and salary ranges of relevant providers at participating health organizations, converting annual salaries with benefits to average daily costs. Supplemental Table 1 demonstrates the stepped-wedge design allocation and the temporal implementation of the intervention during the LIRE trial [9]. Supplemental Table 2 presents examples of the LIRE intervention text inserted in spine imaging reports [9]. We evaluated 238,886 patients (≥18 years old) in participating clinics that were randomized among four health organizations located in five states. Participants received spine imaging between October 2013 and September 2016. We compared patients during 1 year after the LIRE intervention was implemented in clinics to 1-year outcomes of control patients. Providers at control clinics received unaltered imaging reports before their assigned start date for implementing the LIRE intervention. We included all patients receiving eligible imaging studies at participating clinics who had not had lumbar spine imaging within the prior 12 months, thus focusing on patients early in their diagnostic expedition. We excluded only those patients who had signed a declaration opting out of research studies.

Perspective

Our primary analysis was from a health care organization perspective, which we defined as a health organization with groups of primary care providers (PCPs) and specialists, which were also affiliated with emergency and hospital facilities. Our study included organizations employing providers whose care is reimbursed by external payers, as well as systems providing health care through a prepaid health plan model (ie, staff-model health maintenance organization).

Time Horizon

Our time horizon for estimating personnel costs associated with LIRE implementation was 1 month. Our estimates for the amount of time for various types of personnel required to implement the insertion of the intervention text were based on interviewing a radiology IT expert (Dr. M.L. Gunn, University of Washington, personal communication, 2020) and confirmed by LIRE site radiologists.

Estimation of Resources Used for LIRE Implementation

We focused on personnel-related organizational costs associated with implementing the LIRE intervention. To estimate resource needs associated with deploying the intervention, we used ranges of per person efforts for the study-related resource use for each personnel type, using average personnel costs from our LIRE sites and our study team. Estimates for personnel time required for implementation were obtained from our radiology IT expert. As a more generalizable estimate, we used average per employee personnel time and cost estimates for medical providers, project managers, and IT personnel. Our cost estimate focused on average resources used for personnel involved in implementing the LIRE intervention in the radiology spine imaging IT system for report generation and for pilot testing the intervention. We estimated base-case scenarios and low and high ranges for each type of personnel required.

We assumed one radiologist in a health care organization would lead the LIRE intervention implementation, requiring a small amount of time initially (base case: 6 hours). This time could be allocated among two or more radiologists sharing the responsibility. The radiologist would (1) guide the radiology IT specialist to implement and test the age-based, modality-matched LIRE intervention in spine imaging reports, (2) direct a project manager to assist with communication to stakeholders or process-oriented tasks, and (3) communicate with the ordering providers on an as-needed basis related to the LIRE intervention text being inserted in spine imaging reports. Our base-case estimate included a small amount of time (2-4 hours) required for an organization's imaging-ordering providers (primary care and specialist providers) during the initial rollout period. Multiple doctors in a system could be involved via consulting with the radiologist leading the implementation, as well as participating in a pilot to make sure that adding the intervention worked as expected. A range of 2 to 4 hours was included for a radiology IT supervisor and roughly 4 to 6 hours per week for up to 1 month for a midlevel IT programmer. The supervisor would address systemwide issues from an organizational perspective. The programmer would work with the radiologist to insert the intervention text and

Table 1. Average annual and daily cost for personnel associated with implementation

Personnel Categories	Base-Case Annual Salary* ($)	Benefits (35% Rate) ($)	Total Organization Annual Cost ($)	Annual Cost Low Range (−20%) ($)	Annual Cost High Range (+20%) ($)	Total Organization Daily Cost ($)†	Daily Cost Low Range ($)†	Daily Cost High Range ($)†
Medical doctors								
Primary care providers	200,000	70,000	270,000	216,000	324,000	1,080	864	1,296
Radiologists	400,000	140,000	540,000	432,000	648,000	2,160	1,728	2,592
Other medical specialists	400,000	140,000	540,000	432,000	648,000	2,160	1,728	2,592
IT specialists								
Senior programmer or manager	175,000	61,250	236,250	189,000	283,500	945	756	1,134
IT programmer (midlevel)	85,000	29,750	114,750	91,800	137,700	459	367	551
Project staff								
Project manager	75,000	26,250	101,250	81,000	121,500	405	324	486

*Total organization annual cost and daily cost estimates include benefits rate applied to salary.
†Daily amounts calculated based on 250 working days per year.

conduct initial pilot testing. The programmer would run basic reports for the radiologist(s) in the initial phase of implementation to monitor the process and identify any problems. Our higher-range estimate of 24 hours allowed programmer time for conducting additional testing or addressing errors in how the intervention was working for ordering providers. We included a range of time (3-12 hours) for a project manager to work with the lead radiologist and to communicate with the imaging-ordering providers. The manager would record and distribute meeting summaries with required actions for implementation, engage in follow-up activities with the programmer, manage communication with key personnel during the pilot testing of the intervention, and address other project needs related to communication.

Estimation of Costs for Implementation

We estimated total average costs for the intervention implementation during the initial rollout of 1 month. Because we designed the LIRE intervention to require no training of providers, we did not include training as part of the costs. However, we included estimates for conducting pilot testing with imaging-requisitioning providers before a full rollout of the intervention.

RESULTS

Table 1 presents parameter estimates used for calculating personnel costs for the LIRE intervention implementation. The primary personnel required for implementation were medical doctors (radiologists, PCPs, and other specialists), IT specialists, and a project manager. Average daily organization costs and high and low ranges for personnel, based on annual salary estimates with benefits, were $1,080 ($864-$1,296) for PCPs and $2,160 ($1,798-$2,592) for radiologists and other specialists. Daily base-case average costs and ranges for a senior IT manager and a mid-level IT programmer were $945 ($756-$1,134) and $459 ($367-$551), respectively. Project management or administrative support was estimated to cost $405 per day with a range of $324-$486.

Our IT specialist interviews indicated that implementing LIRE would not require the purchase of a new computer system or for organizations to incur costs associated with modifying or updating standard IT interface engines used by most radiology departments. Based on the characteristics of LIRE as a relatively simple text-based addition of standardized, epidemiological information to radiology reports, matched to age groups and imaging modalities, the intervention requires a low level of resources to implement in radiology IT systems. Expert radiology IT guidance indicated LIRE could be implemented in 1 to 2 days with

Table 2. Expected average time and costs for implementing the LIRE intervention

	Base-Case No. of Hours	Low-Range No. of Hours[†]	High-Range No. of Hours[‡]	No. of Personnel	Base-Case No. of Days per Person	Low-Range No. of Days per Person	High-Range No. of Days per Person	Base-Case Cost ($)	Low-Range Cost ($)	High-Range Cost ($)
Primary care providers	4	2	8	2.00	0.50	0.25	1.00	1,080	432	2,592
Radiologists	6	3	12	1.00	0.75	0.38	1.50	1,620	1,296	3,888
Other medical specialists	2	1	4	2.00	0.25	0.13	0.50	1,080	432	2,592
Senior IT specialist (manager)	2	1	4	1.00	0.25	0.13	0.50	236	95	567
IT programmer (midlevel)	12	6	24	1.00	1.50	0.75	3.00	689	275	1,652
Project manager or administrative assistant	6	3	12	1.00	0.75	0.38	1.50	304	122	729
Total estimated personnel cost for implementation								5,009	2,651	12,020

LIRE = Lumbar Imaging With Reporting of Epidemiology.
[†]Low-range cost estimates were calculated using the relevant personnel category and the "Annual Cost Low Range" column from Table 1 and low-range number of hours in Table 2.
[‡]High-range cost estimates were calculated using the relevant personnel category and the "Annual Cost High Range" column from Table 1 and high-range number of hours in Table 2.

additional time for preparatory and progress meetings, as well as for conducting pilot testing with imaging-ordering providers (ie, PCPs and specialists). Overall, the entire process could be completed in 1 month, including implementing the LIRE intervention text for insertion in reports, testing the intervention, and rolling out the LIRE intervention to several clinics within a health system.

Table 2 presents time and cost estimates for implementing the LIRE intervention during initial rollout. Estimated organization total base-case cost for implementing LIRE was $5,009, with low- and high-range estimates of $2,651 and $12,020, respectively. The time for the radiologist and ordering providers accounted for approximately 75% of estimated total costs. We estimated 12 to 24 hours (less than 10% of work time for 1 month or 15% for our higher-range estimate) were required for a midlevel radiology IT specialist, accounting for team meetings, programming, and producing a simplified report in association with testing the intervention. The average cost for the midlevel specialist was $689, and a small amount of time for an IT manager (2-4 hours) costs $236. We estimated 6 to 12 hours were needed for the lead radiologist overseeing the implementation of the LIRE intervention, along with 4 to 8 hours of total PCP time and 2 to 4 hours for other medical specialists to complete pilot testing.

The pilot testing would confirm whether the intervention text was appropriately appearing on spine-related radiology reports. More radiology IT personnel resources would be needed if errors were identified during testing, if a planned rollout is to occur systematically for clinics within a system with specific monitoring rather than implementing LIRE in all clinics simultaneously, or if the IT system connectivity or consistency is suboptimal among the organization's clinics. We included enough personnel time when calculating the high-range estimates in Table 2 to allow for addressing these possibilities.

DISCUSSION

We estimated average organization costs for implementing a pragmatic health care decision support-type intervention that inserted epidemiological information about age-related prevalence of back conditions on spine imaging reports. We based our cost estimates for implementing the LIRE intervention on ranges of expected activities and salaries obtained from our university and health care organizations participating in the LIRE trial. Health policy stakeholders in the United States encourage health care providers to use evidence-based approaches to reduce costs while maintaining or improving the quality of patient experiences and improving population-level outcomes [10]. Interventions that improve outcomes or provide similar effectiveness and have the potential to lessen overall costs to stakeholders align with these stated health system goals.

The opioid crisis in the United States is an example of a multifactor, multistakeholder challenge that requires a variety of potentially helpful solutions. In some cases, opioids are appropriate and necessary but not typically for low back pain [5]. In cases of severe acute pain or end of life pain, opioids are often appropriate in short durations. However, use of caution is recommended in prescribing opioids for longer durations for chronic pain and for any duration in patients with mild to moderate acute pain [3,11]. Despite myriad policies aimed at reducing opioid use for many years, opioid prescribing in the United States continues to add burden to the health care system [2,6,12,13].

Although we found no evidence of intervention effects in the LIRE trial in our primary outcome of a reduction of spine-related relative value units during 1 year among patients whose providers received the intervention, we observed an effect consistent with goals related to opioids. The LIRE study showed that implementing the standardized age-matched language on spine imaging reports resulted in a significant reduction in the probability of providers writing prescriptions for opioid medications after the addition of the intervention in clinics, which was a prespecified secondary outcome. There was a small but statistically significant reduction in patients receiving at least one prescription in 1 year for an opioid from a LIRE provider in the intervention group compared with patients in the pre-intervention (control) group (adjusted opioid rate 36.2% versus 37.0%; odds ratio = 0.95 [95% confidence interval: 0.91-1.00]; $P = .04$) [9]. In addition, we did not observe differences in safety-related end points associated with the LIRE intervention, as measured through assessing deaths, hospitalizations, and emergency or urgent care visits, during the year subsequent to the intervention being inserted on reports [9]. The LIRE trial was completed before the start of the coronavirus disease 2019 pandemic [14].

Larger health care organizations, such as those participating in the LIRE trial, are likely to have established formal or informal networks of providers willing to participate in testing IT modification rollouts. Smaller radiology groups could inquire with their ordering providers about helping with such testing. Testing could occur within 1 month, depending on the size of a health organization and plans for implementation testing in clinics. New decision support-type radiology IT-based interventions are more expensive to implement when they require modifying an IT system's interface or integrating a new "interface engine" to assist with distributing information to providers. The LIRE intervention does not have these barriers and could be implemented across many clinics in a health system quickly

and seamlessly and at a low incremental cost to provider organizations. It is reasonable to expect that costs will be largely incurred in the first month of implementing the LIRE intervention.

Systematically adding age-based prevalence information on imaging reports would require a low level of resources, including a small amount of personnel time for an IT programmer, a manager, and a radiologist. The LIRE intervention could be implemented with roughly 1 to 2 days of effort by a radiology IT specialist, varying with the number of clinics, the level of experience by radiology departments for inserting text on reports, and the interconnectivity of the IT network for clinics in an organization. Best practice recommendations include pilot testing interventions during implementation for quality assurance. Our cost estimates ranged from approximately $2,600 to $12,000 for initial LIRE implementation (base case: $5,000), including costs for pilot testing by providers ordering imaging. Our personnel and total cost estimates allowed for a broad salary range of each personnel type (±20% of base case) and ranges of time or effort.

Opioid-related guidelines encourage appropriate opioid prescribing and reducing the risks associated with long-term opioid therapy [3]. In patients with acute or persistent low back pain, opioids are recommended selectively and with caution [5]. The LIRE patients receiving lumbar spine imaging were early in their spine-related diagnostic process. Systematic reviews of musculoskeletal conditions and work-related outcomes, along with other disability-related research, indicate that early opioid prescribing can increase subsequent health care use—including opioid use—and prolong disability [15-18]. It is likely that multiple strategies are needed to modify behavior in providers, such as for changing opioid prescribing. Although we observed the reduction in opioid prescriptions during a period of intense pressure and several initiatives in the United States by health systems and health care organizations to reduce opioid prescribing [19-23], the LIRE intervention seems to provide a positive complement to other initiatives aimed at reducing opioid prescribing. Implementing LIRE may provide an additional tool for health systems looking to incorporate evidence-based information for providers.

We acknowledge that there may not be persistent annual reductions in opioid prescribing subsequent to implementing the LIRE intervention once an initial effect is realized. However, no intervention will have immediate effects in all providers, so to appreciate the outcomes of the intervention may require a longer time horizon. Despite the pragmatic characteristics of the LIRE intervention (ie, automating the addition of standardized epidemiological information on radiology reports), there are inherent challenges to implementing such an intervention. Radiology information systems use synchronized IT filtering mechanisms for directing patient-specific or group-specific data based on specified criteria, often from electronic medical records or other data sources. The imaging-related intervention would be implemented in radiology IT systems or electronic health record systems in an organization, which likely vary among sites and in terms of provider access. Individual radiologists, for example, may be able to manually modify reports or report templates.

Potential costs and benefits accruing to organizations would depend on whether the health organization was an insurance provider (payer) in addition to being a health care services provider organization. Our study included both types of health systems. In the United States, in a nonstaff model health maintenance organization, medication prescriptions are often filled by patients at pharmacies not affiliated with the health care provider and are covered and reimbursed based on a patient's benefit package. Payers (public or commercial) may benefit from the LIRE intervention through having to pay for fewer opioid prescriptions for plan members receiving spine imaging, all other things equal. At approximately $70 per average opioid prescription for payers, and an annual opioid-related outpatient prescription cost for payers and patients estimated to be greater than $3,000, reducing only a small percentage of opioid prescribing could have meaningful financial effects [6].

We did not assess cost-reduction effects associated with providers writing fewer opioid prescriptions nor downstream effects of potentially fewer adverse events from opioid use. It was beyond the scope of this implementation assessment to estimate secondary effects of opioid prescription reduction, such as costs of subsequent non-spine-related health care use. There are inherent challenges in attributing non-spine-related use to our pragmatic intervention. We did not collect patient-reported outcomes in our trial, so we were not able to assess impacts on quality of life, pain, or other symptom measures. We do not present LIRE development costs as part of our estimation, because these activities were conducted during the planning phase of our trial. We also did not estimate additional personnel time that would be required if the LIRE intervention text required updating based on new epidemiological evidence becoming available in the future.

TAKE-HOME POINTS

- The process of implementing an intervention for lumbar spine imaging reports containing age- and modality-appropriate epidemiological benchmarks for common imaging findings requires radiologists, imaging-ordering providers, IT specialists, and limited testing and monitoring.

- The LIRE intervention seems to be a relatively low-resource-intensive, evidence-based tool that can be quickly and easily integrated into the reporting of spine imaging.
- The LIRE intervention may serve as an example for other imaging indications for adding epidemiological information to imaging reports as a decision support-type tool for imaging-ordering providers and their patients.

ACKNOWLEDGMENTS

This work was supported within the National Institutes of Health (NIH) Health Care Systems Research Collaboratory by the NIH Common Fund through cooperative agreement U24AT009676 from the Office of Strategic Coordination within the Office of the NIH Director and cooperative agreements UH2AT007766 and UH3AR066795 from the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS). It was also supported by the University of Washington (UW) Clinical Learning, Evidence and Research Center for Musculoskeletal Disorders funded by NIH/NIAMS P30AR072572. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. We thank Dr Martin L. Gunn of the UW Department of Radiology for his expertise and guidance related to implementing radiology IT-based interventions. Renditions of our Supplemental Table 1 and Supplemental Table 2 were previously published in JAMA Network Open, 2020; 3(9):e2015713. https://doi.org/10.1001/jamanetworkopen.2020.15713, under the terms of the CC-BY license.

REFERENCES

1. Mostofian F, Ruban C, Simunovic N, Bhandari M. Changing physician behavior: what works? Am J Manag Care 2015;21:75-84.
2. National Academy of Sciences Engineering, and Medicine. Pain management and the opioid epidemic: Balancing societal and individual benefits and risks of prescription opioid use. Washington, DC: National Academies Press; 2017.
3. Dowell D, Haegerich DM, Chou R. CDC guideline for prescribing opioids for chronic pain—United States, 2016. MMWR Recomm Rep 2016;65(1).
4. Buchbinder R, van Tulder M, Öberg B, et al. Low back pain: a call for action. Lancet 2018;391:2384-8.
5. Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet 2018;391:2368-83.
6. Ding Y, Miller GE. Total expenses, total utilization, and sources of payment for outpatient prescription opioids in the U.S. adult civilian noninstitutionalized population, 2017. Statistical Brief, #529. Rockville, MD: Agency for Healthcare Research and Quality; 2020.
7. Chen JH, Humphreys K, Shah NH, Lembke A. Distribution of opioids by different types of Medicare prescribers. JAMA Intern Med 2016;176:259-61.
8. Jarvik JG, Comstock BA, James KT, et al. Lumbar Imaging With Reporting of Epidemiology (LIRE)—protocol for a pragmatic cluster randomized trial. Contemp Clin Trials 2015;45 Pt B:157-63.
9. Jarvik JG, Meier EN, James KT, et al. The effect of including benchmark prevalence data of common imaging findings in spine image reports on health care utilization among adults undergoing spine imaging: a stepped-wedge randomized clinical trial. JAMA Network Open 2020;3:e2015713. https://doi.org/10.1001/jamanetworkopen.2020.15713
10. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. Health Aff (Millwood) 2008;27:759-69.
11. CDC. Turn the tide. Prescribing opioids for chronic pain. Available at: https://www.cdc.gov/drugoverdose/pdf/TurnTheTide_PocketGuide-a.pdf. Accessed August 25, 2021.
12. Kiang MV, Basu S, Chen J, Alexander MJ. Assessment of changes in the geographical distribution of opioid-related mortality across the United States by opioid type, 1999-2016. JAMA Netw Open 2019;2:e190040.
13. Owens P, Weiss AJ, Barrett ML. Hospital burden of opioid-related inpatient stays: metropolitan and rural hospitals, 2016. HCUP Statistical Brief #258. Rockville, MD: Agency for Healthcare Research and Quality; 2020.
14. Archived World Health Organization Timeline—COVID-19. Available at: https://www.who.int/news/item/27-04-2020-who-timeline—covid-19. Accessed May 20, 2021.
15. Carnide N, Hogg-Johnson S, Côté P, et al. Early prescription opioid use for musculoskeletal disorders and work outcomes: a systematic review of the literature. Clin J Pain 2017;33:647-58.
16. Webster BS, Verma SK, Gatchel RJ. Relationship between early opioid prescribing for acute occupational low back pain and disability duration, medical costs, subsequent surgery and late opioid use. Spine 2007;32:2127-32.
17. Franklin GM, Stover BD, Turner JA, Fulton-Kehoe D, Wickizer TM. Early opioid prescription and subsequent disability among workers with back injuries: the Disability Risk Identification Study Cohort. Spine 2008;33:199-204.
18. Haight JR, Sears JM, Fulton-Kehoe D, Wickizer TM, Franklin GM. Early high-risk opioid prescribing practices and long-term disability among injured workers in Washington State, 2002 to 2013. J Occup Environ Med 2020;62 538-30.
19. Strickler G, Kreiner PW, Halpin JF, et al. Opioid prescribing behaviors—prescription behavior surveillance system, 11 states, 2010–2016. MMWR Surveill Summ 2020;69(SS-1):1-14.
20. National Institute on Drug Abuse. California: opioid-involved deaths and related harms Available at: https://www.drugabuse.gov/drug-topics/opioids/opioid-summaries-by-state/california-opioid-involved-deaths-related-harms Published April 3, 2020. Accessed September 17, 2020.
21. National Institute on Drug Abuse. Washington: opioid-involved deaths and related harms Available at: https://www.drugabuse.gov/drug-topics/opioids/opioid-summaries-by-state/washington-opioid-involved-deaths-related-harms Published April 3, 2020. Accessed September 17, 2020.
22. National Institute on Drug Abuse. Minnesota: opioid-involved deaths and related harms Available at: https://www.drugabuse.gov/drug-topics/opioids/opioid-summaries-by-state/minnesota-opioid-involved-deaths-related-harms Published April 3, 2020. Accessed September 17, 2020.
23. National Institute on Drug Abuse. Michigan: opioid-involved deaths and related harms Available at: https://www.drugabuse.gov/drug-topics/opioids/opioid-summaries-by-state/michigan-opioid-involved-deaths-related-harms Published April 3, 2020. Accessed September 17, 2020.