NOWAK, Anna, DUDZIAK, Piotr, GOLIŃSKA, Maria, MAJ, Wojciech, ŁYKO, Mateusz, KURASZ, Jakub, SIUDZIŃSKI, Paweł, SKOCZYLAS, Alicja, TOMASZEWSKA, Wiktoria, PALA, Katarzyna and PODLASIEWICZ, Wiktoria. The Impact of Anesthetic Modality Selection on Surgical Outcomes in Trauma Management. Quality in Sport. 2025;38:58209. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.38.58209
https://apcz.umk.pl/QS/article/view/58209

The journal has been 20 points in the Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 25.01.2025. Revised: 10.02.2025. Accepted: 11.02.2025 Published: 11.02.2025.

The Impact of Anesthetic Modality Selection on Surgical Outcomes in Trauma Management

Anna Nowak [AN] University of Opole plac Kopernika 11A, 45-040 Opole

ORCID: 0009-0005-8833-1107

e-mail: anulla1008@gmail.com

Piotr Dudziak [PD] University of Opole plac Kopernika 11A, 45-040 Opole

ORCID: 0009-0000-6173-740X

e-mail: piotr-dudziak@outlook.com

Maria Golińska [MG] University of Opole plac Kopernika 11A, 45-040 Opole

ORCID: 0009-0008-2772-6131

e-mail: maria.golinska99@gmail.com

Wojciech Maj [WM] University of Opole plac Kopernika 11A, 45-040 Opole

ORCID: 0009-0003-2869-3718

e-mail: Rottel45@gmail.com

Mateusz Łyko [MŁ] University of Opole plac Kopernika 11A, 45-040 Opole

ORCID: 0009-0009-2530-2789

e-mail: matlyk@wp.pl

Jakub Kurasz [JK] University of Opole plac Kopernika 11A, 45-040 Opole
ORCID: 0009-0004-3955-1552
e-mail: jakubkurasz30@gmail.com
Paweł Siudziński [PS] University of Opole plac Kopernika 11A, 45-040 Opole
ORCID: 0009-0002-4476-9412
e-mail: pawelsiudzinski99@gmail.com
Alicja Skoczylas [AS] University of Opole plac Kopernika 11A, 45-040 Opole
ORCID:0009-0002-2185-5406
e-mail: alicjasko1999@gmail.com
Wiktoria Tomaszewska [WT] University of Opole plac Kopernika 11A, 45-040 Opole
ORCID: 0009-0005-6166-1659
e-mail: wiktomaszewska@o2.pl
Wiktoria Podlasiewicz [WP] Wroclaw Medical University wybrzeże Ludwika Pasteura 1, 50-367 Wrocław
ORCID: 0009-0001-6578-5297
e-mail: wiktoria.podlasiewicz@student.umw.edu.pl
Katarzyna Pala [KP] University of Opole plac Kopernika 11A, 45-040 Opole
ORCID: 0009-0004-0787-3872
e-mail: kaspal109@gmail.com

Disclosure

Author's contribution: AN, MG, WM

Conceptualization: PS, MŁ, WT

Methodology: MG, PD, AS

Software: KP, WP, JK

Check: WT

Formal analysis: AS, WM,

Investigation: PS, AN

Resources: JK, PD, MG

Data curation: MŁ, WM

Writing rough preparation: AN, MG

Writing review and editing: PD, MŁ

Visualization: AS, KP

Supervision: AN, MG

Project administration: AN, WM

Supplementary Materials: They have not been provided.

Funding Statement: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflict of Interest: The authors declare no conflict of interest.

All authors have read and agreed to the published version of the manuscript

ABSTRACT

Introduction

The selection of anesthesia during surgical management of injuries is of paramount importance in ensuring patient comfort, procedural safety, and optimal surgical outcomes. The determination of the anesthetic modality is made by the anesthesiologist in consultation with the surgical team, taking into consideration the patient's medical status, the nature and extent of the injury, the anticipated duration of the procedure, and, when feasible, the patient's preferences**.**

Material

This article provides a detailed analysis and literature review of the advantages and disadvantages of both general and regional anesthesia. We will explore the current evidence supporting each approach, critically evaluate their benefits and challenges, and provide recommendations based on available research and clinical experience.

Conclusion

The decision regarding the choice of anesthesia method—regional or general—is made by the anesthesiologist in consultation with the patient (if the patient's condition allows) and is determined on an individual basis, considering: Medical indications: Regional anesthesia may be advantageous in certain cases (e.g., lower limb procedures), but there are situations where it is contraindicated, such as coagulation disorders, infections at the puncture site, or patients unable to cooperate. Patient preferences: If the patient expresses fear of regional anesthesia or has other reasons to avoid it, general anesthesia may be chosen, provided it is feasible. Patient

comfort and safety: In some procedures, even if regional anesthesia is an option, general anesthesia may be preferred due to factors such as procedure length or concerns about achieving adequate pain control. If regional anesthesia is feasible, the anesthesiologist may propose it as a less invasive option, but it is not mandatory. General anesthesia can be administered when medically justified or for other valid reasons. The decision, where possible, should be made collaboratively.

Keywords
General anaesthesia, Regional anaesthesia, POCD, Carbon footprint, Trauma

General Anesthesia (GA):

Mechanisms of Action

According to guidelines from the American Society of Anesthesiologists (ASA) and the European Society of Anaesthesiology (ESA), general anesthesia is a medically induced, complex state that includes loss of consciousness, pain suppression, and sensory blockade. This enables surgical or diagnostic procedures to proceed without pain perception. It has been in use since 1846 for procedures requiring the suppression of consciousness and pain. GA involves airway protection, hemodynamic support, and maintenance of other vital functions, creating a controlled and safe surgical environment [1, 2].

A combination of intravenous and inhaled medications (or non-gaseous alternatives) induces unconsciousness, muscle relaxation, and analgesia. GA is particularly advantageous for complex surgeries, including emergency cases, procedures involving uncooperative patients (e.g., infants or elderly individuals), or situations where regional anesthesia might fail due to patient anxiety or psychological reasons. It is also commonly used for pediatric diagnostics, such as MRI procedures [3,4].

GA offers significant control over the patient's condition during surgery, with tools to monitor anesthesia depth, preventing insufficient anesthesia or overdosing, while facilitating adjustments based on surgical needs. Airway intubation protects against regurgitation and ensures adequate ventilation, especially during abdominal or thoracic surgeries [5, 6].

Risks and Complications

Although generally safe, GA carries risks, particularly for elderly individuals or those with chronic conditions like diabetes or kidney diseases. Common side effects include nausea, vomiting [7] sore throat (from intubation), chills, and disorientation, typically resolving within hours [8]. However, complications like pneumonia or prolonged ventilation may arise, particularly in high-risk groups [9].

Severe reactions, such as malignant hyperthermia (a life-threatening hypermetabolic state), are rare but require prompt management [10]. Additionally, post-operative cognitive dysfunction (POCD) may impair memory, attention, or learning, especially in older patients, necessitating early recognition and counseling [11, 12]. Over-sedation may mask early signs of complications, highlighting the importance of patient education on post-operative symptom monitoring [13].

Regional Anesthesia (RA)

Regional anesthesia (RA) is defined as a technique for temporarily blocking sensory and motor function in a specific body area by administering local anesthetics near a nerve or group of nerves. Techniques include:

- **Spinal anesthesia** (e.g., subarachnoid block),
- **Epidural anesthesia**,
- **Peripheral nerve blocks** [14]

RA aims to provide optimal analgesia or anesthesia while minimizing systemic drug effects, making it particularly advantageous for patients with comorbidities or specific surgical procedures [14].

Benefits of RA

RA is associated with shorter recovery times and fewer post-operative complications compared to general anesthesia (GA). For example, orthopedic and gynecological surgeries often show faster recovery and reduced hospital resource use when RA is employed [14]. It provides effective post-operative pain control, especially with nerve blocks, reducing opioid requirements and associated side effects such as nausea, respiratory depression, or addiction. Combining RA with multimodal analgesia optimizes pain management [15, 16].

Additionally, complications typical of GA, such as cognitive dysfunction or respiratory issues, occur less frequently with RA. This is particularly beneficial for elderly patients and those with chronic diseases. RA also reduces thromboembolic risks (e.g., deep vein thrombosis) and pulmonary infections seen more often with GA. The localized effect minimizes inflammation and maintains stable blood pressure during surgery, crucial for patients with cardiac conditions [17, 18].

Applications

RA is widely used in orthopedic procedures (e.g., joint replacement), gastrointestinal surgery (e.g., colon resections), and obstetrics (e.g., cesarean sections). Research indicates that spinal anesthesia for cesarean delivery lowers the risk of respiratory complications and allows earlier bonding with the newborn [19].

Risks and Limitations

Potential risks of RA include nerve damage leading to neuropathic pain or paresthesia, and, in rare cases, permanent nerve injury. Precise technique and highly trained personnel are critical to minimizing such risks [20].

Spinal anesthesia may cause post-procedural headaches due to cerebrospinal fluid leakage from dural puncture. Sudden blood pressure drops are another risk, particularly for elderly patients or those with cardiovascular issues [20].

RA has limitations for extensive or prolonged surgeries requiring full-body anesthesia, where GA may be more appropriate. Challenges may also arise in patients with anatomical anomalies or difficult access to the injection site (e.g., spinal deformities). Additionally, systemic toxicity from local anesthetics (LAST) is a serious complication; lipid emulsion therapy is recommended as a treatment [21, 22].

American Society of Regional Anesthesia and Pain Medicine (ASRA) has developed protocols to address LAST effectively [23].

Literature review

Regional anesthesia (RA) has proven effectiveness in surgeries involving upper and lower limbs. Studies comparing anesthesia methods in distal radius fractures [24] revealed a higher median opioid consumption within the first 24 hours following general anesthesia (GA) compared to RA. However, total opioid use within the first three days and long-term outcomes did not differ between the two groups.

Research on lumbar spine surgery [25] compared RA and GA in terms of anesthesia duration, transition time (from surgery to post-anesthesia care), pain scores using the Visual Analog Scale (VAS), and patient satisfaction at discharge. RA was associated with shorter anesthesia and transition times, lower immediate post-operative pain scores, and higher patient satisfaction, although there was no difference in morphine consumption within the first 48 hours.

A meta-analysis [26] demonstrated that lumbar plexus blocks (LPB) provided superior post-operative pain relief compared to GA, reduced overall opioid consumption, minimized adverse effects, and improved functional recovery. LPB facilitated earlier mobilization, with more patients achieving greater mobility by the second post-operative day compared to continuous femoral nerve blocks. Patient satisfaction was also higher among those receiving LPB.

In hip arthroplasty [27], spinal anesthesia showed the best reduction in surgical stress during the early post-operative period compared to other anesthesia methods. RA frequently resulted in shorter hospital stays and reduced healthcare costs. In upper limb surgeries, RA achieved cost savings of 15–30% compared to GA [28]. Additionally, reduced opioid requirements following RA decreased the risk of side effects and lowered pain management costs [29].

Invastigation [20] the incidence of postdural puncture headache (PDPH) in patients aged 12-45 years undergoing ambulatory lower extremity surgery with spinal anesthesia using a 27G pencil-point needle. Adolescents had nearly three times the odds of developing PDPH compared to adults after adjusting for covariates. Despite this, the need for an epidural blood patch remained low across both age groups. While the overall incidence of PDPH in patients under 45 years old undergoing ambulatory surgery is low, the risk is notably higher in adolescents aged 12-19 compared to adults aged 20-45. Adolescents demonstrated a 2.8-fold increased likelihood of developing PDPH compared to adults, emphasizing the importance of considering age as a significant risk factor when planning spinal anesthesia in this population. Despite the higher incidence of PDPH in adolescents, this did not correlate with an increased need for therapeutic interventions, such as epidural blood patches. This suggests that while PDPH may be more common in younger patients, its severity or clinical consequences are generally manageable [20]

Patient preferences play a crucial role in anesthesia selection. While some prefer RA to remain conscious, others favor GA to avoid intraoperative awareness. Patient education about anesthesia options has been shown to reduce anxiety and improve satisfaction [30].

This randomized controlled observational study investigated whether training anesthesiologists in structured interview techniques improves communication skills, enhances patient satisfaction, and reduces preoperative anxiety and fear of anesthesia [34]. A total of 47 patients were interviewed by either trained anesthesiologists (TA group) or those without specific communication training (CA group). Anxiety and fear levels were measured using a visual analog scale (VAS) before and after the interviews. Additionally, interview duration and patient satisfaction with the anesthesiologist were assessed. The study revealed that structured interviews reduced anxiety and fear more effectively, especially in younger patients (<47 years). However, the reduction in anxiety was not statistically significant in older patients (≥47 years). Interview duration was not significantly impacted by the structured approach. Structured interview techniques reduced preoperative anxiety more effectively in younger patients compared to standard techniques. The impact on older patients was less pronounced. The data suggest structured interviews may provide targeted benefits for specific age groups. Fear of anesthesia was significantly reduced across all patients following the interviews, with the structured approach showing a stronger effect than the standard technique. Although not statistically significant, structured interviews showed a tendency to reduce interview duration, indicating potential efficiency gains. Structured interview techniques improve patient communication and psychological outcomes. Training anesthesiologists in this method is recommended to enhance patient satisfaction and reduce anxiety, particularly in younger populations [34].

Spinal anesthesia combined with continuous epidural anesthesia (SCEA) demonstrates superior efficacy over continuous epidural anesthesia (CEA) for painless labor in primiparas. SCEA effectively reduces labor pain, alleviates anxiety and inflammation, optimizes serum hormone expression, and minimizes complications. These findings suggest that SCEA is a more effective and safer approach for managing labor in primiparas, contributing to better maternal and neonatal outcomes [35].

A comprehensive meta-analysis [36] examined the incidence and risk factors associated with the failure of transitioning from epidural labor analgesia to cesarean section anesthesia. This analysis included 19 studies involving a total of 9,926 patients. The overall incidence of conversion to general anesthesia was 6% (95% CI: 5–8%). Patients in the failure group were younger, taller, and more likely to experience incomplete epidural blockade compared to those in the successful transition group. Additional findings indicated that these patients required higher doses of epidural medication and were more frequently managed by non-obstetric anesthesiologists. Emergency cesarean sections were also more prevalent in this group. No significant differences were observed regarding gestational age, BMI, primiparity, cervical dilation at epidural placement, or the duration of epidural analgesia.

The transition failure rate of 6% underscores the importance of recognizing modifiable and non-modifiable risk factors to optimize anesthetic care in cesarean deliveries. The findings highlight key risk factors, including inadequate epidural blockade, emergency cesarean sections, and non-specialist anesthetic providers. These factors suggest that improving block techniques, ensuring optimal staffing, and enhancing training in obstetric anesthesia may reduce the likelihood of conversion to general anesthesia. Additionally, younger and taller patients may require closer monitoring to ensure the effectiveness of epidural anesthesia during labor and cesarean delivery [36]

Long-term outcomes suggest RA may improve quality of life and cognitive function, particularly in elderly patients, due to reduced opioid use. Conclusions from the article. In the study Association Between Exposure to General Versus Regional Anesthesia and Risk of Dementia in Older Adults by Velkers et al., the relationship between the type of anesthesia and the risk of developing dementia in older adults was analyzed. Based on retrospective data from a large cohort of patients, it was found that both general anesthesia (GA) and regional anesthesia (RA) are used in similar demographic groups, with minimal differences in their impact on dementia risk. No clear association: The study did not demonstrate a statistically significant increase in dementia risk associated with exposure to general anesthesia compared to regional anesthesia. In some clinical contexts, RA may be associated with a potentially better neurocognitive profile; however, these differences were not significant enough to recommend a specific type of anesthesia based on dementia risk. Other factors, such as patient age, comorbidities, and the type and extent of surgery, had a greater influence on predicting dementia development than the choice of anesthesia. The findings highlight the need for future studies with longer follow-up periods and more detailed exploration of the biological mechanisms that could explain neurocognitive differences between anesthesia types [31].

Based on the article Carbon Footprint of General, Regional, and Combined Anesthesia, regional anesthesia (RA) has a significantly lower carbon footprint compared to general anesthesia (GA). This is primarily due to the absence of anesthetic gases, which are potent greenhouse gases with a high global warming potential (GWP). Regional anesthesia generates a smaller carbon footprint due to reduced use of disposable medical supplies and the lack of emissions from anesthetic gases. Higher GWP (global warming potential) in GA. General anesthesia substantially contributes to greenhouse gas emissions, especially when gases such as desflurane or sevoflurane are used. Combining regional and general anesthesia (combined anesthesia) increases the carbon footprint, approaching levels observed with general anesthesia alone. Optimizing anesthetic techniques with a focus on environmental impact can be a component of sustainable development strategies in anesthesiology. Choosing regional anesthesia when feasible contributes to environmental sustainability and should be considered in clinical practice and environmental policy planning.[21][32].

Enhanced Recovery After Surgery (ERAS) protocols emphasize the incorporation of regional anesthesia (RA) as a key component to optimize post-operative outcomes. The use of RA in these protocols is designed to effectively minimize post-operative pain by providing targeted analgesia, which reduces the reliance on systemic opioids and their associated side effects. Furthermore, RA has been shown to facilitate early mobilization and functional recovery, thereby contributing to shorter hospital stays and decreased healthcare costs. In addition to its analgesic benefits, RA is associated with a lower incidence of post-operative complications, such as respiratory depression, nausea, and ileus, which are more commonly observed with general anesthesia or systemic analgesics. This approach is particularly advantageous in abdominal and pelvic surgeries, where the control of visceral pain and mitigation of surgical stress responses are critical for enhancing recovery and improving overall patient outcomes. By integrating RA into ERAS protocols, clinicians can achieve a more patient-centered, evidence-based approach to perioperative care. [33].

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