# Institution-Based Quality and Safety Improvement Initiatives in Spine Surgery: A Scoping Review

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## Abstract

**Background:** Improving patient safety and healthcare quality is necessary to advance value-based health care. Spine surgery is complex, entailing joint efforts between different disciplines. This scoping review aimed to map the research on establishing and implementing institution-based quality improvement (QI) initiatives in spine surgery.

**Methods:** Studies were identified in electronic searches of PubMed, Web of Science, and Scopus databases. Qualitative or quantitative studies that report the implementation of QI programs that occurred in or covered spine surgery were included; studies that did not describe the establishment, implementations, impacts, barriers, and facilitators of QI initiatives were excluded. Three reviewers independently screened the retrieved studies, and 2 reviewers extracted data and conducted a quality assessment of full-text articles. Studies were categorized according to dimensions of quality (timely, effective, patient-centered, efficient, equitable, and safe), and quality appraisal was conducted using the Standards for Quality Improvement Reporting Excellence reporting guidelines.

**Results:** The search from the 3 databases yielded 2,876 returns; after removing duplicates, there were 1,274 in total. After screening, 228 records were entered into a full-text review, resulting in 133 records included in the review. Specifically, 88 addressed aspects of efficiency, 74 on safety, 32 on improving effectiveness, 23 on patient-centeredness, 7 on timeliness, and 1 on equity. Of the studies included, 71 rely on retrospective audits, 19 are prospective, and only 8 are interventional trials. Only 67 QI initiatives leveraged the advantages of multidisciplinary teams or the rigor of evidence-based protocols. Study gaps include limited follow-up, small sample sizes, and lack of comprehensive assessment using both objective measures and patient-reported outcomes.

**Conclusions:** This scoping review maps the current research on developing and implementing institution-based QI initiatives in spine surgery. Although most of the initiatives reported show improvement in the quality of health care and patient safety from multiple aspects,

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the sustainability of these initiatives remains unknown, and further studies are needed to trace the long-term effects and generalizability of these initiatives.

Unexpected yet preventable harm or adverse events can occur at any stage of healthcare delivery across all healthcare facilities[1-4]. Despite technological improvements, in 2019, a systematic review by Panagioti et al. reported that approximately 6% of patients are still exposed to unsafe healthcare services, with 12% of these events being severe or life-threatening[5]. The financial impact of substandard care is significant, forcing hospitals to face unsustainable costs and frequent penalties for preventable harm[6,7]. In response, there is an urgent call for value-based health care, emphasizing improving patient safety and quality of health care[8-11].

World Health Organization and the Institute of Medicine (IOM), now the National Academy of Medicine of the United States, define quality health care as care that is timely, effective, patient-centered, efficient, equitable, and safe[12]. In other words, quality health care ensures that evidence-based services are delivered promptly to those in need while maximizing resource utilization and minimizing waste. Many improvement programs aimed at achieving these standards have been developed and sustained globally[13-19].

Spine surgery is a costly and complex procedure entailing joint efforts across different disciplines during the perioperative period. Spinal conditions are ranked as the 10th most expensive conditions among Medicare patients aged 65 and older[20]. Degenerative cervical myelopathy is the leading cause of spinal cord impairment worldwide[21,22]. Adolescent idiopathic scoliosis (AIS) is the most common pediatric spinal disorder in North America, with approximately 5,000 AIS spine fusions performed annually[23,24]. In addition, back pain is a major global health problem causing disability and the leading reason for hospital visits[25], with its prevalence and burden increasing with age[26,27].

Moreover, the overutilization of medical resources is also at stake. Over 5 million Americans currently have opioid use disorder, and 10.3 million have abused opioids at some point in their lives[28,29]. Between 42% and 71% of outpatient opioids prescribed after surgery go unused[30], and one-third of postsurgical prescriptions are misused[31].

Complications in spine surgeries are potentially preventable[32-34]. Complications can lead to prolonged hospital stays, long-term morbidity, and increased costs of care[35,36]. With an increasing number of spine surgery patients and the escalating healthcare costs associated with suboptimal health care, physicians and administrators are increasingly focused on redesigning care delivery models to improve value, specifically through cost reduction[37-40]. However, operational challenges persist in reducing hospital charges and optimizing resource allocation[41], which underscore the urgent need for improving healthcare services' cost-effectiveness[42-45] and healthcare quality[12].

Despite the growing emphasis on value-based care, there is a lack of knowledge on the status of quality improvement (QI) studies in spine surgery. Unlike conventional clinical research, QI studies are defined as iterative, systematic, and data-guided activities aimed at achieving rapid improvements in localized healthcare delivery (Appendix 1). The primary goal of QI studies is to enhance care delivery and achieve immediate positive outcomes, whereas clinical research focuses on generating generalizable knowledge and achieving long-term advancements in understanding.

This study aims to map the research on establishing and implementing institution-based quality and safety improvement initiatives in spine surgery. The review question is, "How do institution-based QI initiatives improve patient safety and healthcare quality in spine surgeries?"

## Methods

A scoping review was systematically conducted following the framework of Arksey and O'Malley[46] as enhanced by Levac et al.[47] and further refined by the Joanna Briggs Institute[48,49]. This methodology, characterized by its narrative and descriptive approach, facilitates synthesizing and extracting an overview of the available studies.

The reporting of this review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses—extension for scoping reviews checklist[50]. The steps included formulating the research question, identifying relevant studies, selecting appropriate studies, charting data, and collating and reporting the results. This scoping review methodology is particularly valuable for systematically mapping the literature, examining a specific issue, and identifying key concepts, theories, evidence, and research gaps in the field.

### *Data Source and Search Strategy*

Systematic searches were undertaken to synthesize knowledge from diverse study designs and sources[51]. Peer-reviewed published records were searched on April 5, 2025, in the Web of Science, PubMed, Scopus, and gray literature. A topic search was performed with the search terms developed based on the review question, formulated according to the Population-Intervention-Comparison-Outcome framework for its modifiability and higher sensitivity[52]. The search terms contain the following keywords: populations (spinal diseases and surgeries) and context (QI, safety, quality, initiative, intervention, lean principle, Six Sigma, Plan-Do-Study-Act [PDSA], Plan-Do-Check-Act

[PDCA], Model for Improvement)[53], as shown in Appendix 2.

Boolean operators, syntax and Medical Subject Headings, and relevant free-text terms related to surgical interventions, spine diseases, safety, and QI initiatives were explicitly applied across all databases. Gray literature was searched using a combination of formulated key terms in Google Scholar and scanning reference lists of relevant articles. Search strategies were iteratively refined to optimize the final search. In addition, an electronic search included a review of references cited within the selected articles to ensure comprehensive coverage of the literature. The search results were filtered to include only scientific publications published in English and Human subjects. The full record and cited references were retrieved.

### *Eligibility Criteria and Study Selection*

All abstracts were independently reviewed by a multidisciplinary team of 3 reviewers (Z.H., D.C., and M.A.). Studies were included if they met the inclusion criteria: (1) qualitative or quantitative studies (1991 onward, English) reporting QI programs in spine surgery centers or spine disease management; (2) documented the establishment or implementation of QI initiatives, programs, or measures in spine surgeries; and (3) described barriers/facilitators of QI initiatives or measured system/surgical outcomes.

Exclusion criteria were as follows: (1) not QI programs, including those limited to audits without QI, guideline adherence alone, or tool development without implementation, and new model of care implemented without QI components and (2) nonspine surgery contexts or studies lacking QI methodology.

We adopted the definition of QI reported in BMJ's "Quality improvement into practice,"[54] as shown in Appendix 1. Specifically, the QI study encompasses the following elements:

1. evaluating and measuring care quality using Donabedian framework: structure (resources/training), process (care actions), and outcomes (health impacts);
2. identifying gaps between current and optimal practices;
3. designing and testing improvement strategies;
4. detecting errors and hazards in care delivery;
5. understanding and applying safety design principles (standardization, simplification, and human factors training); and
6. evaluating QI effectiveness.

Disagreements about inclusion were resolved by discussion and consensus of the 3 reviewers. Two independent investigators (Z.H. and M.A.) retrieved and further reviewed full-text articles. Citation management software EndNote 20 was used for record management. Eligible records were reviewed in full-text, as shown in Figure 1.

### *Data Abstraction*

Initial data abstraction was performed by 2 independent reviewers using a customized standardized data abstraction matrix form (Microsoft Excel), as given in Table S1. Study characteristics include the year of publication and reported factors relating to quality and safety. Initiatives or programs to improve quality and safety were categorized based on the IOM definition of quality of health care. Included papers were visualized using Alluvial plot in ggplot2 package with R.

### *Quality Appraisal*

The Standards for Quality Improvement Reporting Excellence (SQUIRE) guidelines, described elsewhere[55], were used to enhance the critique and capture rigor within the variations in reporting across published studies of QI. As given in Table S2, the coverage and thoroughness in reporting SQUIRE items were assessed.

## Results

### *Literature Search and Screening*

Literature screening identified 2,876 studies from 3 databases. After deduplication and automation screening of English language and human subjects, 1,274 records remained. Exclusion of 1,075 papers left 228 full-text articles for review (Fig. 1), with 133 meeting all inclusion criteria.

### *Summary of Research on Quality and Safety Improvement Programs in Spine Surgery*

Papers were categorized according to the IOM dimensions (effective, efficient, timely, patient-centered, safety, and equity), as given in Table S3, and the SQUIRE scoring in Table S4[12]. Of the 133 papers regarding the improvement programs in spine surgeries included in this study, 88 papers addressed the improvement of efficiency, 74 on safety, 32 papers on effectiveness, 23 on patient-centeredness, 7 on timeliness, and 1 on equity, as presented in Figure 2 and Table S3.

Geographically, most research originated from the United States/Canada, followed by China and the United Kingdom (Fig. S1). Study quality was robust, with SQUIRE scores averaging high; 3 outliers scored below 15[56-58]. Four main themes of QI initiatives are summarized, namely, process optimization, multidisciplinary coordination, safety and infection control, and patient-centered transformation, as shown in Figure 2.

### Initiatives Focused on Improving Efficiency

Totally, 88 studies reported initiatives addressing the efficiency improvements, primarily through perioperative protocols to reduce length of stay (LOS) and optimizing medical resource utilization using Lean/Six Sigma workflows. Current pain points of efficiency in spine surgery are summarized in Figure 3.

First, 51 studies implemented evidence-based perioperative protocols, such as the enhanced recovery after surgery (ERAS) pathway[59-72] and

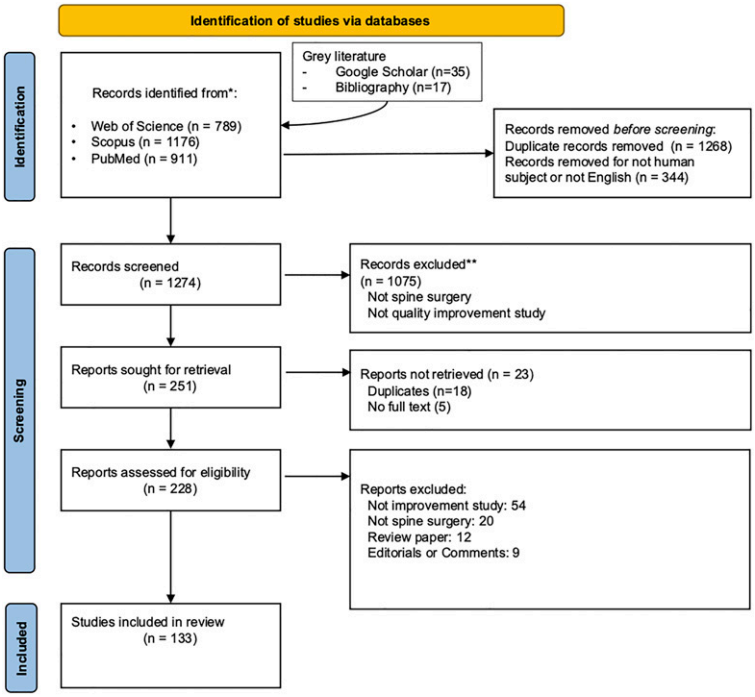


Fig. 1
Study selection process.

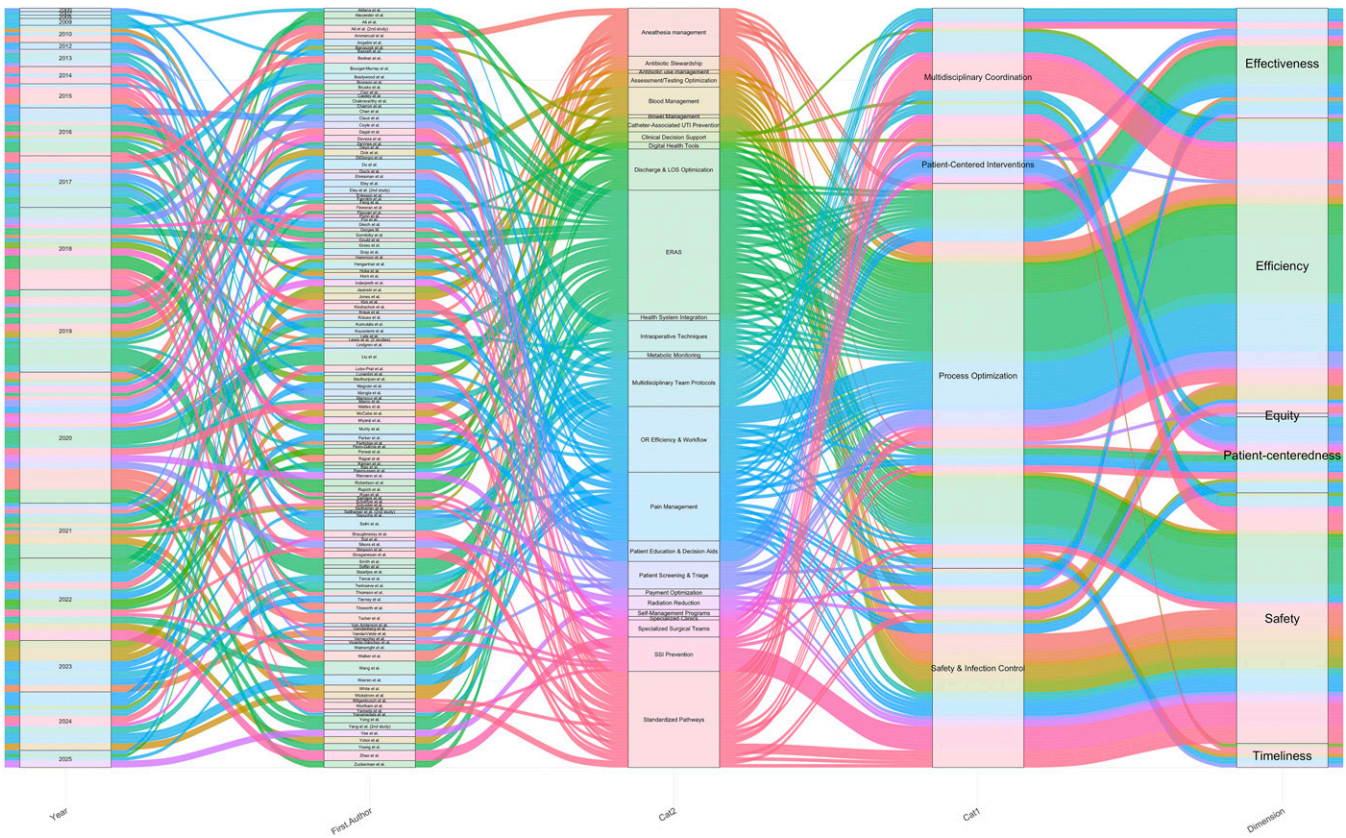


Fig. 2
The Alluvial plot of included studies based on quality improvement dimensions.

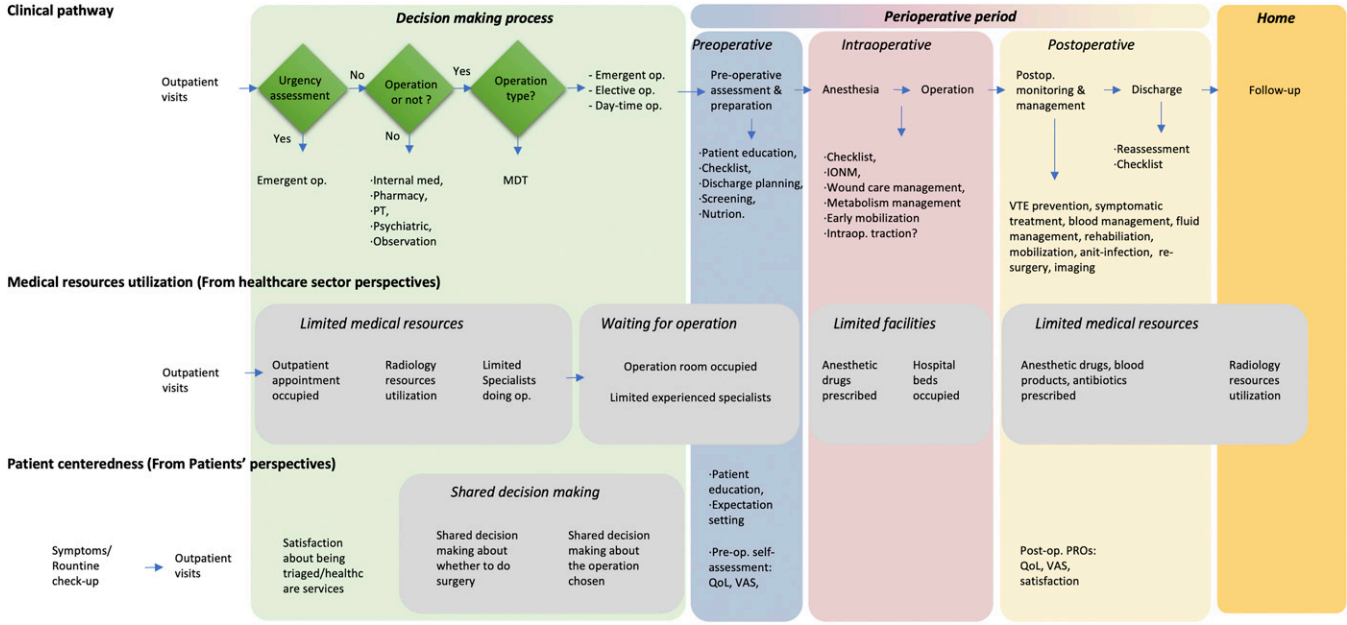


Fig. 3

The clinical stages in spine surgery that warrant quality improvement.

integrated care pathway[73-80] to standardize perioperative anesthesia management[81-85], respiratory management[86], blood and fluid management[87-91], mobilization enhancement[58,92], and pain management[60,64,77,81,93-96]. Several models were reported, such as Saskatchewan Spine Pathway[97,98], Rapid Recovery Pathway[23,96], a day-surgical program[56,99], overnight-stay[100], morning-after discharge[56,100], and perioperative surgical home model[101,102] to facilitate faster discharge and shortened LOS[103-105].

Moreover, perioperative protocols were built for patients with specific needs such as nonambulatory patients with neuromuscular scoliosis after corrective spinal surgery[106], patients with Chiari malformation decompression surgery[107], or patients prioritized for social functioning improvement[108].

These protocols demonstrated positive outcomes, including reduced length of hospital stay, reduced opioid usage, better blood management, and improved pain scores, implemented in AIS surgery [23,62,67,69,70,72,74,96,101-103,109,110], major spine surgery[63,73,75,78], minimally invasive (MIS) lumbar decompression surgery[62], MIS transforaminal lumbar interbody fusion surgery[61,64], and intraspinal tumor surgery[111].

Thirty-seven studies have demonstrated that various strategies can help reduce surgical rates and medical resource utilization, such as operating room (OR) time, optimizing magnetic resonance imaging use[97,112,113], blood consumption[87], and unnecessary surgeries[114]. Practical approaches include building dedicated teams[115-117], pairing inexperienced attending surgeons with experienced surgeons[118,119], using intraoperative skull-femoral traction and navigated sequential drilling for posterior spinal instrumentation and fusion in AIS[120], redesigning OR processes[121], using barbed sutures[122,123], implementing multidisciplinary care pathways for triage of psychological disorders and severe cases[98,112,124-127], and use of mobile tools to improve accurate documentation[128]. Enhancing the communication between different disciplines of healthcare workers[129] and conducting regular meetings to enhance clinical decision support[114,130-132] have also shown improved efficiency.

Specifically, various methods such as Lean processes[133-136], PDSA[137,138], Six Sigma[139,140], PDCA[141], and model for improvement[142] have been used to reiteratively deduct the improvement protocols for healthcare workflows and waste optimization[143].

Some QI initiatives aimed to improve delivering and paying for care by implementing the Bundled Payments for Care Improvement program for lumbar spine fusion[144] and setting up an insurer rule requiring physiatrist consultation before nonurgent surgical consultation to relieve the pressing need for surgery[124].

## Initiatives Focused on Improving Safety

Herein, 74 studies have shown that implementing standardized, systematic protocols in spine surgery can effectively reduce complication rates and secure patient safety. First, screening was conducted to screen mental disorders[127], metabolic alterations[145], and coexisting diseases[146] in complex pediatric patients to facilitate patient treatment[147]. Intraoperatively, electroencephalograph monitoring was conducted[148] for burst suppression during spine

instrumentation surgery and a novel method to place pedicle screws[149] and count the breakaway components of spinal implants intended to be removed during surgery[150].

Bundled interventions reduced surgical site infections through preoperative skin antisepsis, antibiotic timing, and wound closure innovations[66,151-157]. Besides prevention of infection, studies have sought to minimize unnecessary antibiotic use through pharmacist-led allergy clarifications[158] and localized prophylaxis policies[159-162].

Postoperative systemic approaches were conducted to prevent hypothermia[163], reduce indwelling urinary catheter use[164-166], facilitate bowel management[167], reduce opioid prescription[81,95,168-171], prevent respiratory complications[86], and prompt triage to postanesthesia care unit upon known or suspected obstructive sleep apnea[172].

Moreover, studies have also established feedback system using temp data to facilitate communication[173], and reduced radiation exposure using ultrasound after magnetically controlled growing rods treatment[174] and ultra-low-dose computed tomography for pediatric patients with neuromuscular scoliosis[175].

### Initiatives Focused on Improving Effectiveness

Thirty-two studies reported initiatives improving healthcare effectiveness. Patient education and shared decision-making have important roles in improving patient outcomes, such as patient education booklet, tailored self-management program for ankylosing spondylitis[176], and integration of patient decision aids into clinic workflow[177,178].

Moreover, integrative management programs, such as ERAS[77] and Seattle Spine Team Protocol[147], could effectively reduce pain scores[111] and improve social functioning[108]. Hospital-wide system optimization and academic health system electronic health record with system-level goals and real-time actionable analytics has proved effective[179].

### Initiatives Focused on Improving Timeliness

Timeliness efforts (7 studies) targeted preoperative wait times through multidisciplinary pathways and PDSA cycles, achieving expedited care services by training for healthcare workers and multidisciplinary clinical pathways[180,181]. For instance, White et al. reported using 3 PDSA cycles to improve turnaround times for *HLA-B27* and *HLA-B57:01* gene testing for ankylosing patients[138]. Gray et al. reported to reduce the preoperative wait time from 2 hours to 1.5 hours within a spine specialty practice[181].

### Initiatives Focused on Improving Patient-Centeredness

Twenty-three studies prioritized shared decision-making[182] and tailored pain management. For instance, 3 studies reported their efforts by providing educational contents[178,182-186]. Dedicated multidisciplinary clinics[57,187] or patient-tailored multidisciplinary care[188,189] has been reported to better cater to the needs of patients. Improved pain management has been reported by monitoring of patients' oxycodone/naloxone level[190] and assessing patients' level of pain and satisfaction with pain control[191]. Moreover, a self-administered questionnaire before patient consultation was also found to have improved patient assessment and clinical outcomes[192].

### Equity of Healthcare Improvement

Only 1 study addressed equity, testing a value-based reimbursement program combining bundled payment with pay-for-performance to reduce disparities[193].

### The Ideation and Implementation of QI Programs in Spine Surgery

QI implementation largely followed PDSA cycles[194], as depicted in Figure 4; yet, heterogeneity persisted, where 71 studies used retrospective designs, while only 8 were interventional trials. Moreover, only 67 QI initiatives leveraged the advantages of multidisciplinary teams or the rigor of evidence-based protocols.

## Discussion

### *Primary Findings*

Over the past 2 decades, QI initiatives in spine surgery have prioritized efficiency and safety, reflecting clinical priorities to reduce costs and complications. The underrepresentation of equity-focused initiatives also underscores a critical gap in addressing systemic disparities. Furthermore, objective measures were not always employed to assess the outcomes of these initiatives. This suggests that the field of QI in spine surgery may still be underdeveloped.

### *Medical Resource Overutilization Caused Excessive Medical Costs*

Resource optimization strategies, such as OR workflow redesign and multidisciplinary care pathways, help reduce anesthesia and operative time, improve patient outcomes, increase OR capacity, reduce waste, and reduce institutional costs[195-198].

The limited medical resources have led to overcrowded hospitals and prolonged wait times for patients to receive appropriate diagnoses and treatment. Two approaches have been attempted to address these challenges to reduce the extended duration of OR and hospitalization stays. The first is to reduce the operation time by building a dedicated team[115-118], improving intraoperative techniques[122], and redesigning the OR process with clear protocols[121]; the second is to reduce the LOS, by joining multidisciplinary efforts and satisfying patients' need, as well as controlling potential complications to expedite discharge, such as adopting ERAS[56,100] and facilitating patient education.

On the other hand, efforts to reduce resource utilization and avoid excessive treatment have focused on prescribing alternatives to surgery and optimizing resource use. For instance, patients with back pain have

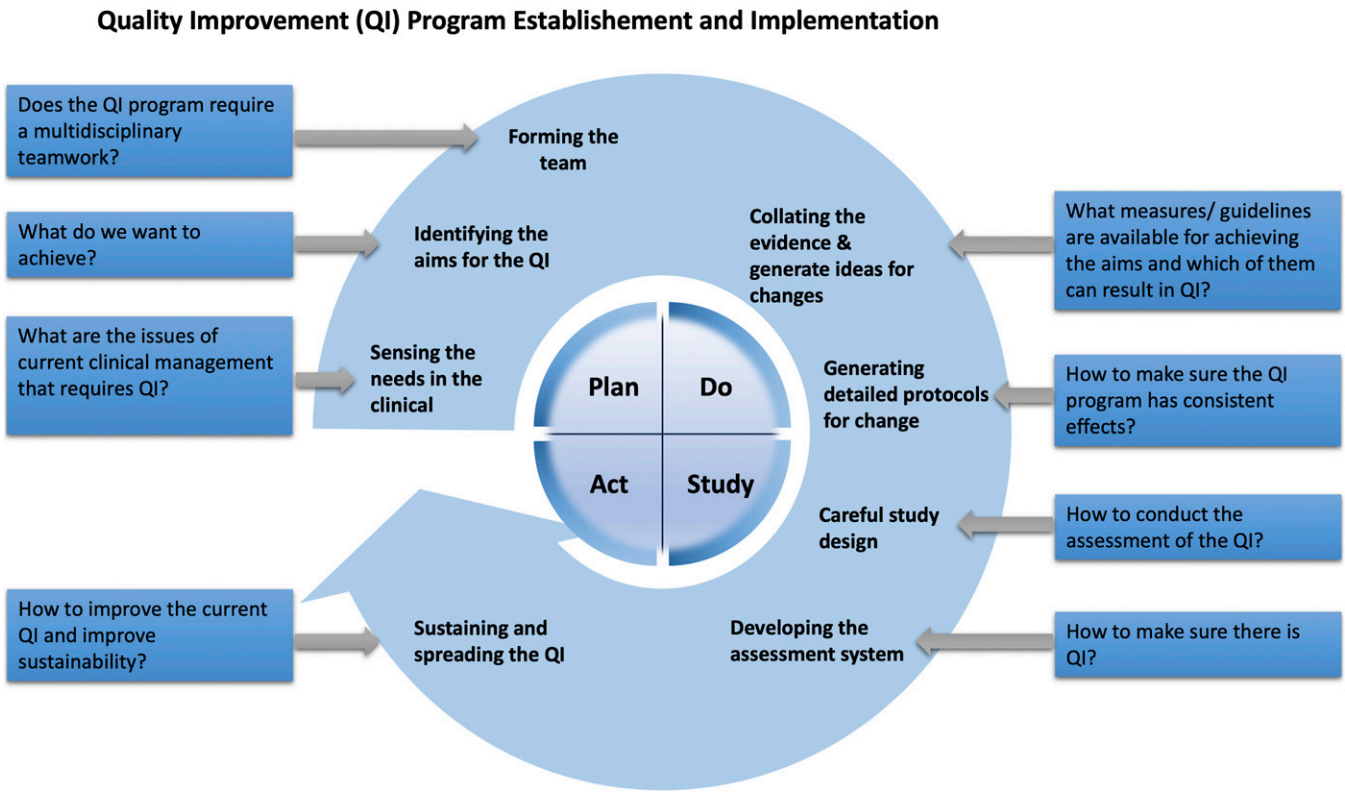


Fig. 4

The cycle of quality improvement in spine surgery. IONM = intraoperative neurophysiological monitoring, MDT = multidisciplinary team, PRO = patient-reported outcome, PT = physical therapy, QoL = quality or life, VAS = visual analog scale, and VTE = venous thromboembolism.

been triaged to psychiatric, pharmaceutical, or physiotherapeutic treatments rather than surgery, where appropriate.

### *Enhanced Recovery After Surgery Is Widely Employed in Spine Surgeries*

ERAS synergistically integrates perioperative interventions to improve overall clinical outcomes, minimize surgical stress responses, reduce perioperative complications, lower readmission rates, and optimize healthcare resource utilization by decreasing LOS and associated costs[62,199,200].

Current systematic reviews have consistently confirmed the benefits of using ERAS in various spine surgeries[201-205]. However, there lack high-level scientific evidence and standardized reporting of the effects of ERAS from both objective clinical perspectives and from patients' perspectives. Therefore, it is strongly recommended that future QI studies, as well as those assessing the impact of ERAS, focus on improving study quality, adopt prospective research designs, utilize patient-reported outcomes (PROs) to assess the patient perspectives, and further validate existing findings[206].

### *PROs Are Underutilized for Assessment*

The patient-centeredness of the current healthcare services in spine surgeries is underinvestigated. In spine surgery, surgeons may encounter situations where despite significant improvements in clinical outcomes, patients remain dissatisfied with the surgery or experience no postoperative improvement in QoL[207]. Hence, using PROs in clinical practice can help tailor treatments to meet individual patient needs and actively engage patients in their care[108,189].

Nevertheless, considering the knowledge gap between the patients and doctors, providing enough patient decision aids is vital for promoting patient participation, reducing decision conflict, and improving decision quality. Clinicians often have a limited understanding of patients' needs, relying primarily on questionnaires or interviews. To address this gap, it has been strongly recommended that patients be actively involved throughout the full cycle of care to design truly patient-centered care pathways[208-210], as shown in Figure 5.

### *Equitable Care in Spinal Surgery*

Equity gaps persist[193], as QI studies are predominantly implemented in high-income settings, limiting accessibility in rural or low-resource hospitals[211]. Therefore, we highly recommend that educational training programs on QI and collaboration be strengthened from the scales of departments, institutions, regions, and countries. Moreover, we also recommend that disaggregated data be collected and tracked by race,

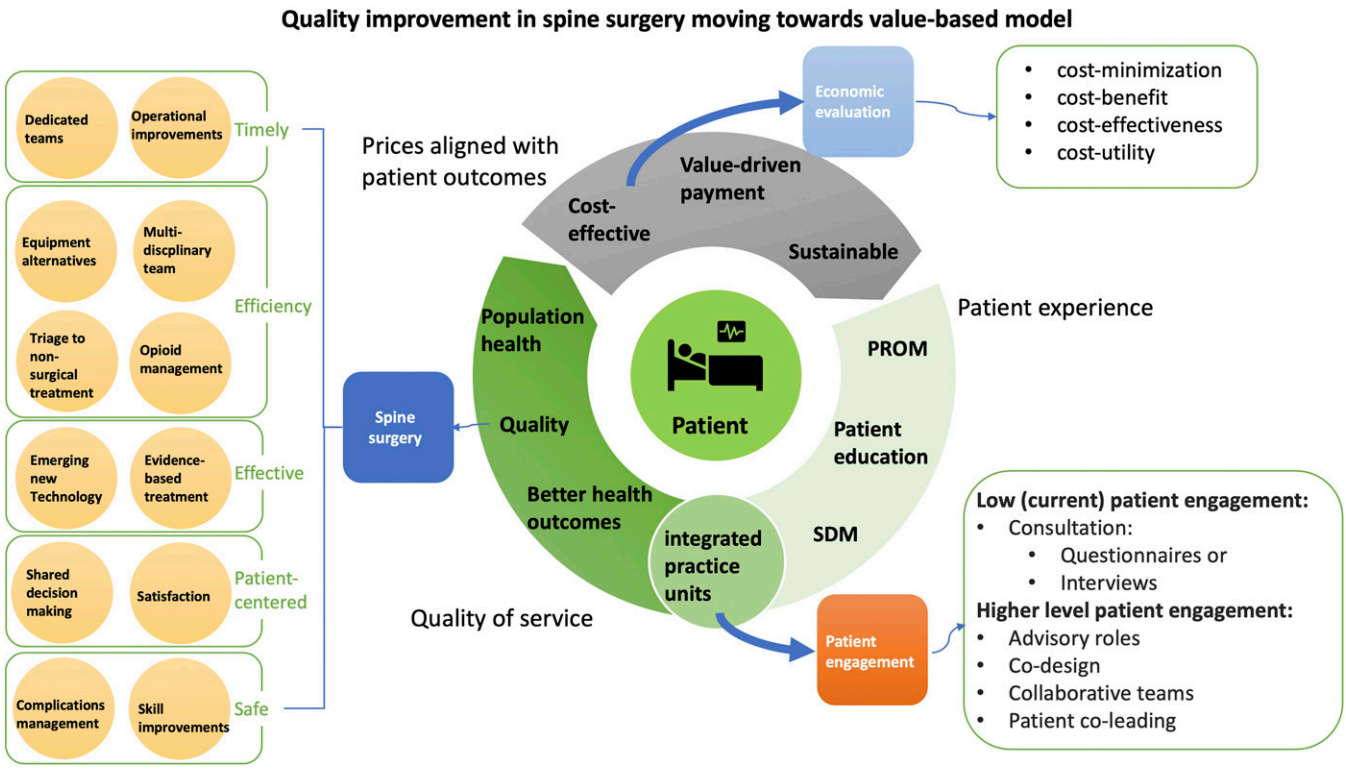


Fig. 5

Quality improvement in spine surgery moving toward the value-based model. PROM = patient-reported outcome measure, and SDM = shared decision-making.

income, and geography to identify disparities, QI protocols be tailored to underserved populations, and community stakeholders be involved in codesigning culturally responsive care models.

### *Clinical Research is Vital for Providing Clinical Evidence for QI*

Clinical analytics plays an important role in scalable, sustainable QI. Organizations can leverage analytics tools to understand patient harm at their facilities better and prevent it from occurring in critical areas. The best examples are various multicenter and nationwide databases, such as the American College of Surgeon (ACS) National Surgical Quality Improvement Program (NSQIP).

These multicenter and nationwide databases have undoubtedly contributed to establishing an assessment and surveillance system for monitoring improvement and enhancing system integration. Such systems enable coordinated care across different levels and providers, ensuring the availability of a comprehensive range of health services. Various predictive models based on these large-scale databases have been reported[212-214]; yet, how these predictive models improve healthcare quality in real-world settings, and their effectiveness in improving healthcare delivery remains unknown. Few studies have reported the effects of these large-scale QI programs at the hospital-level or institution-level or department-level[215].

### *Clinical Interpretation and Future Directions*

QI initiatives have transformed spine surgery by standardizing care and reducing variability. While standardized pathways improved consistency, their success relied on institutional resources, limiting generalizability to low-resource settings.

Nevertheless, understanding institution-based QI initiatives can enlighten the frontline healthcare workers to identify local problems, and equip them with methodologies and examples for QI initiatives to solve local problems, even in resource-limited settings, as the ultimate goal of QI is to optimize resource reallocation and move toward value-based health care.

Only 40% of studies explicitly reported using standardized QI frameworks, suggesting a need for greater methodological transparency. Moreover, considering the ambiguous and heterogeneous study design in the studies included, future initiatives should prioritize evidence-based frameworks such as SQUIRE 2.0 and hybrid effectiveness-implementation designs to balance rigor and real-world applicability.

### *Strengths and Limitations*

This review has limitations. First, the broad search strategy did not account for variability in operational definitions of "quality" and "safety," which may have led to study misclassification and

omission. Although this study retrieved studies from 3 renowned databases, there may still be omission of the retrieval; hence, the interpretation should be cautious. Second, the inclusion of only English-language articles introduces potential selection bias, limiting the global applicability of findings. Third, the review focused exclusively on institutional-level QI initiatives in spine surgery, excluding database-driven national improvement program such as ACS-NSQIP; hence, there may be potential selection bias. National-level improvements often follow policy or governmental strategies, and these studies usually report efficacy from a research perspective rather than a QI approach, whereas institution-wide QI programs typically originate from frontline clinicians. This focus provides insights into initiating, adopting, and sustaining QI programs from clinical settings to larger scales. Consequently, this review did not find eligible studies from large database research on improving health care for spine surgery. In addition, the high heterogeneity in study designs, improvement strategies, and intervention scopes among included studies posed challenges for systematic summarization, potentially leading to overlooked nuances; hence, interpretation of the findings should be cautious. To tackle this, this study incorporated the SQUIRE frameworks and used the dimension of healthcare quality to separate the studies, and used alluvial plot to track the improvement strategy and scope, which may help provide a general picture of the current states and development trend of institution-based QI initiatives in spine surgery.

## Conclusions

This scoping review mapped the current research on developing and implementing QI initiatives in spine surgery. Most initiatives demonstrated improvements in healthcare efficiency and safety, including reduced length of stay, readmission rate, and complication rates. However, the sustainability of these initiatives remains unknown. Further studies are suggested to trace these initiatives' long-term effects and generalizability.

### *Data Availability*

The data sets used and/or analyzed during this study are available from the corresponding author upon reasonable request.

### *Source of Funding*

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## Appendix

Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSREV/B228). This content was not copyedited or verified by JBJS.

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