Patient Safety in Surgery

REVIEW

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Exploring strategies to enhance patient safety in spine surgery: a review

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Abstract

Patient safety is the foundation of spine surgery, where the intricate nature of spinal procedures and the unique risks involved call for exceptional diligence and comprehensive protocols. In this high-stakes field, developing and implementing rigorous safety protocols is not only vital for minimizing complications but also for achieving the best possible outcomes and strengthening the confidence patients have in their care team. Each patient entrusts their well-being to their surgical team. This trust underscores the responsibility healthcare providers have to prioritize safety at every stage. In spine surgery, thorough preoperative planning, clear communication during informed consent, and vigilant postoperative care are all crucial for creating a safe environment tailored to each patient's needs. A commitment to patient safety requires more than individual efforts; it calls for a coordinated, multidisciplinary approach where surgeons, nurses, anesthesiologists, and rehabilitation specialists work closely together. This collaboration ensures that each step of the patient's journey is aligned with best practices for safety and care. This review highlights the critical need for ongoing evaluation and refinement of safety protocols in spine surgery. As surgical techniques and technologies advance, and as patients' needs evolve, healthcare teams must remain responsive, cultivating a culture of safety that is both proactive and adaptable. Continuous investment in quality improvement and research is essential to fine-tune these protocols, ensuring they remain both relevant and effective in addressing the unique challenges of spine surgery. Prioritizing comprehensive safety measures goes beyond improving surgical outcomes; it plays a pivotal role in strengthening the trust and confidence patients have in their healthcare providers. By committing to these robust protocols, we reaffirm our dedication to patient-centered care, enhancing not only patient safety and recovery but also fostering a deeper faith in a healthcare system that places patient well-being at the forefront.

Keywords Patient safety, Spine surgery, Safety protocols, Patient-centered care, Multidisciplinary collaboration

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Introduction

Ensuring patient safety in spine surgery requires an unwavering commitment to precise and adaptable protocols that address the unique challenges and inherent risks of each procedure [1, 2]. Given the high-stakes nature of spinal surgery, prioritizing these safety measures is crucial not only for minimizing complications but also for enhancing surgical outcomes and reinforcing the patient's trust in their care team [1–3]. As advancements in surgical techniques and technologies continue to unfold, there is a growing need for comprehensive patient safety protocols that span the entire continuum of care, from meticulous preoperative assessment to vigilant postoperative monitoring [4, 5].

Spine surgeries, ranging from decompression and fusion procedures to advanced minimally invasive techniques, present distinct challenges, including risks of neurological deficits, infections, and unforeseen intraoperative events that demand structured, preventive approaches [6, 7]. Effective patient safety protocols address these challenges head-on, ensuring that each step in the surgical process is carefully managed to reduce potential risks [8, 9].

This review explores the current landscape of patient safety protocols specifically designed for spine surgery, emphasizing their importance in safeguarding patient well-being. By examining key components of these protocols such as preoperative planning, informed consent, intraoperative precision, and postoperative care. This review aims to illustrate how structured, evidence-based approaches can significantly mitigate risks and improve overall surgical outcomes [5, 7, 10, 11]. Furthermore, this review underscores the crucial role of multidisciplinary collaboration among surgeons, anesthesiologists, nursing staff, and rehabilitation specialists, whose integrated efforts foster a culture of safety within the surgical environment [4, 10].

Ultimately, by critically reviewing the effectiveness of current patient safety protocols in spine surgery, this paper aims to contribute to the ongoing discourse on best practices, advocating for continuous improvements that place patient safety at the core of surgical excellence [4, 12]. Establishing robust safety measures is not only essential to achieving successful outcomes but also central to maintaining patient confidence in a healthcare system dedicated to their well-being [13–15].

Methods

Literature search strategy

A comprehensive literature review was conducted to evaluate current patient safety protocols in spine surgery. The search was performed across major medical and scientific databases, including PubMed, Scopus, EMBASE, and CINAHL, ensuring broad coverage of relevant literature. No temporal restrictions were applied to capture the widest range of studies; however, only English-language articles were included to maintain consistency in the review process. The search strategy was designed to identify studies focusing on critical components of patient safety, including checklists, informed consent procedures, patient education, postoperative care protocols, and psychological considerations.

Inclusion criteria

Studies were included in the review if they met the following criteria:

- **Peer-reviewed articles** addressing spine surgery safety protocols.
- **Focused content** on specific safety measures and their impact on patient outcomes.
- **Relevance to key areas**, including the use of checklists, informed consent processes, patient education, postoperative care, and psychological aspects.
- **Methodological rigor** sufficient to ensure the reliability of findings.

Exclusion criteria included non-peer-reviewed articles, studies outside the scope of patient safety in spine surgery, and studies published in languages other than English.

Study selection

The study selection process followed a systematic approach. First, the titles and abstracts of all identified articles were screened for relevance to the topic of patient safety in spine surgery. Full-text articles of potentially relevant studies were then assessed against the inclusion criteria and evaluated for methodological quality. Studies that demonstrated strong alignment with the review's objectives and high methodological rigor were included. A systematic and transparent process ensured that only studies contributing meaningful insights were incorporated into the synthesis.

Data extraction and synthesis

Data were systematically extracted from the included studies, emphasizing pivotal findings related to the efficacy of patient safety protocols. Key variables collected encompassed study design, participant demographics, targeted safety interventions, and measured clinical outcomes. A qualitative synthesis was conducted to discern overarching patterns, identify significant advancements, and distill best practices in spinal surgery safety. Particular focus was given to protocols that showcased substantial enhancements in patient outcomes or notable

reductions in complication rates, underscoring their clinical relevance and impact.

Quality assessment

The methodological quality of each included study was rigorously evaluated using standardized tools tailored to the respective study designs. This assessment aimed to identify potential biases and ensure the reliability and validity of findings. Criteria such as study design, sample size, intervention clarity, outcome measures, and statistical analysis were used to evaluate quality. Only studies meeting the highest standards of research excellence were included in the synthesis to uphold the reliability and credibility of the review.

Reporting

The review process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, ensuring transparency and rigor throughout. A PRISMA flow diagram was employed to detail the study selection process, including the number of records identified, screened, assessed for eligibility, and ultimately included. The findings were systematically organized and reported to provide a clear and comprehensive synthesis of patient safety protocols in spine surgery. This approach ensures that the review serves as a reliable resource for guiding best practices and improving patient outcomes in this high-stakes field.

The role of checklists in enhancing patient safety in spine surgery

Checklists serve as a crucial instrument for enhancing patient safety in spine surgery, ensuring that all necessary steps are meticulously followed and reducing the likelihood of errors in complex, high-stakes procedures [15, 16]. By standardizing processes and fostering clear communication among surgical team members, checklists contribute significantly to improved outcomes and patient confidence [17, 18]. Within the context of spine surgery, a discipline characterized by its complexity and potential for serious complications, the implementation of checklists can play a critical role in mitigating risks and improving surgical outcomes [19, 20].

One of the primary advantages of checklists is the standardization of care processes [21]. In spine surgery, where multiple steps must be followed meticulously to ensure the safety and well-being of the patient, checklists provide a structured approach to confirm that no critical steps are overlooked [22, 23]. For instance, the surgical checklist often includes items related to patient identification, surgical site verification, and confirmation of the planned procedure, helping to prevent errors such as wrong-site surgery [24]. This standardization not only enhances safety but also fosters consistency in care delivery among surgical teams [25, 26].

Spine surgeries typically involve a multidisciplinary team, including surgeons, anesthesiologists, nurses, and support staff [27, 28]. Checklists facilitate clear communication among team members by providing a common framework for discussing and reviewing essential surgical elements [23, 27]. Regularly employing checklists during time-outs, where the entire team pauses to confirm critical information, helps to ensure that everyone is on the same page and aware of their roles [27]. This collaborative communication is essential in reducing misunderstandings and potential errors that can compromise patient safety [16, 29].

The implementation of checklists has been shown to significantly reduce surgical errors and adverse events in various surgical disciplines, including spine surgery [18, 29]. Studies have demonstrated that surgical checklists can lead to a decrease in complications such as infections, hemorrhages, and even death [14, 18]. By systematically addressing key safety concerns and verifying critical elements before, during, and after the procedure, checklists empower surgical teams to identify potential risks and take corrective actions proactively [16, 18, 30].

Checklists also contribute to fostering a culture of safety within the surgical environment [23, 29]. When teams regularly engage in checklist usage, it normalizes safety discussions and emphasizes the importance of collective responsibility for patient care [31, 32]. This culture encourages team members to speak up and voice concerns if they notice discrepancies or potential threats to patient safety [31, 32]. Furthermore, management and surgical leadership that prioritize checklist use signal their commitment to patient safety and encourage adherence across the organization [15, 32].

Despite the numerous benefits, implementing checklists effectively in spine surgery does present certain challenges [33, 34]. Resistance from team members who might perceive checklists as mere bureaucratic requirements can hinder their use [34, 35]. Additionally, variables such as differences in surgical practices and the dynamics of surgical teams can complicate checklist application [35]. To overcome these challenges, it is vital to involve surgical teams in the development and implementation of checklists, ensuring that they are tailored to specific practices and are user-friendly [13, 24].

A comparative analysis of various checklists utilized in surgical practice offers valuable insights into their effectiveness in enhancing patient safety [22, 24]. Reviewing each checklist's specific characteristics, benefits, and limitations provides a clearer understanding of how these tools support standardized protocols, minimize errors, and improve team communication in high-intensity surgical environments [22, 24]. By thoroughly analyzing

these prominent checklists we can identify best practices and areas for refinement, ultimately contributing to safer and more reliable surgical outcomes [22, 24, 31].

The following section lists and details several key checklists, highlighting their unique features and their roles in promoting patient safety in surgical settings.

WHO surgical safety checklist

Developed by the World Health Organization, this checklist is designed to reduce surgical mortality and morbidity through standardized procedures [13, 19].
Key Components:

- Team introductions.
- Patient identification.
- Procedure verification.
- Site marking.
- Critical safety steps before anesthesia, before skin incision, and before the patient leaves the operating room.

Benefits:

- Widely recognized and adopted globally.
- Encourages team communication and collaboration.
- Increases compliance with safety protocols.

Limitations:

- Implementation may vary across different institutions and cultures.
- Requires buy-in from all surgical team members to be effective [16, 19].

ACS national surgical quality improvement program (NSQIP) checklist

This checklist, developed by the American College of Surgeons, focuses on preoperative and postoperative assessments to reduce complications [3, 36].
Key Components:

- Preoperative risk assessment.
- Documentation of patient history and physical examination.
- Review of lab results and imaging studies.
- Postoperative monitoring criteria.

Benefits:

- Data-driven approach based on quality improvement.
- Addresses specific risk factors related to surgical outcomes.
- Provides feedback and benchmarking for hospitals.

Limitations:

- More complex and may require extensive training.
- Relies on accurate data collection, which can be a challenge [3, 36].

The surgical team checklist

This checklist varies in format but generally serves to guide surgical teams through critical steps during the surgical procedure [37].
Key Components:

- Confirming patient and procedure specifics.
- Ensuring availability of necessary equipment and implants.
- Time-out procedures before incision.

Benefits:

- Can be customized based on specific surgical practices or specialties.
- Promotes the active participation of all team members.

Limitations:

- May lack standardization, which can decrease its effectiveness.
- Variability in implementation can lead to gaps in safety practices [14, 37].

Comparative insights

- Standardization vs. Customization: The WHO Surgical Safety Checklist is highly standardized, making it easier to implement across various settings, while checklists like the Surgical Team Checklist allow for customization to address specific surgical needs [16, 31].
- Data Utilization: The ACS NSQIP Checklist integrates data collection and analysis, which can provide valuable feedback for hospitals and lead to continuous quality improvement, in contrast to more traditional checklists that may not leverage data effectively [16, 23].
- Focus Areas: Different checklists emphasize varying aspects of patient safety. For instance, the WHO checklist focuses heavily on team communication and procedural verification, while the Pediatric Surgery Safety Checklist targets patient-specific needs based on age [16, 23].

Implementing a checklist tailored to the specific context of spine surgery, integrating best practices from these

various checklists, could enhance surgical safety. Ultimately, the effectiveness of any checklist depends on its adoption, the extent to which the surgical team engages with it, and how it is integrated into the broader culture of patient safety. Continuous evaluation and adaptation based on outcomes can further enhance the effectiveness of these tools in improving patient safety [16, 24].

In conclusion, checklists serve as an essential instrument in enhancing patient safety within the realm of spine surgery [21, 24]. By providing a structured, standardized way to communicate critical information, checklists help to reduce errors and improve outcomes [25, 33]. Their role in fostering a culture of safety, promoting teamwork, and facilitating quality improvement initiatives cannot be overstated [10, 23]. As the field of spine surgery continues to evolve, the integration and optimization of checklists will remain a cornerstone of patient safety strategies, ultimately leading to better surgical results and improved patient experiences [23, 26].

The importance of informed consent and how patient education contributes to safety and satisfaction

Informed consent is a foundational ethical and legal requirement in healthcare, particularly in surgical settings such as spine surgery [12, 38]. It represents a critical communication process between healthcare professionals and patients, ensuring that individuals understand the nature of their medical condition, the proposed interventions, their potential risks and benefits, and alternative treatment options [38, 39].

Informed consent is rooted in the principles of autonomy and respect for individuals' rights to make informed decisions about their own health care [40]. It not only serves to protect patients legally but also empowers them to engage actively in their treatment planning. By achieving informed consent, healthcare providers affirm their commitment to patient-centered care, demonstrating respect for patients' values, preferences, and concerns [40, 41].

The informed consent process is fundamentally about communication. Providing patients with comprehensive, understandable information about their condition and treatment options is essential for facilitating informed decision-making [40, 41]. In spine surgery, where treatment options can be complex and outcomes uncertain, effective patient education plays a crucial role in helping patients weigh the benefits and risks. Clear explanations written in layman's terms, supplemented by visual aids or models, can significantly enhance understanding, enabling patients to make confident choices regarding their care [10, 33].

Undergoing spine surgery can evoke significant anxiety in patients, often driven by fear of the unknown. A thorough informed consent process, coupled with strong patient education, can alleviate this anxiety by providing clarity about what to expect before, during, and after the procedure [10, 38]. When patients feel informed, they are more likely to trust their healthcare providers and be satisfied with their care. Building this trust is crucial, as it can improve adherence to postoperative instructions and follow-up care, thereby enhancing safety and outcomes [24, 28].

From a legal perspective, effective informed consent is crucial in preventing potential litigation arising from misunderstandings about procedural risks [6, 42]. A well-documented informed consent process that emphasizes patient education can serve as a protective measure for healthcare providers, showing that they fulfilled their responsibilities in sharing pertinent information [2, 4]. Ethically, ensuring that patients are fully informed before consenting to treatment minimizes conflicts and supports shared decision-making, enhancing the overall healthcare experience [12, 18].

Despite the importance of informed consent, several challenges persist. Patients may have varying levels of health literacy, making it difficult to ensure comprehension. Language barriers and cultural differences can further complicate the process [15, 16]. Additionally, time constraints in clinical settings may hinder thorough discussions. Strategies to enhance the informed consent process include utilizing interpreters, providing educational materials tailored to different literacy levels, and allowing adequate time for patients to ask questions and reflect on their decisions [17, 42].

In summary, informed consent is a critical component of patient safety and satisfaction in spine surgery. It serves as a bridge of communication that empowers patients, fosters trust, and supports shared decision-making [41, 42]. By prioritizing patient education throughout the informed consent process, healthcare providers can enhance patients' understanding, alleviate anxiety, and promote adherence to treatment plans [16, 41]. As a result, both informed consent and robust patient education contribute significantly to improved surgical outcomes, heightened safety, and greater overall satisfaction within the spine surgical landscape [22]. Addressing challenges associated with informed consent and continuously seeking innovative ways to educate and involve patients will remain essential strategies for healthcare providers committed to delivering exceptional care [7, 35].

Postoperative care and its importance for patient safety in spine surgery

Postoperative care constitutes a vital component of the surgical process, particularly in complex procedures such as spine surgery [43, 44]. The period following surgery is

critical for patient recovery, safety, and the achievement of optimal outcomes. A comprehensive understanding of postoperative care and its significance in promoting patient safety is essential for healthcare providers [44, 45].

Postoperative care encompasses all actions taken to monitor and support patients after a surgical procedure, focusing on their recovery, pain management, and identification of potential complications [45]. In spine surgery, where the surgical site may be delicate and the implications of complications can be severe, effective postoperative care is crucial. It includes physical assessments, pain control interventions, infection prevention measures, and patient education regarding recovery expectations [45, 46].

One of the primary focuses of postoperative care in spine surgery is vigilant monitoring for potential complications [27, 31, 46]. Common postoperative complications include:

- Surgical site infections (SSIs) pose significant risks and can lead to increased morbidity. Keeping the surgical area clean and employing proper wound care techniques is vital to prevent infections.
- Given the sensitive nature of spinal surgery, patients may experience changes in neurological function postoperatively. Regular assessments of motor and sensory function help identify issues early on.
- Patients are at risk for deep vein thrombosis (DVT) following surgery. Implementing preventive measures such as early mobilization and the use of anticoagulants contributes to safety.
- Effective pain management is essential to patient comfort and recovery. Utilizing multimodal analgesia approaches can enhance pain control while minimizing reliance on narcotics, optimizing patient safety.

Education plays a crucial role in postoperative care, enhancing patient safety and satisfaction. Once stabilized in the postoperative period, patients should receive clear instructions regarding [27, 30]:

- Educating patients on early warning signs of complications, such as increased pain, fever, or drainage from the surgical site, empowers them to seek prompt medical attention when necessary.
- Patients must understand any restrictions related to mobility, weight-bearing, and specific movements post-surgery to avoid strain on the surgical site.
- Clear guidance on prescribed medications, including pain management, antibiotics, and anticoagulants, ensures patients adhere to their treatment plan, thereby promoting recovery and safety.

Despite the importance of postoperative care, various challenges exist, including [10, 11]:

- Variability in Recovery: Each patient may respond differently to surgery, necessitating personalized care plans that address specific needs and potential complications.
- Patient Compliance: Factors such as health literacy, understanding of postoperative care instructions, and socioeconomic status can impact patient adherence and complicate recovery.
- Resource Limitations: Accessibility to rehabilitation services and follow-up care can vary widely, particularly in underserved areas.

Postoperative care in spine surgery is crucial due to the complex nature of spinal procedures and the potential for significant complications. Existing recommendations aim to optimize patient outcomes, enhance recovery, and ensure safety [5, 45].

Pros of existing recommendations

1. **Enhanced Patient Safety**:
    a. **Benefit**: Recommendations for postoperative care, such as strict monitoring for neurological signs, vital sign checks, and pain management guidelines, can significantly reduce the risk of complications like infection, hematoma, or neurological deficits.
    b. **Example**: Protocols that dictate regular monitoring of neurological function can lead to early detection of complications, allowing for timely intervention [43, 45].
2. **Standardization of Care**:
    a. **Benefit**: Guidelines provide a framework for standardizing care across different healthcare settings, ensuring that all patients receive a consistent level of postoperative care, regardless of the surgical team or institution.
    b. **Example**: A standardized approach to postoperative antibiotics or anticoagulation can help minimize variability and ensure adherence to best practices in spine surgery [10].
3. **Evidence-Based Practices**:
    a. **Benefit**: Many postoperative care recommendations in spine surgery are derived from clinical studies and expert consensus,

which can improve the overall quality of care and surgical outcomes.
   b. **Example**: Evidence-based guidelines on pain management (such as multimodal analgesia) promote more effective pain control and can help reduce opioid consumption [45].

4. **Focus on Rehabilitation and Early Mobilization**:
   a. **Benefit**: Recommendations often emphasize the importance of early mobilization and rehabilitation, which has been shown to enhance recovery and decrease hospital lengths of stay for spinal surgery patients.
   b. **Example**: Early physical therapy protocols encourage quicker recovery of function and a return to daily activities [10, 45].

5. **Improved Communication**:
   a. **Benefit**: Guidelines foster better communication among the surgical team, nursing staff, and rehabilitation providers, which is essential for a seamless transition from surgery to recovery.
   b. **Example**: Effective communication during handoffs can help prevent critical information from being lost, ensuring continuity of care [45].

Cons of existing recommendations

1. **Variability in Implementation**:
   a. **Drawback**: While guidelines aim to standardize postoperative care, their implementation can vary significantly across institutions and even among surgical teams within the same facility. This variability can lead to disparities in patient outcomes.
   b. **Example**: Some institutions may have limited resources to provide adequate postoperative monitoring, impacting patient safety and recovery [10].

2. **Inflexibility to Individual Patient Needs**:
   a. **Drawback**: Existing recommendations may not fully account for individual patient factors such as comorbidities, age, or specific surgical considerations, which can lead to suboptimal care.
   b. **Example**: A standardized pain management approach might not be suitable for all patients, particularly those with a history of substance use or adverse reactions to certain medications [44, 45].

3. **Focus on Protocols Over Patient-Centered Care**:
   a. **Drawback**: An overemphasis on adhering to protocols can detract from a patient-centered approach, potentially leading to a disconnect between patient preferences and treatment decisions.
   b. **Example**: Rigid adherence to a specific mobilization schedule might not consider a patient's comfort level or anxiety, ultimately affecting their recovery experience [47].

4. **Limited Adaptability to New Evidence**:
   a. **Drawback**: Some existing recommendations may not be updated frequently enough to incorporate the latest research findings and emerging best practices, leading to outdated protocols.
   b. **Example**: Recommendations that do not integrate newer approaches to pain management or surgical techniques may hinder optimal recovery processes [10, 47].

5. **Potential for Over-Medicalization**:
   a. **Drawback**: Strict adherence to certain postoperative recommendations can lead to unnecessary interventions or prolonged hospital stays, which may negatively impact patient satisfaction and recovery.
   b. **Example**: Over-monitoring or excessive diagnostic testing may create anxiety for patients and extend hospital stays without clear clinical benefit [44, 45].

In summary, postoperative care is of paramount importance for ensuring patient safety in spine surgery [4, 48]. Vigilant monitoring for complications, effective pain management, patient education, and interprofessional collaboration are critical elements that contribute to a successful recovery [48, 49]. By prioritizing comprehensive postoperative care, healthcare providers can significantly enhance patient safety, optimize outcomes, and foster positive surgical experiences. As the field continues to evolve, ongoing research and quality improvement initiatives will be essential for refining postoperative strategies, ultimately leading to better care and satisfaction for patients undergoing spine surgery [13, 19].

The psychological aspects of patient safety in spine surgery

Patient safety is a multi-faceted issue that encompasses not only the technical and procedural elements of surgical practice but also the psychological aspects that can significantly influence patient outcomes [50, 51]. In spine surgery, the psychological state of the patient before, during, and after surgery can have profound implications on safety and recovery. Understanding these psychological factors is essential for healthcare providers to create an environment conducive to healing, minimize anxiety, and enhance the overall surgical experience [50, 51].

Preoperative anxiety is a common experience among patients undergoing spine surgery and can affect not only the patient's mental well-being but also their physical health [52, 53]. Elevated anxiety levels can lead to:

- Increased Perception of Pain: Studies have indicated that anxious patients may report higher pain levels and may require more intense analgesia post-surgery. This can complicate pain management strategies and influence recovery.
- Altered Neurophysiological Responses: Anxiety can trigger physiological responses such as increased heart rate, blood pressure, and heightened stress hormone levels, which may impact healing and increase the risk of complications.
- Compliance and Engagement: Patients with high levels of anxiety may be less likely to comply with preoperative instructions, rehabilitation protocols, or follow-up care, which can adversely affect their recovery journey.

Recognizing and addressing preoperative anxiety through pre-surgical education, counseling, and relaxation techniques can help mitigate its impact, ultimately leading to enhanced patient safety [53, 54].

Patients' coping mechanisms play a crucial role in their psychological well-being before and after spine surgery [55, 56]. Adaptive coping strategies, such as positive thinking, seeking social support, and engaging in stress-reduction activities, can foster resilience, improve patient safety, and enhance recovery outcomes [55]. Conversely, maladaptive coping strategies, such as avoidance, denial, or substance abuse, may hinder recovery and increase the risk of complications [55, 56].

Healthcare professionals can support patients in developing effective coping strategies by providing resources, encouraging open communication, and promoting active participation in their care plans. Empowering patients to take an active role in their recovery can build resilience and improve adherence to safety protocols [11, 57].

Effective communication between healthcare providers and patients is fundamental to patient safety [58, 59]. Building trust and rapport can alleviate anxiety and encourage patients to express their concerns and preferences regarding surgery [47, 59]. Key elements include:

- Clearly explaining the surgical procedure, risks, benefits, and expected outcomes empowers patients with knowledge, reducing uncertainty and fostering a sense of control.
- Healthcare providers should practice active listening to understand patients' concerns fully, addressing their fears while providing reassurance. This approach can lead to a more collaborative relationship and improved compliance with postoperative care.
- Encouraging patients to provide feedback about their experiences during surgery and recovery can enhance communication and enable healthcare teams to address any issues proactively.

The presence of robust social support systems can significantly impact psychological well-being and patient safety in spine surgery [47, 60]. Patients who feel supported by family and friends are more likely to experience positive emotional outcomes and engage actively in their recovery process [55, 60]. Support systems can facilitate:

- Having someone to talk to about fears and uncertainties can help alleviate anxiety and foster a more positive outlook on recovery.
- Support from caregivers or family members can assist patients with daily activities, encourage adherence to rehabilitation, and provide transportation to follow-up appointments, enhancing patient safety.
- Connecting with others who have undergone similar procedures can provide valuable insights and emotional reassurance, demystifying the process and potentially reducing anxiety levels.

> The psychological aspects of patient safety in spine surgery play a critical role in overall surgical outcomes and recovery [55, 58]. Addressing preoperative anxiety, supporting adaptive coping mechanisms, fostering effective communication, and strengthening support systems are essential components of a patient-centered approach [56]. By remaining attentive to the psychological needs of patients throughout the surgical continuum, healthcare providers can enhance patient safety, optimize recovery, and support the holistic well-being of individuals undergoing spine surgery [57]. As the field continues to advance, integrating psychological considerations into the surgical

experience will be paramount in achieving exceptional patient care and outcomes [54, 57].

Prevention of wrong-level spine surgery

Wrong-level spine surgery (WLSS) is a significant concern in orthopedic and neurosurgical practices, leading to adverse patient outcomes, increased healthcare costs, and potential legal ramifications [61, 62]. Given the complexity of spinal anatomy and the intricacies involved in surgical planning, ensuring the correct surgical site is critical for patient safety and treatment effectiveness. Numerous strategies can be employed to prevent WLSS, beginning with thorough preoperative planning and imaging [61, 62].

A comprehensive preoperative evaluation is paramount in minimizing the risk of WLSS. This includes detailed imaging studies, such as MRIs or CT scans, which help confirm the precise location of any pathology [63, 64]. Surgeons should meticulously review these images and, if necessary, collaborate with radiologists to resolve any uncertainties. A robust preoperative plan should include a careful assessment of the patient's medical history and symptomatology, ensuring that clinical signs correlate with imaging findings to establish a clear rationale for surgery [61, 62].

Marking the surgical site is another widely accepted practice aimed at preventing WLSS [62]. This process involves marking the intended surgical site while the patient is awake, often including the level of surgery and any specific indications that remain visible during the procedure [62, 63]. The responsibility for site marking ideally should involve the collaboration of the surgeon and the surgical team to ensure agreement on the intended operation. Consistent adherence to this practice mitigates ambiguity and reinforces the identification of the correct surgical site [8, 63].

Effective communication among the surgical team is essential in preventing WLSS. This includes conducting thorough discussions during surgical briefings and huddles before the procedure, where team members review the surgical plan, confirm the intended level, and address any special factors. Utilizing checklists, similar to those in aviation, can enhance team coordination and establish a systematic approach to confirming readiness for surgery, including surgical site verification [61, 63].

In recent years, modern technologies have emerged as valuable tools in enhancing the accuracy of spine surgeries. Image-guided surgery and intraoperative navigation systems provide real-time verification of the surgical site, allowing for alignment of the planned procedure with the patient's anatomy [63, 65]. Additionally, fluorescence-guided techniques can assist in distinguishing between levels, contributing to precise targeting of the intended surgical site. The integration of these technologies acts as a crucial safeguard against WLSS [9, 61].

Finally, establishing a culture of safety and continuous improvement within surgical practices is vital in mitigating the risk of WLSS. Regular reviews of surgical outcomes, incident reporting, and root cause analyses are essential components of this culture. By understanding the contributing factors to WLSS, healthcare institutions can develop targeted interventions, refine protocols, and consistently enhance patient safety [61, 66].

Risks and benefits of navigated spine surgery

Navigated spine surgery has emerged as a significant advancement in spinal surgery, combining traditional surgical techniques with cutting-edge imaging and navigational technology [65]. This approach aims to improve the accuracy of surgical procedures, enhance patient outcomes, and minimize complications. However, like any surgical innovation, it comes with its own set of risks and benefits that must be carefully weighed to ensure optimal patient care [63, 65].

One of the primary benefits of navigated spine surgery is the enhanced precision it offers. By utilizing real-time imaging and computer-assisted navigation systems, surgeons can navigate complex spinal anatomy with remarkable accuracy [63, 65]. This increased precision can lead to more effective outcomes, particularly in procedures such as pedicle screw placement, where accurate positioning is critical to avoid neural and vascular injuries [67]. Studies have demonstrated that navigated procedures significantly reduce the rates of misplacement compared to conventional techniques, which can ultimately lead to lower rates of revision surgery and associated complications [67].

Furthermore, navigated spine surgery often results in shorter operative times and reduced blood loss. With improved visualization and guidance, surgeons can complete procedures more efficiently, minimizing the patient's exposure to anesthesia and surgical trauma. This, in turn, can lead to quicker recovery times and shorter hospital stays, enhancing patient satisfaction and reducing overall healthcare costs [67, 68].

Another benefit of navigated spine surgery is its potential to improve surgical training. The integration of navigational technology allows for better visualization of the surgical field and anatomy, which can be particularly beneficial for less experienced surgeons. This technology serves as an educational tool that can help trainees develop their skills in a controlled environment, ultimately improving the quality of care provided to patients [68, 69].

However, despite these advantages, navigated spine surgery is not without its risks. One major concern involves the potential for technology malfunctions or

inaccuracies in the navigation system. While rare, such malfunctions can lead to incorrect placements or surgical errors, which may have serious consequences for the patient [67, 69]. Additionally, the reliance on technology can create a false sense of security among surgeons. It is essential that surgeons maintain a solid understanding of spinal anatomy and surgical principles rather than becoming overly reliant on navigational aids [67].

Moreover, the cost of navigated spine surgery can be a significant drawback. The acquisition and maintenance of navigational technology can be expensive, potentially contributing to higher overall procedure costs [67]. This financial burden may limit access to these advanced techniques, particularly in resource-constrained healthcare settings. Consequently, healthcare providers must consider the balance between the financial implications and the clinical benefits when deciding whether to utilize navigated techniques [70].

Another consideration is the learning curve associated with adopting new technology. Surgeons must invest time and effort into training and familiarization with navigational systems to maximize their benefits. This learning phase can introduce additional risks during the initial implementation period, where surgeons may be less proficient in using the technology effectively [69, 70].

Intraoperative irradiation safety

Intraoperative irradiation safety is another critical aspect of spine surgery, particularly as imaging techniques such as fluoroscopy and intraoperative CT scans are frequently used [64, 71]. While these technologies enhance visualization and surgical accuracy, they also expose both patients and surgical staff to ionizing radiation [71]. To mitigate this risk, it is essential to implement safety protocols that minimize radiation exposure, including limiting the number of images taken, ensuring proper shielding for personnel, and employing real-time imaging whenever possible [71, 72]. Additionally, educating surgical teams about radiation safety measures and monitoring exposure levels can further promote a safe working environment. Prioritizing irradiation safety not only protects patients but also safeguards the future well-being of surgical teams [71, 72].

The "July effect" in surgical residency programs

The "July effect," a phenomenon observed in teaching hospitals when new residents begin their training in July, raises concerns about patient safety and quality of care [73, 74]. This transition period often coincides with increased risks for medical errors and surgical complications due to the inexperience of new residents [74]. To address this issue, residency programs should emphasize structured onboarding processes and mentorship, ensuring that new residents are well-supported as they transition into their roles [73]. Additionally, enhancing communication between experienced staff and incoming residents can foster a collaborative learning environment. By recognizing this transitional challenge, surgical programs can implement strategies that promote safety and maintain high standards of care for patients, thereby mitigating the adverse effects often associated with the "July effect" [73, 74].

Limitations

This review identifies several limitations that may affect the applicability and comprehensiveness of its findings regarding patient safety in spine surgery.

First, the scope of this review is primarily focused on spine surgery protocols, which may not encompass safety practices from other surgical specialties. As such, while the insights may inform spine surgery specifically, they may not be applicable across broader surgical contexts. Additionally, the safety protocols discussed may vary significantly among different healthcare institutions, influenced by factors such as surgeon experience and regional practices. This variability can impact the implementation and effectiveness of recommended measures.

Moreover, the rapid evolution of surgical techniques and technologies poses a challenge, as the recommendations herein reflect current literature and practices that may become outdated as advancements occur. The article also relies on existing studies, which may vary in methodological quality, sample sizes, and reporting rigor. Consequently, differences in the quality of evidence may influence the strength and applicability of our conclusions.

Another limitation is the lack of real-world data supporting some of the proposed protocols. Many recommendations stem from theoretical frameworks or controlled environments, potentially overlooking the unique challenges faced in everyday clinical practice. Furthermore, the patient population diversity, including factors such as age, comorbidities, and social determinants of health, means that the experiences and outcomes of different patient groups may not be fully represented in the literature reviewed.

The article emphasizes the importance of a multidisciplinary approach to improving patient safety; however, achieving effective collaboration in practice can be fraught with challenges, such as communication barriers and differing levels of engagement among healthcare team members. Additionally, the review may reflect certain biases in the selected literature or in the authors' interpretations, which could limit objectivity.

Lastly, while short-term evaluation of safety protocols is crucial, the long-term effectiveness of these measures remains imperative for establishing sustained improvements in patient outcomes. Further longitudinal studies

are necessary to assess the ongoing impact of safety protocols in spine surgery effectively. Collectively, these limitations highlight the need for continuous research and evaluation to refine safety practices in alignment with evolving surgical standards and patient needs.

Conclusion

In conclusion, robust patient safety protocols are essential in spine surgery to minimize risks and enhance outcomes, as even minor oversights can lead to significant complications. Effective communication and teamwork among surgical staff are critical for ensuring a safe environment and improving procedural efficiency. As spine surgery continues to evolve with new technologies, it is imperative to regularly update safety protocols to reflect these advancements. Future research should focus on evaluating current practices and exploring innovative strategies to address emerging challenges, ultimately reinforcing the commitment to patient-centered care and excellence in surgical practice.

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EA and KB had the idea for this study. EA and KB participated in outlining the concept and design. EA and CG wrote the first draft of the manuscript. All authors revised the final manuscript and approved the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study received ethics approval by the Kermanshah University of Medical Science Ethics Committee. Written informed consent to participate was obtained from all patients. All methods were carried out in accordance with relevant guidelines and regulations. The patient's data included in this manuscript has not been previously reported.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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