



Analyzing Unnecessary Imaging for Low Back Pain in Nebraska from a Statewide Health Information Exchange

Joy Doll¹ · Madison Kreikemeier² · Cassie Maddigan² · Nathaniel Marshall² · Maggie Young²

Received: 26 May 2020 / Accepted: 27 May 2022 / Published online: 9 June 2022
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

Abstract

Excessive amounts of resources in healthcare are wasted due to duplicated or unnecessary health screenings, especially in the diagnosis of low back pain (LBP). Research shows that two-thirds of people will present with LBP at some point throughout their lifetime, but 20–50% of high-tech imaging procedures fail to provide information that improves the patient’s condition, representing unnecessary services. The purpose of this study was to evaluate the existence of unnecessary imaging for low back pain throughout healthcare systems in Nebraska based on what was documented in the electronic health record. This study was a retrospective electronic health record analysis of a limited data set focused on procedures related to imaging for LBP extracted from Nebraska Health Information Exchange (HIE) managed by CyncHealth. The sample included 937 patient records with a diagnosis of LBP who received imaging in the state of Nebraska and whose health record was recorded in the Nebraska HIE. To determine necessity, records were categorized in three areas including necessary imaging, likely wasteful imaging, or wasteful imaging based on the criteria from the “First, Do No Harm” study conducted by the Washington Health Alliance. Results revealed a total of 51% of low back pain imaging considered wasteful, 35% likely wasteful, and 14% necessary. Based on these results, further research is warranted to determine specific demographics related to necessary, likely wasteful, and wasteful imaging and the purpose for performing these expensive imaging procedures.

Keywords Health information exchange · Low back pain · Imaging

Background

There are hundreds of billions of unnecessary and duplicated healthcare services in the United States which leads to extreme waste in the healthcare system [1]. Referring to healthcare costs from 2017, Choi, Hoban, Michelson, and Vichare noted the potential cost improvement of as much as 30 to 35 percent when seeking to ameliorate certain aspects and qualities of the \$3.5 trillion healthcare economy [2]. In 2018, The Washington Health Alliance discovered excessive amounts of money were wasted due to duplicated or

unnecessary health screenings [3]. According to Burke and Ryan, “Medicare pays physicians and hospitals based on a variety of factors—including geographic region, indirect medical education, and the hospital’s ‘disproportionate share’- but very little based on quality” [4]. Today, electronic health record networks give health care systems an opportunity to address waste and the factors involved by providing a means of communication with other providers and identifying potential duplicative services which lead to waste [5]. According to Kruse, Kristof, Jones, Mitchell, and Martinez, when an EHR is used effectively, it has great potential to improve efficiency and cost savings throughout the healthcare system by improving coordination and communication from one healthcare professional to another, which could avoid excessive spending on duplicated or unnecessary screenings [5].

Health Information Exchanges (HIE) are databases that store data from electronic health records (EHRs), often aggregated and available to demonstrate a longitudinal health record. Multiple studies have found that the use of electronic health records (EHRs) improves the quality of

This article is part of the Topical Collection on *Implementation Science & Operations Management*

✉ Joy Doll
Jdoll@nehii.org

¹ CyncHealth, Dba Nebraska Health Information Initiative, PO Box 27842, Omaha, NE 68127, USA

² Former Students at Creighton University, 2500 California Plaza, Omaha, NE 68178, USA

healthcare delivered [6, 7]. HIEs further expand that impact through interoperability aggregating data and making it available to clinicians to support informed clinical decision making. In fact, HIEs have been shown to directly impact the overuse of imaging reducing duplication, specifically [8–12]. Additionally, they have been shown that when used effectively, they reduce duplicated imaging for low back pain, a significant factor related to waste [9]. One study demonstrated that most duplicated imaging occurs due to a lack of access to previous imaging [10]. Although this study shared in this article is not focused on the impact of the HIE, HIEs have been identified as a tool to explore to impact low back imaging and waste.

One significant health problem in the United States is low back pain, ranking as the fifth most common reason for all physician visits [13]. Research shows that two-thirds of people will present with low back pain at some point throughout their lifetime, but 20–50% of high-tech imaging procedures fail to provide information that improves the patient's condition, representing unnecessary services [14, 15]. Reduction in the amount of duplicated health screenings, specifically low back pain imaging, has the potential to financially protect patients who might have otherwise paid for identical tests or procedures. The Washington Health Alliance found that 83 percent of the imaging received by the 19,673 individuals was identified as either wasteful or likely wasteful, an estimated \$4 million out of the \$4.8 million spent [3]. A survey from previous research revealed that after physicians explained the unnecessary need for imaging related to low back pain, more than one third of patients still insisted on requiring the imaging [16]. This leads to physicians choosing between satisfying their patient or preventing wasteful costs associated with the imaging [16]. Recent research has highlighted potential reasons as to why clinicians order testing when it is otherwise not recommended. Almost all clinicians were aware that an imaging test was not indicated for patients with uncomplicated low back pain, which are those not displaying signals of severe problems, agreeing with the recommendation to forego testing [17]. These tests are often ordered because clinicians feel they have insufficient time to educate their patients on the risks and benefits in addition to having concerns regarding medical liability if tests are not administered and rare diagnoses are missed [17]. Many also specified that they cannot refer patients to a specialist without first ordering imaging, even if they believe the imaging will be of no benefit to potential management of the patient's condition [17]. Although many clinicians are aware that not all imaging is necessary, there is often still an obligation to complete imaging to rule out other health factors and to maintain patient satisfaction.

Acceptable criteria for use of early imaging for low back pain includes risk of cancer, suspicion of spinal infection, signs of cauda equina syndrome, and severe neurological

deficits [18]. According to the American Academy of Family Physicians, low back imaging is not recommended within the first 6 weeks of reported pain unless there are severe neurological deficits or serious underlying conditions are suspected. If these clinical issues are not a concern, then imaging before 6 weeks has not been proven to improve outcomes [13]. Although there has been research to support that higher restrictions on imaging guidelines do reduce waste, the rate of complex imaging has increased by 50% over the last 21 years in countries in North America, Europe, and Australia [19].

Wasteful imaging is a concern with the diagnosis of low back pain due to the large percentage of the population receiving early imaging even though research has shown it to be ineffective for improving outcomes, which serves as the medium for this study due to its commonality among the population nationwide [20]. More research needs to be done using HIEs to determine the extent of waste in health care. There is a gap in knowledge about healthcare redundancies for the imaging of low back pain prevalent in the state of Nebraska. The purpose of this retrospective electronic health record analysis is to evaluate the existence of unnecessary imaging for low back pain throughout healthcare systems in Nebraska to support the fundamental need for a resolution to the escalating healthcare costs and inefficiency of care being received in the United States.

Methods

Research design

This study was a retrospective descriptive study of a limited dataset from electronic healthcare records extracted from a statewide health information exchange that focused on procedures related to imaging for low back pain to examine necessary, likely wasteful, or wasteful services in the state of Nebraska. The limited data set included extracted data from the HIE that met the criteria in the data request. The data request included individual patient records that met the diagnosis criteria for low back pain, type of imaging procedure, gender, hospital location of service, age at procedure date, and whether there was a neurological diagnosis pre-existing the imaging procedure. The study replicated a portion of a previous study “First, Do No Harm” conducted by the Washington Health Alliance focused on low back pain and used their criteria for wasteful imaging [3]. Prior to study implementation, the proposal was reviewed by a data governance committee at CyncHealth, who runs the state's health information exchange. Once approved by CyncHealth's data governance committee, a data use agreement was created and signed prior to submission to the University Institutional Review Board. The study was reviewed

and approved through the University partner's Institutional Review Board and declared non-human subject research.

As part of the data request process, the researchers worked with a data analyst at CyncHealth to generate the code set. The data included the following data elements: procedure code, low back pain diagnosis code, whether the patient had a neurological diagnosis or not, date of procedure, hospital location of procedure, gender, and age at procedure date. In collaboration and based on the Do No Harm study, the inclusion criteria were those individuals who received healthcare services in the state of Nebraska with health records in the Nebraska Health Information Exchange who have been diagnosed with low back pain and had imaging of their lower back [3]. In addition, the procedure codes for imaging were identified with the data analyst including: XR Spine, Thoracic 3 VW; XR L-Spine 2 or 3V; XR Spine, Lumbrosacral, 2 or 3 views; XRAY Exam LS Spine 23 VWS; XR L-Spine Complete >OR=4V; XRAY Spine, Lumbosacral, min 4 views; XRAY Exam L2 Spine 4VWS; 72114: XR L-Spine >OR=6V W Flex & Ext; 72131: CT L-Spine WO; CT Lumbar Spine WO Dye; CT Lumbar Spine without Contrast; 72132: CT L-Spine W **; CT Lumbar Spine W Dye; 72148: MR MRI L-spine WO **; 72149: MRI SP Lumb W CM; 72158: MR MRI L-Spine W WO **.

In addition, the data set included whether or not the patients had a co-existing neurological condition with their LBP. Co-occurring neurological conditions were identified through ICD-10 codes for the following neurological conditions: Stroke, Traumatic Brain Injury, Multiple Sclerosis, Transient Ischemic Attack, Epilepsy, Meningitis, Parkinson's Disease, Alzheimer's, Dementia, Mild Cognitive Impairment, Postpartum Psychosis, Aneurysm, Mild Traumatic Brain Injury/Concussion, Demyelination of Brain, Conversion Disorder, Posterior Encephalopathy, Subdural Hematoma, Cerebral Palsy, Guillain Barre, fall with headache, and migraines resulting from trauma. Central nervous system conditions were considered neurological and peripheral nervous system conditions were not. The following data elements were included in the data request and final data set to be analyzed: age, gender, hospital location, neurological co-morbidity, and date of imaging procedure. The data set was delivered to the researchers following best practices in security and privacy as outlined in the data use agreement. In 2019, at the time of extraction, the data was representative of over 75% of hospitals. Since this time, legislation has been put in place in Nebraska that has mandated data sharing but this legislation was not yet in place at the time of the study.

Data procedures

Records were categorized in Excel into three areas including necessary imaging, likely wasteful imaging, or wasteful

imaging based on the criteria from the "First, Do No Harm" study conducted by the Washington Health Alliance [3]. Criteria consisted of: 'Necessary imaging' includes MRI for patients with neurologic deficits or other serious underlying conditions or in those >70 years old. 'Likely wasteful imaging' includes X-ray lumbar spine and CT lumbar spine without contrast in patients with neurologic deficits or other serious underlying conditions or in those >70 years old. 'Wasteful imaging' includes X-ray, MRI and CT of uncomplicated acute low back pain with no neurologic deficits or underlying conditions in those < 70 years old" [3].

Each record was reviewed by the research team and identified to fit into one of the 3 categories. All tracking was documented and performed in Excel. Upon review, a patient record under 70 with a neurological diagnosis who had a magnetic resonance imaging (MRI) was deemed necessary. For each record under 70 with a neurological diagnosis that received a computed tomography (CT) scan or x-ray were deemed likely wasteful. A record with a patient under 70 years old with no neurological diagnosis who received either a MRI, CT scan or x-ray was identified as wasteful. For individuals identified as over 70 years of age, those with a neurological condition who received a MRI were categorized as necessary while those with a neurological condition who received a CT scan or x-ray were identified as likely wasteful. Lastly, those over 70 with no neurological condition who received a MRI, CT scan or x-ray were deemed likely wasteful.

Researchers met consensus. If consensus could not be reached about the categorization, an expert clinician was consulted to assist with appropriate categorization. The categorization was discussed and agreed upon based on clinical expertise by a subject matter expert. After records were categorized, researchers determined the average amount of all CPT codes found in each individual category of necessary, likely wasteful, and wasteful tests. A chi-square test was completed to determine whether low back pain imaging is dependent upon gender. Results were entered into the matrix in Excel to identify which CPT codes were most wasteful.

Results

The study population includes 937 individual patient health records of individuals with 1,164 CPT codes of a low back pain diagnosis from Nebraska Health Information Exchange (HIE) housed within CyncHealth for January 2019-December 2019. The sample is from health records housed in Nebraska's Health Information Exchange (HIE) at CyncHealth, which includes patients from health facilities that have an agreement with CyncHealth and received care in the state in Nebraska. At the time of the study, the HIE contained 75% of the hospitals in the state.

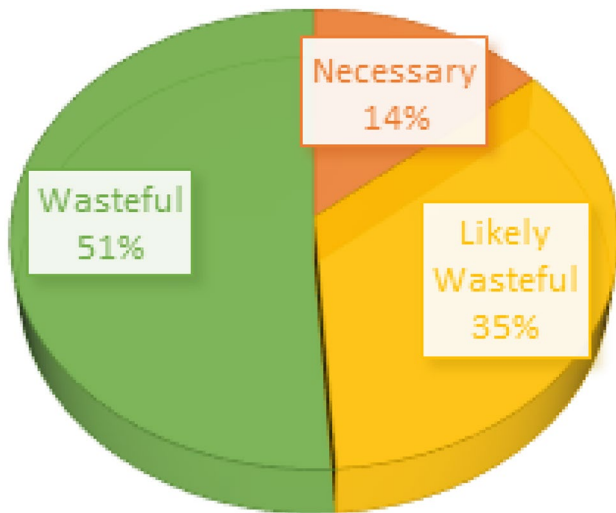


Fig. 1 Percentage Categories of Imaging

Overall, 164 of the 1,164 procedure codes indicated that imaging was necessary with 162 MRIs, 0 CT scans and 2 x-rays deemed as necessary. These numbers indicate that 14.1% of low back imaging was considered necessary in the sample of codes. Four hundred and six were deemed likely wasteful with 39 CT scans, 0 MRIs and 367 x-rays indicating 34.9% of the sample codes were likely wasteful. In the wasteful categorization, a total of 26 CT scans, 235 MRIs and 333 x-rays were deemed wasteful indicating a rate of 51.0% wasteful (Table 1 and Fig. 1). X-Ray imaging made up 70% of the wasteful and likely wasteful categories combined. While CT imaging only made up 6.5% of the likely wasteful and wasteful categories. Of all MRI codes, 41.1% were considered necessary. There was a total of 644 CPT codes that were below the age of 70 and 520 that were 70 years old or above. The sample represented 652 codes from females and 512 codes from males (Table 2). A Chi-Square test of gender revealed a p-value of 0.00004. These results reveal a significant relationship between gender and imaging. Data revealed that only 12.4% of records for low back imaging also had codes relating to a neurologic deficit (Table 3).

Table 1 Data Matrix of Imaging Categories

Count of Categories					
Row Labels	CT	MRI	XR	Total	Percentage
Necessary	0	162	2	164	14%
Likely Wasteful	39	0	367	406	35%
Wasteful	26	235	333	594	51%
Total	65	397	702	1164	

Table 2 Gender Counts for Imaging with Low Back Pain Diagnosis in Sample

CPT Code Count of GENDER					
Row Labels	CT	MRI	XR	Total	Percentage
Female	34	207	411	652	56%
Male	31	190	291	512	44%
Total	65	397	702	1164	

Discussion

This study was a replication of a study conducted within the state of Washington by the Washington Health Alliance [3]. The study found evidence to suggest the existence of costly and possibly avoidable redundancy regarding the use of imaging. In the state of Nebraska, wasteful imaging for low back pain constituted, not only the greatest percentage, but the majority of imaging, whereas fewer than one in five tests were deemed to be necessary. This aligns with the Do No Harm study in Washington as most imaging performed in that study was identified as likely wasteful, with known wasteful imaging recognized as the next most significant category. Both the Washington and this study displayed consistency with respect to the proportion of testing considered necessary, wherein fewer than one in five tests held this categorization in the state of Washington as well [3]. Although further research is necessary, the studies point to a tenable parallelism between the redundant imaging for low back pain in these states and in the entire country. The findings also support research regarding long-standing incongruencies that exist in the healthcare system as it relates to expenditure, which itself has been extensively [21–28]. For example, adverse treatment has been conservatively estimated to account for 5 percent of total healthcare spending, and there is evidence to suggest that a large number of antibiotics prescribed for treatment are in fact medically unnecessary [29, 30]. The number of resources misused and wasted, which amounts to an expenditure of nearly a trillion dollars each year within the current structure, is substantial [1]. Despite this significant waste, the researchers believe these occurrences are preventable and can be mitigated. EHRs are a proven

Table 3 Neurological Deficits Accounted for in Sample

CPT Code Count of Neurological Deficits					
Row Labels	CT	MRI	XR	Total	Percentage
No	57	361	602	1,020	88%
Yes	8	36	100	144	12%
Total	65	397	702	1164	

means to allow the review of data to understand waste and unnecessary treatment, and their implementation can provide hospitals with a reliable mechanism for sharing information. Research has indicated patients at hospitals where EHRs are utilized cost less to treat and have shorter lengths of stay than patients at facilities where they are not present [31, 32]. With consistent overtreatment, insufficient coordination, and a complex administration system hampering the efficacy and efficiency of care, when used for this effort, EHRs can be valuable for performance and quality assurance [33, 34]. EHRs connected with HIEs focused on interoperability of services can offer a way for researchers to understand population health in a holistic manner. EHRs, alone, can be limited in their dataset if not interoperable or connected to systems like a health information exchange.

Obviously, the reasons and rationale for use of imaging in low back pain varies and there are multiple factors that interplay as to why imaging occurs. In a study on patient and clinician beliefs on low back pain, imaging was often perceived as a reliable form of diagnosis [35]. Additionally, reimbursement for imaging and concerns about missing an important diagnosis also drive the impact in why imaging occurs. At the same time, waste and overuse are factors driving up cost and the gross domestic product. A study from the British Medical Journal recently identified that more than 90% of low back imaging is unnecessary and low back pain “should be managed with conservative treatments such as advice and reassurance, exercise, physical therapy, chiropractic care, cognitive-behavioural therapy, or pain management” [36]. The authors indicate the imaging may cause more harm by causing prolongation of the low back pain rather than intervention. They suggest following the guidelines of the “Choosing Wisely” campaign [36]. Patient perception appears to play a significant role in patient belief that imaging is an important part of diagnosing low back pain [37]. Due to the perception issue, multiple studies have emerged on patient education about imaging and low back [37–39]. All of these factors demonstrate the complexity around imaging and low back pain that continue to impact its use in clinical practice. These factors call for multi-prong approaches that identify opportunities to reimburse conservative services, reduce reimbursement for imaging, clinician education and patient education. The issue of overuse will need to continue to be monitored and studied as these approaches are implemented.

There are several limitations to the study that need to be acknowledged. First, there is the possibility that additional ICD codes exist which have not been included in the current study, which if so, may alter the values of the outcomes and statistical findings. Second, if the data received contained errors or irregularities, the interpretation of the data may then be flawed and not an accurate description of the current

reality. Lastly, this study does not provide definitive evidence for generalizability to the population outside of the state of Nebraska as well as across other diagnoses.

Declarations

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Conflict of interest All authors declare no conflict of interest in the project.

References

- Berwick, D, Hackbarth, AD. Eliminating waste in U. S. health care. *The Journal of American Medical Association* 2018; 307:1513–1516. <https://doi.org/10.1001/jama.2012.362>
- Choi, S, Hoban, C, Michelson, J, Vichare, S. (2019). Special report: It’s time to drive impact. *Oliver Wyman Health Innovation Journal* 2019; 3. Retrieved from <https://health.oliverwyman.com/2019/09/special-report--it-s-time-to-drive-impact.html>
- Washington Health Alliance. First, do no harm: calculating health care waste in Washington State 2018: Retrieved from <https://wahealthalliance.org>
- Burke, L, Ryan, A. The complex relationship between cost and quality in US health care. *Virtual Mentor* 2014; 16:124-130. <https://doi.org/10.1001/virtualmentor.2014.16.02.pfor1-1402>
- Kruse, C, Kristof, C, Jones, B, Mitchell, E, Martinez, A. Barriers to electronic health record adoption: A systematic literature review. *Journal of Medical Systems* 2016; 40(12): 252. <https://doi.org/10.1007/s10916-016-0628-9>
- Campanella, P, Lovato, E, Marone, C, Fallacara, L, Mancuso, A, Ricciardi, W, Specchia, M. The impact of electronic health care records on healthcare quality: a systematic review and meta-analysis. *The European Journal of Public Health* 2016; 26(1): 60-64. <https://doi.org/10.1093/eurpub/ckv122>
- King, J, Patel, V, Jamoom, E, Furukawa, M. Clinical benefits of electronic health record use: National findings. *Health Service Research* 2013; 49(1): 392-402. <https://doi.org/10.1111/1475-6773.12135d>
- Bailey, J.E., Pope, R.A., Elliott, E.C., Wan, J.Y., Waters, T.M. and Frisse, M.E., 2013. Health information exchange reduces repeated diagnostic imaging for back pain. *Annals of emergency medicine*, 62(1), pp.16-24.
- Lammers, E. J., Adler-Milstein, J., & Kocher, K. E. (2014). Does health information exchange reduce redundant imaging? Evidence from emergency departments. *Medical care*, 227–234.
- Sadoughi, F., Nasiri, S. and Ahmadi, H., 2018. The impact of health information exchange on healthcare quality and cost-effectiveness: A systematic literature review. *Computer methods and programs in biomedicine*, 161, pp.209-232.
- Yayac, M., Toci, G.R., Smith, E.B., Star, A.M., Parvizi, J. and Saxena, A., 2021. The Frequency, Reasoning, and Impact of Repeated Radiographs at the Initial Orthopedic Arthroplasty Visit. *The Journal of Arthroplasty*, 36(11), pp.3641-3645.
- Yuan, Y., Price, M., Schmidt, D.F., Ward, M., Nebeker, J. and Pizer, S., 2022. Integrated Health Record Viewers and Reduction in Duplicate Medical Imaging: Retrospective Observational Analysis. *JMIR Medical Informatics*, 10(5), p.e32168.

13. American Academy of Family Physicians. Imaging for low back pain. No date. Retrieved from <https://www.aafp.org/patient-care/clinical-recommendations/all/cw-back-pain.htm>
14. Hendee, W, Becker, G, Borgstede, J, Bosma, J, Casarella, W, Erickson, B, et al. Addressing overutilization in medical imaging. *Radiological society of North America* 2010; 257(1): 240-245. <https://doi.org/10.1148/radiol.10100063>
15. Wáng, Y, Wu, A, Ruiz-Santiago, F, Nogueira-Barbosa, M. Informed appropriate imaging for low back pain management: A narrative review. *Journal of orthopaedic translation* 2018; 15: 21–34. <https://doi.org/10.1016/j.jot.2018.07.009>
16. Chou, R, Qaseem, A, Owens, D, Shekelle, P. Diagnostic imaging for low back pain: advice for high-value health care from the American College of Physicians. *Annals of Internal Medicine* 2011; 154(3): 181–189. <https://doi.org/10.7326/0003-4819-154-3-201102010-00008>
17. Sears, E, Caverly, T, & Kullgren, J. Clinicians' perceptions of barriers to avoiding inappropriate imaging for low back pain- knowing is not enough. *Journal of the American Medical Association* 2016; 176(12): 1866-1868. <https://doi.org/10.1001/jamainternmed.2016.6364>
18. Hooten, W, Cohen, S. Evaluation and treatment of low back pain: a clinically focused review for primary care specialists. *Mayo Clinic Proceedings* 2015; 90(12): 1699–1718. Retrieved from <https://doi.org/10.1016/j.mayocp.2015.10.009>
19. Downie, A, Hancock, M, Jenkins, H, Buchbinder, R, Harris, I, Underwood, M, et al. How common is imaging for low back pain in primary and emergency care? Systematic review and meta-analysis of over 4 million imaging requests across 21 years. *British Journal of Sports Medicine* 2019; 12: 699–718. <https://doi.org/10.1136/bjsports-2018-100087>
20. Reed, S, Pearson, S. Imaging for nonspecific low back pain. 2015: Retrieved from http://www.choosingwisely.org/wp-content/uploads/2015/05/ICER_Low-Back-Pain.pdf
21. Papanicolas, I, Woskie, L, & Jha, A. Health-care spending in the United States and other high-income countries. *JAMA*, 2018; 319(10): 1024-1039. <https://doi.org/10.1001/jama.2018.1150>
22. Lyu, H, Xu, T, Mayer-Blackwell, B, Cooper, M, Wick, E, Saini, V, Brownlee, S, Makary, M. Overtreatment in the United States. *PLOS One* 2017; 12(9): e0181970. <https://doi.org/10.1371/journal.pone.0181970>
23. Cola, C, Morden, N, Sequist, T, Schpero, W, Rosenthal, M. Choosing wisely: Prevalence and correlates of low-value health care services in the United States. *Journal of General Internal Medicine* 2014; 30: 221-228. <https://doi.org/10.1007/s11606-015-3420-5>
24. Andel, C, Davidrow, S, Hollander, M., & Moreno, D. A. The economics of health care quality and medical errors. *Journal of Health Care Finance*, 39(1). Retrieved from http://www.ctcps.org/pdfs/JHCF_Fall12_Andel_etal.pdf
25. Weinstein, M, Skinner, J. Comparative effectiveness and health care spending – implications for reform. *New England Journal of Medicine* 2010; 362(5): 460-465. <https://doi.org/10.1056/NEJMs0911104>
26. Balu, S. Estimated annual direct expenditures in the united states as a result of inappropriate hypertension treatment according to national treatment guidelines. *Clinical Therapeutics* 2009; 31(7): 1581-1594. <https://doi.org/10.1016/j.clinthera.2009.07.010>
27. Casalino, L, Nicholson, S, Gans, D, Hammons, T, Morra, D, Karrison, T, Levinson, W. What does it cost physician practices to interact with health insurance plans? *Health Affairs* 2009; 28(1): 534-543. <https://doi.org/10.1377/hlthaff.28.4.w533>
28. Bentley, T, Effros, R, Palar, K, Keeler, M. Waste in the U.S. health care system: A conceptual framework. *The Milbank Quarterly* 2008; 86(4): 629–659. <https://doi.org/10.1111/j.1468-0009.2008.00537.x>
29. Ray, M, Tallman, G, Bearden, D, Elman, M, McGregor, J. Antibiotic prescribing without documented indication in ambulatory care clinics: national cross sectional study. *BMJ* 2019; 367: 1-7. <https://doi.org/10.1136/bmj.l6461>
30. New England Healthcare Institute. Waste and Inefficiency in the U.S. healthcare system. 2008. Retrieved from https://media.washingtonpost.com/wpsrv/nation/pdf/healthreport_092909.pdf
31. Wani, D, Malhorta, M. Does the meaningful use of electronic health records improve patient outcomes? *Journal of Operations Management* 2018; 60: 1-18. <https://doi.org/10.1016/j.jom.2018.06.003>
32. Kazley, A, Simpson, A, Simpson, K, Teufel, R. Association of electronic health records with cost savings in a national sample. *Am J Manag Care* 2014; 20(6): e183-e190. Retrieved from <https://www.ajmc.com/journals/issue/2014>
33. Adler-Milstein, J, Everson, J, Lee, S. EHR adoption and hospital performance: Time-related effects. *Health Services Research* 2015; 50(6): 1751-1771. <https://doi.org/10.1111/1475-6773.12406>
34. Kern, L, Barron, Y, Dhopeswarker, R, Edwards, A, Kaushal, R. Electronic health records and ambulatory quality of care. *Journal of General Internal Medicine* 2013; 28(4): 496-503. <https://doi.org/10.1007/s11606-012-2237-8>
35. Sharma, S., Traeger, A.C., Tcharkhedian, E., Harrison, J., Hersch, J.K., Pickles, K., Harris, I.A. and Maher, C.G., 2021. "I would not go to him": Focus groups exploring community responses to a public health campaign aimed at reducing unnecessary diagnostic imaging of low back pain. *Health Expectations*, 24(2), pp.648-658.
36. Hall, A.M., Aubrey-Bassler, K., Thorne, B. and Maher, C.G., 2021. Do not routinely offer imaging for uncomplicated low back pain. *bmj*, 372.
37. To, D., De Carvalho, D., Pike, A., Etchegary, H., Patey, A., Toomey, E. and Hall, A., 2021. Exploring perceived barriers and enablers to fidelity of training and delivery of an intervention to reduce imaging for low back pain: a qualitative interview study protocol. *HRB Open Research*, 4(49), p.49.
38. Boyle, E.M., Fary, R.E., Kang, K., Evans, K., Rebbeck, T. and Beales, D.J., 2021. A systematic scoping review of patient health outcomes and perceptions following management of low back pain via care pathways in primary health care.
39. Braeuninger-Weimer, K., Anjarwalla, N., McGregor, A., Roberts, L., Sell, P. and Pincus, T., 2021. Improving consultations for persistent musculoskeletal low back pain in orthopaedic spine settings: an intervention development. *BMC Musculoskeletal Disorders*, 22(1), pp.1-11.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.