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Clinical Study

Clinical utility of immediate postoperative radiographs in spinal fusion surgery

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Abstract

BACKGROUND CONTEXT: It is a common practice to obtain immediate postoperative radiographs prior to hospital discharge after instrumented spinal fusion. There is limited evidence to support the clinical benefits of such a practice, which may result in unnecessary radiation exposure and added healthcare costs.

PURPOSE: To determine differences in 90-day and 1-year reoperation between patients who underwent instrumented cervical, thoracic, or lumbar fusion and received immediate postoperative radiographs prior to hospital discharge compared to those who did not.

STUDY DESIGN: Retrospective cohort study.

PATIENT SAMPLE: We identified patients who underwent cervical, thoracic, or lumbar instrumented fusion between 2016 and 2023. All patients had at least 1-year follow up.

OUTCOME MEASURES: Primary outcome was all cause revision at 90-days and 1-year. Secondary outcome consisted of mechanical failure.

METHODS: Patients were dichotomized into those who had immediate postoperative radiographs prior to hospital discharge versus those that did not. Patient age, biologic sex, body mass index, race, American Society of Anesthesiologists Classification, spinal region of surgery and number of surgical levels were recorded. Incidence of all cause or mechanical revision at 90-day and 1-year were documented for each patient. Inverse probability weighting was used to determine associations between obtaining predischarge radiographs and subsequent revision surgery while adjusting for confounders.

RESULTS: We included a total of 1,678 patients. Of these cases, 833 (49.6%) did not have immediate postoperative X-rays and 845 (50.4%) did. Following inverse probability weighting, there were no significant differences in 90-day all cause revision (Odds ratio (OR) 1.58, 95% CI 0.85–2.95, p=.15) or 1-year all cause revision (OR 1.39, 95% CI 0.91–2.13, p=.13) between patients who did not have an immediate postoperative X-ray versus those that did. Similarly, there were no significant differences in rates of 90-day mechanical revision (OR 0.43, 95% CI 0.08–2.49, p=.36) or 1-year mechanical revision (OR 1.37, 95% CI 0.60–3.14, p=.41)) between the 2 groups.

CONCLUSION: Obtaining routine formal postoperative radiographs prior to hospital discharge following spinal fusion surgery did not result in any clinically meaningful benefit. To reduce cost and radiation exposure, spine surgeons should consider obtaining formal postoperative radiographs for specific indications only, such as increasing postoperative pain or

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neurologic deficits.

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Introduction

Health care expenditures are on the rise in the United States, and the costs of spine surgery in particular are exceptionally high [1]. A widely recognized major contributor to costs is the rising number of spinal fusion procedures across the country [2,3]. Thus, in the setting of spine surgery, efforts to reduce expenditures must be approached through careful evaluation of each clinical decision including diagnostic tests, procedures, and medical management. Notably, the inappropriate use of health care resources represents a sizeable portion of healthcare expenditures, with one study reporting waste comprising an estimated 25% of total spending [4].

Imaging studies are a suitable domain for healthcare savings, as they are often considered low-value services that may elevate costs, increase radiation exposure, and provide little clinically meaningful information [5–7]. In the context of spinal fusion surgery for degenerative pathologies, in addition to intraoperative fluoroscopy, surgeons often obtain subsequent radiographs prior to discharge [8,9]. In many instances, the second radiograph can lead to a delay in discharge with corresponding increased cost, along with increased patient exposure to radiation [9–11]. In addition, there are direct costs associated with obtaining the imaging itself and the radiologist's interpretation [12]. It should be emphasized that there is currently no evidence to suggest that routine use of such radiographs provides meaningful clinical information or otherwise alters the course of clinical care. To our knowledge, only 1 study has previously examined the clinical utility of routine imaging in lumbar fusion patients during the immediate postoperative period [13]. However, this prior study is outdated due to advancements in surgical technology and procedural interventions, did not include all types of spinal fusion, and did not effectively assess mechanical failures. Further, that prior investigation did not account for confounding by indication that may have been associated with the decision to obtain postoperative imaging. For example, if intraoperative events or other clinical circumstances influenced a surgeon's decision to obtain imaging postoperatively, such realities could be associated with an elevated risk of downstream events such as mechanical failure or the need for revision surgery.

In this context, we sought to evaluate differences in 90-day and 1-year reoperation between patients who underwent instrumented cervical, thoracic, or lumbar fusion and underwent immediate postoperative radiographs prior to hospital discharge compared to those that did not. Our dataset was developed from a multicenter registry that spans the modern period of spine surgery and represents the current state of spinal instrumentation and minimally invasive procedures. We hypothesized that the use of routine postoperative predischarge X-ray imaging would not result in any significant clinically meaningful difference in the likelihood of reoperation.

Methods

Patient population

This study was deemed exempt by the IRB prior to commencement. This retrospective cohort study was conducted using data from a large academic healthcare system representing surgeries performed at 1 of 4 hospitals (2 tertiary academic and 2 community facilities). An organizational database, the Research Patient Data Repository (RPDR), which has previously been used in health services research [14,15] was queried to identify patients; manual abstraction was subsequently done to verify inclusion criteria.

The study cohort included adults (≥18) who underwent instrumented cervical, thoracic, or lumbar spinal fusion surgery from August 1, 2016-August 1,2023. All patients that underwent surgery for spinal deformity (eg, >6 levels fused), infection, trauma, metastatic disease, revision indications, or tumor were excluded. These patients were excluded on the basis that such conditions would likely require further imaging and close surveillance which would confound the findings of our study. All patients under study had at least 1-year of postoperative surveillance.

We abstracted the following variables for use as covariates in the study analyses: age at the time of surgery, biologic sex (self-reported; male or female), self-reported race, body mass index (BMI; kg/m^2), American Society of Anesthesiologists (ASA) score at time of surgery, region of surgery (cervical, thoracic lumbar), number of fused levels, whether an immediate predischarge X-ray was obtained, presence of 90-day and 1-year revision, and cause of revision, (with a subset classification of mechanical associated with instrumentation failure, subsidence or interbody case extrusion). Patients were dichotomized into 2 groups: those who had immediate postoperative radiographs prior to hospital discharge versus those that did not.

Statistical analysis

Data was summarized using standard descriptive statistics, including means and standard deviations for continuous data and numbers with percentages for categorical variables. For continuous variables, bivariate comparisons were performed using independent samples t-tests. Chi-

squared or Fischer's exact tests were utilized for bivariate comparisons of categorical variables. Association between all cause or mechanical revisions and immediate predischarge X-rays were assessed using inverse probability weighting. Inverse probability weighting was chosen in order to minimize the effects of confounding by indication. Specifically, based on known practice patterns of the surgeons who were included, there were instances in which an immediate postoperative X-ray was obtained by surgeons who routinely do not obtain them. Unfortunately, it is not possible to determine the clinical need for these occurrences as the rationale was not consistently documented in the medical chart. Inverse probability weighting is a causal inference technique that adjusts for the propensity to obtain immediate postoperative imaging in this analysis and accounts for the potential for selection or indication bias in the decision for such imaging. Weighting was conducted using a propensity score developed via logistic regression utilizing all patient demographic and surgical variables with the performance of immediate postoperative radiographic imaging as the outcome of interest. The use of inverse weighting allowed conservation of the full study cohort, as opposed to techniques such as matching that would have required cohort truncation and a resultant loss of statistical power and clinical variation [16]. All statistical analyses were performed using Stata version 14 (StataCorp, LP, College Station, TX).

Results

Patient population

A total of 1,678 patients who underwent cervical, thoracic, or lumbar instrumented fusion were identified for inclusion. Of these cases, 833 (49.6%) did not have an immediate postoperative X-ray and 845 (50.4%) did (Table 1). There were no significant differences in age, sex, BMI, ASA, or number of levels fused between the 2 groups (p>.05).

Table 1
Demographics of patients who had an immediate predischarge X-ray versus those that did not

Total	Did not have X-ray N= 833	Had X-ray N = 845	p-value*
	Mean (SD)	Mean (SD)	
Age (years)	62.3 (11.9)	61.9 (16.9)	.59
BMI (kg/m^2)	29.8 (6.4)	29.6 (9.8)	.59
ASA	2.5 (0.6)	2.5 (0.6)	.39
Number of levels fused	1.9 (1.2)	1.9 (1.2)	.86
	N (%)	N (%)	
Sex			.18
Male	359 (43.1%)	392 (46.4%)	
Female	474 (56.9%)	453 (53.6%)	
Race			**.003**
Asian	18 (2.2%)	20 (2.4%)	
Black	58 (7.0%)	37 (4.4%)	
White	698 (83.8%)	755 (89.4%)	
Other/Declined	59 (7.1%)	33 (3.9%)	
Region			**<.001**
Cervical	281 (33.7%)	352 (41.7%)	
Thoracic	40 (4.8%)	61 (7.2%)	
Lumbar	512 (61.5%)	432 (51.1%)	

* Chi-squared or T-test were used to compare these variables (significant at p<.05).Bolding indicates statistical significance.ASA, American Society of Anesthesiologists classification.

Rate of revisions

There were no significant differences in 90-day all cause revision (2.2% vs 3.1%, p=.24) or 1-year all cause revision (4.9% vs 6.5%, p=.16) between patients who did not have an immediate postoperative X-ray and those who did (Table 2). Similarly, there were no significant differences in rates of 90-day mechanical revision (0.5% vs 0.2%, p=.45) or 1-year mechanical revision (1.2% vs 1.7%, p=.43) between the 2 groups. Of note, of the patients that were taken back to the operating room within 90-days for all cause revision, 7 out of 44 (15.9%) occurred during the patient's index hospital admission. Of the patients that were taken back to the operating room within 90-days for mechanical revision, 1 out of 6 (16.7%) occurred during the patient's index hospital admission. In this 1 patient, an immediate postoperative X-ray was not obtained. The patient had new onset leg weakness thought to be from a new disc/osteophyte seen on postoperative MRI postulated to be due to aggressive compression of the construct during the index surgery.

Table 2
Rate of revision between patients who had an immediate predischarge x-ray versus those that did not

Total	Did not have X-ray N=833 N (%)	Had X-ray N=845 N (%)	p-value*
All cause revision			
90-day	18 (2.2%)	26 (3.1%)	.24
1-year	41 (4.9%)	55 (6.5%)	.16
Mechanical revision			
90-day	4 (0.5%)	2 (0.2%)	.45
1-year	10 (1.2%)	14 (1.7%)	.43

* Chi-squared or Fisher's exact tests were used to compare these variables (significant at p<.05)

Following inverse probability weighting, there were no significant differences in 90-day all cause revision (OR1.58, 95% CI 0.85–2.95, p=.15) or 1-year all cause revision (OR1.39, 95% CI 0.91–2.13, p=.13) between patients who did not have an immediate postoperative X-ray versus those that did (Table 3). Similarly, there were no significant differences in rates of 90-day mechanical revision (OR0.43, 95% CI 0.08–2.49, p=.36) or 1-year mechanical revision (OR 1.37, 95% CI 0.60–3.14, p=.41) between the 2 groups.

Table 3
Treatment effects on rates of revision between patients who had an immediate predischarge X-ray versus those that did not

	Did not have X-ray	Had X-ray			
Total	N=833 N (%)	N=845 N (%)	OR	95% CI	p-value*
All cause revision					
90-day	18 (2.2%)	26 (3.1%)	1.58	0.85–2.95	.15
1-year	41 (4.9%)	55 (6.5%)	1.39	0.91–2.13	.13
Mechanical revision					
90-day	4 (0.5%)	2 (0.2%)	0.43	0.08–2.49	.36
1-year	10 (1.2%)	14 (1.7%)	1.37	0.60–3.14	.41

* Inverse probability weighting (IPW) was used for estimation of treatment effects.CI, confidence interval (95%); OR, odds ratio.

Discussion

A nationwide increase in healthcare expenditures, particularly in spine surgery, has resulted in concerted efforts to reduce costs and improve the efficiency of care [1–4,17]. One area of potential savings is imaging, as many clinicians often order radiographic studies without clear clinical benefit [6]. This practice is perhaps fueled by a lack of evidence to the contrary, the perception of need for medical-legal protections, and the desire to compare postoperative images of the same modality over time if fluoroscopy is used intraoperatively. We performed a robust causal inference analysis that accounted for confounding by indication in the association with surgeons' decisions to obtain postoperative imaging. Our sample was large, with relative balance between the cohorts receiving imaging and those who did not. In light of these characteristics and our analytic approach, we believe that this study could be viewed as modeling the characteristics of a randomized controlled trial on the subject. Ultimately, we found no significant difference between all cause or mechanical revision events within 1 year between patients who underwent spinal fusion and received an immediate predischarge X-ray versus those that did not.

Postoperative radiographs are associated with increased exposure to radiation, prolonged hospital stays, and increased costs [18–21]. Numerous studies have considered the use of routine postoperative radiographs following elective spine surgery. None of these prior investigations have maintained that routine postoperative radiographs are clinically useful [18–21]. Our study is advantaged over most others in that it is reflective of current spine surgical practice and considered all types of fusion-based procedures as opposed to a particular region (ie, solely lumbar) or fusion construct (ie, lumbar interbody procedures). Furthermore, ours is among the first to apply robust analytic techniques that are able to account for confounding by indication in the decision to obtain postoperative imaging. In the current procedural environment, surgeons are relying on intraoperative imaging and adjunctive technologies that increase radiation exposure to the patient. These have been shown to increase procedural radiation exposure and the associated risk of cancer, with consequent calls for appropriate "radiation budgeting [22]." One of the most effective ways to budget radiation exposure is to eliminate unnecessary postoperative imaging studies. The fact that such changes in practice are unlikely to impact postsurgical outcomes is clearly substantiated in the work we have done here.

In addition, in light of bundled payment models and other types of "risk-based reimbursement," healthcare facilities and physicians are looking to collaborate to provide more efficient, cost-effective care. Reducing the number of imaging studies would decrease the overall cost for both the healthcare facility and payers [23,24]. Moreover, without immediate postoperative radiographs, patients would be exposed to lower levels of radiation, and experience fewer delays in discharge due to pending imaging orders. In mitigating delays in discharge, patients may be less susceptible to surgical site infections and other risks associated with longer hospital stays [25]. Further, this would increase bed availability and decrease costs associated with the overall hospital or ambulatory encounter [11,23,26].

Routine postoperative radiographs have been studied in the context of other common orthopedic procedures, such as distal radius fractures, lower extremity fractures, and total knee arthroplasty. In all of these scenarios they have been found to offer limited little clinical utility at the expense of increased radiation exposure and episode of care costs [27–30]. For example, in patients undergoing fixation of ankle fractures, none of the patients without postoperative radiographs had a complication that could have been detected by immediate postoperative imaging [28,31]. The issue at hand is one of pretest probability. When the likelihood of an adverse event is small (in the case of revision surgery on the whole <7% in this study) the value provided by routine imaging of all patients is concomitantly low. Moreover, across an array of orthopedic procedures, it has been previously shown that intraoperative imaging studies are of better quality than immediate postoperative radiographs [9,28,29]. Importantly, Carter et al [31] reported that intraoperative images scored higher in quality, focus, centering and rotation. Taken as a whole, this body of evidence provides little rationale for performing immediate postoperative radiographs.

Our work adds to the growing body of literature in support of eliminating routine immediate postoperative radiographs in patients undergoing spinal instrumentation. We believe a more thoughtful approach would be to reserve such imaging orders for those patients with clinical events, symptoms, or presentation that warrant further surveillance [32,33]. For example, McCabe et al and Martin et al have previously reported that following anterior cervical discectomy and fusion, clinical deterioration was the best indicator for repeat operative intervention, as opposed to radiographic results [11,26].

While we believe the findings of our study are clinically relevant, we acknowledge certain limitations. The study design is retrospective in nature, and is subject to documentation inaccuracies, and limited understanding of the reasons for clinical decision making. The latter issue is addressed to the fullest extent possible via our use of causal inference analytic techniques. We are also unable to speak to any Bayesian effect regarding the decision for immediate postoperative radiographs, although this is also accounted for in our analytic approach. While insignificant, those that had immediate postoperative X-rays exhibited a higher likelihood of all cause revision and mechanical revision in unadjusted analyses. This is not surprising, given confounding by indication on the part of a surgeon's decision to obtain postoperative radiographs would be included in these findings. We believe that our robust statistical approach mitigates these concerns as highlighted above. Furthermore, this study was conducted within one integrated health system and may be subject to restricted clinical variation and clustering bias. At the same time, we believe our sample is representative of broader trends in treatment decisions as lumbar fusions are performed most frequently, followed by cervical and thoracic fusions. We wish to emphasize that while our integrated hospital system does have overlap of faculty, the clinical decision making of our physicians is similar to that of other large academic healthcare systems. While our work does not analyze the quality of imaging performed in the operating room versus postoperatively, the notion that intraoperative films are comparable if not superior has been substantiated in other investigations. In addition, based on known practice patterns of the surgeons who were included, there were instances in which an immediate postoperative X-ray was obtained by surgeons who routinely do not obtain them. Unfortunately, it is not possible to determine the clinical need for these instances as the rationale was not consistently documented in the medical chart. In order to address the effects of this confounding by indication, inverse probability weighting was utilized in the analysis. Finally, there was a disproportionate number of Caucasian individuals in this study, and these individuals received more immediate postoperative X-rays than other racial and ethnic groups. We attribute this difference to the patient populations seen by surgeons across our healthcare system. Surgeons that routinely do not obtain immediate postoperative radiographs may see more diverse patient populations than those that do. We believe that the considerable number of surgeons accounted for in this study, as well as the inclusion of both neurosurgeons and orthopedic surgeons with diverse training experiences fundamentally address these concerns. For this reason, we believe that our findings have translational capacity to other institutions with similar patient populations and resources as our own.

In conclusion, we maintain that immediate postoperative radiographs prior to hospital discharge offer little clinical benefit after spinal fusion surgery. Therefore, we recommend that surgeons obtain formal postoperative radiographs only in specific circumstances, such as increasing postoperative pain or new neurologic deficits. In this way, radiation exposure can be reduced for patients, as well as overall costs to the healthcare system. In the United States, approximately 1.6 million spinal fusions are performed annually [34]. At a cost of approximately $250 per X-ray imaging study [35], the estimated cost savings from the elimination of routine immediate postoperative imaging would potentially amount to approximately $400 million per year.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Patawut Bovonratwet: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kaitlyn E. Holly:** Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Investigation, Data curation, Conceptualization. **Joshua M. Coan:** Writing – original draft, Visualization, Resources, Project administration, Investigation, Data curation. **Malina O. Hatton:** Writing – original draft, Validation, Resources, Investigation, Data curation. **Jonathan Hintz:** Writing – original draft, Validation, Resources, Investigation, Data curation. **Joseph Macksood:** Writing – original draft, Validation, Resources, Investigation, Data curation. **Zenaida Enchill:** Writing – review & editing, Writing – original draft, Validation, Resources, Investigation, Data curation. **Daniel G. Tobert:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Investigation, Data curation. **Stuart H. Hershman:** Writing – review & editing, Validation, Supervision, Software, Resources, Investigation, Data curation. **James D. Kang:** Writing – review & editing, Visualization, Validation, Investigation, Data curation. **Andrew J. Schoenfeld:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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