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The Impact of Anesthesia on Muscle Strength and Function After Orthopedic Surgery: An Experimental Study

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Abstract
Postoperative muscle weakness and impaired function are common complications after orthopedic surgery. This study aims to assess the impact of two commonly used anesthesia types—general anesthesia (GA) and regional anesthesia (RA)—on muscle strength and functional recovery after orthopedic surgery. A total of 100 patients undergoing lower-limb orthopedic surgery were randomly assigned to receive either GA or RA. Muscle strength and functional recovery were evaluated using isometric strength tests and functional mobility scores at 1 week, 1 month, and 3 months post-surgery. The results showed that RA was associated with faster recovery of muscle strength and function compared to GA.
Keywords- Muscle weakness, Anesthesia, Orthopedic surgery.

INTRODUCTION

Orthopedic surgery, particularly on lower limbs, often leads to postoperative muscle weakness and delayed functional recovery. Anesthesia plays a critical role in these outcomes, with different types potentially having varying impacts on muscle strength and rehabilitation. While general anesthesia (GA) is widely used, regional anesthesia (RA) is increasingly being adopted due to its potential benefits in preserving muscle function. This study investigates the impact of GA versus RA on postoperative muscle strength and functional outcomes in patients undergoing orthopedic surgery.

MATERIALS AND METHODS

Study Population

This study involved 100 patients (aged 30-65) undergoing lower-limb orthopedic surgeries (e.g., total knee arthroplasty, hip replacement) at a single medical center. Patients were randomly assigned to two groups:
Group 1 (GA Group, n=50): Received general anesthesia during surgery.
Group 2 (RA Group, n=50): Received regional anesthesia (spinal or epidural anesthesia).

Assessment Tools

Muscle Strength Measurement: Muscle strength was assessed using isometric strength testing (measured in Newton-meters, Nm).

Functional Recovery: Functional mobility was assessed using the Timed Up and Go (TUG) test, where shorter times indicate better mobility.

Data Collection Points

Muscle strength and functional recovery were measured at three time points:
1 week post-surgery
1 month post-surgery
3 months post-surgery

Statistical Analysis

Comparisons between groups were made using paired t-tests and analysis of variance (ANOVA). A p-value < 0.05 was considered statistically significant.

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RESULTS

The results from the study reveal a significant advantage of regional anesthesia (RA) over general anesthesia (GA) in terms of postoperative muscle strength recovery and functional mobility following lower-limb orthopedic surgeries. The key findings can be summarized as follows:

1. Muscle Strength Recovery: RA consistently led to better muscle strength outcomes across all time points. At 1 week, patients in the RA group exhibited a 19.6% higher muscle strength than those in the GA group. This trend continued at 1 month and 3 months, where the RA group maintained an 11.3% greater muscle strength. This suggests that RA better preserves neuromuscular function during surgery, contributing to faster rehabilitation and reduced muscle weakness postoperatively.
2. Functional Recovery: Functional mobility, assessed through the Timed Up and Go (TUG) test, also demonstrated a marked improvement in the RA group. Patients receiving RA were able to mobilize more quickly, with a 22.9% faster recovery in mobility at 1 week compared to the GA group. This improvement persisted at 1 month and 3 months, emphasizing the superior functional outcomes associated with RA. Faster mobility recovery is critical for reducing the risk of postoperative complications and improving quality of life.
3. Reduction in Postoperative Complications: RA was associated with significantly fewer postoperative complications, including nausea and dizziness, both of which were more prevalent in the GA group. These side effects are likely contributors to the delayed recovery observed in GA patients. The reduced incidence of complications in the RA group further supports the idea that RA not only facilitates better short-term recovery but also enhances overall patient comfort and satisfaction post-surgery.
4. Clinical Implications: The study supports the use of RA over GA in lower-limb orthopedic surgeries due to its clear benefits in muscle strength preservation, faster functional recovery, and reduced postoperative complications. These findings align with existing literature emphasizing the advantages of RA in minimizing the need for postoperative opioids, thus reducing opioid-related side effects. Moreover, the superior recovery of mobility in the early stages post-surgery underscores the importance of choosing RA to improve rehabilitation outcomes.

Table 1: Muscle Strength Comparison Between General Anesthesia (GA) and Regional Anesthesia (RA)

Time Post-Surgery	Muscle Strength (Nm) – GA Group	Muscle Strength (Nm) – RA Group	Percentage Difference
1 week	35.2 ± 5.4	42.1 ± 4.8	+19.6%
1 month	50.6 ± 6.8	58.3 ± 6.0	+15.2%
3 months	65.5 ± 7.3	72.9 ± 6.5	+11.3%

Table 2: Functional Recovery (TUG Score) Comparison Between GA and RA

Time Post-Surgery	TUG Score (seconds) – GA Group	TUG Score (seconds) – RA Group	Percentage Improvement in RA Group
1 week	25.3 ± 3.2	19.5 ± 2.8	+22.9%
1 month	18.7 ± 2.4	14.2 ± 1.9	+24.1%
3 months	12.1 ± 1.8	9.5 ± 1.3	+21.5%

Table 3: Postoperative Complications

Complication	GA Group (n=50)	RA Group (n=50)	P-Value (Significance)
Nausea	22 (44%)	8 (16%)	$p < 0.01$
Dizziness	18 (36%)	6 (12%)	$p < 0.05$
Delayed Recovery (TUG)	15 (30%)	5 (10%)	$p < 0.01$

These tables offer a clearer breakdown of the differences in muscle strength, functional recovery, and postoperative complications between the GA and RA groups, highlighting the significant benefits associated with regional anesthesia.

DISCUSSION

Muscle Strength

The RA group exhibited significantly higher muscle strength compared to the GA group at all time points ($p < 0.05$). At 1 week post-surgery, the RA group had a mean muscle strength of 42.1 Nm compared to 35.2 Nm in the GA group, indicating that RA better preserves muscle function in the early recovery phase. By 3 months, the RA group maintained a 10% higher muscle strength than the GA group, suggesting that RA promotes faster long-term recovery of muscle function.

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Functional Recovery
Similarly, patients in the RA group showed superior functional mobility across all time points. At 1 week, the RA group completed the TUG test in 19.5 seconds, significantly faster than the 25.3 seconds observed in the GA group. By 3 months post-surgery, the RA group demonstrated faster recovery, completing the TUG test in 9.5 seconds compared to 12.1 seconds in the GA group. This finding suggests that RA facilitates quicker mobility recovery, which is essential for enhancing the overall quality of life and reducing the risk of postoperative complications.

Side Effects and Complications
There were fewer reports of nausea and dizziness in the RA group, whereas the GA group had a higher incidence of these side effects, which may have contributed to delayed recovery in the early postoperative period.

Comparative Analysis with Other Studies
In this study, we found that regional anesthesia (RA) resulted in significantly better muscle strength and functional recovery compared to general anesthesia (GA) in patients undergoing lower-limb orthopedic surgery. The findings are consistent with previous studies, but certain variations and insights emerge when compared with other research in the field.

1. Muscle Strength Recovery
Our study found that patients in the RA group experienced faster recovery of muscle strength across all postoperative time points compared to the GA group. By 3 months, the RA group exhibited a 10% greater muscle strength than the GA group. This result is in line with the findings of Kehlet and Wilmore[1], who emphasized that RA preserves muscle function by limiting the extent of neuromuscular block and reducing postoperative pain, which often hinders rehabilitation efforts in GA patients.

Macfarlane et al.[3], in their meta-analysis, also concluded that RA leads to better functional outcomes in the early postoperative period compared to GA, but their findings primarily focused on pain management, rather than direct muscle strength measurements. Our study adds to this by demonstrating that the preservation of muscle strength is another key advantage of RA.

In contrast, a study by Abdallah and Brull[5], which compared GA and RA in hip surgery, found less pronounced differences in muscle strength recovery. This disparity could be attributed to the types of surgeries investigated. Hip surgery may involve more invasive procedures with greater muscle and tissue disruption than the lower-limb surgeries examined in our study, potentially diminishing the benefits of RA in that context.

2. Functional Mobility
Our study showed that RA was associated with significantly better functional mobility, as evidenced by superior Timed Up and Go (TUG) test scores at all time points. By 3 months, the RA group completed the TUG test in 9.5 seconds compared to 12.1 seconds in the GA group, which indicates a faster recovery of mobility. Similar findings were reported by Memtsoudis et al.[7], who showed that RA improves early functional mobility and reduces the length of hospital stays after lower-limb surgeries.

In contrast, Johnston et al.[8] found that the difference in functional mobility between GA and RA groups was not statistically significant beyond 6 weeks postoperatively. The variation in outcomes could be due to differences in postoperative rehabilitation protocols or patient populations, as Johnston's study included a higher proportion of elderly patients, who might experience slower recovery regardless of anesthesia type.

3. Postoperative Complications and Side Effects
In our study, patients in the GA group reported higher incidences of side effects such as nausea, dizziness, and delayed recovery, consistent with previous findings by Fischer et al.[2]. Fischer's study also highlighted a higher rate of postoperative complications in GA patients, including respiratory issues, which likely contributed to slower recovery.

In contrast, the RA group in our study experienced fewer complications and reported higher satisfaction, aligning with Ilfeld et al.[4], who noted that continuous regional anesthesia significantly reduces the need for opioids postoperatively, thereby minimizing opioid-related side effects like nausea and constipation, commonly seen in GA patients. However, Katz et al.[10] cautioned that while RA offers advantages in the immediate postoperative period, potential complications such as local anesthetic toxicity and nerve damage, though rare, must be considered.

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4. Comparative Long-Term Outcomes
While our study focused on short-term outcomes (up to 3 months), long-term outcomes must also be considered. Kehlet et al.[1] and Memtsoudis et al.[7] both suggested that RA has long-term benefits in preserving joint mobility and reducing the incidence of chronic pain compared to GA. This aligns with our results in the short term, but further research is needed to evaluate whether the observed benefits of RA continue beyond the 3-month mark.

5. Pain Management and Opioid Consumption
Our study did not specifically measure opioid consumption, but it is well documented that patients receiving RA generally require fewer postoperative opioids compared to those receiving GA. This aligns with the findings of Ilfeld et al.[4], who reported that RA, particularly continuous peripheral nerve blocks, significantly reduces the need for opioids postoperatively. This reduction in opioid consumption is crucial in minimizing opioid-related side effects, such as nausea, vomiting, and constipation, which were more commonly observed in the GA group of our study.

In contrast, Fischer et al.[2] observed similar opioid requirements in both RA and GA groups in their study on knee arthroplasty, suggesting that the choice of anesthesia may not always have a significant impact on opioid consumption. This discrepancy may be attributed to differences in postoperative pain management protocols, with some centers adopting multimodal analgesia approaches that can balance opioid use between the two anesthesia types.

6. Postoperative Cognitive Function
One area that was not directly assessed in our study is postoperative cognitive function, an important consideration, particularly in older patients. Previous research by Katz et al.[10] noted a higher incidence of postoperative cognitive dysfunction (POCD) in patients undergoing GA compared to those receiving RA. This may be due to the deeper levels of sedation and systemic effects of GA on the central nervous system. While our study focused on muscle strength and functional recovery, future research could incorporate cognitive assessments to determine whether RA offers protective effects against POCD.

7. Long-Term Outcomes and Chronic Pain
Our study focused on short-term recovery (up to 3 months), but the question of long-term outcomes remains critical. Kehlet et al.[6] emphasized that while RA may offer short-term benefits, its role in preventing chronic pain remains less clear. The authors suggest that regional anesthesia could help reduce the development of chronic postoperative pain, particularly in lower-limb surgeries, by minimizing the acute pain response and subsequent central sensitization.

This contrasts with Lee et al.[9], who found no significant difference in long-term outcomes between RA and GA when evaluating pain and mobility in hip fracture patients beyond the 6-month mark. This suggests that while RA provides early advantages in terms of pain relief and functional recovery, the long-term effects may equalize as rehabilitation progresses.

Conclusion of Comparative Analysis
The comparative analysis reveals that RA consistently demonstrates better short-term outcomes in terms of muscle strength recovery, functional mobility, and reduced side effects compared to GA. However, discrepancies exist in the literature regarding long-term outcomes, opioid consumption, and chronic pain management. Further research is needed to explore these areas and confirm whether the early benefits of RA translate into long-term advantages across different surgical contexts.

Limitations
The study was limited by its relatively small sample size and short follow-up period. Future research should include larger patient cohorts and examine long-term outcomes beyond 3 months, such as muscle atrophy and chronic pain management.

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