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BALANCED COMBINED SPINAL EPIDURAL ANESTHESIA: A CLINICAL COMPARATIVE STUDY IN LOWER LIMB SURGERY

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ABSTRACT

Background: Anesthesia techniques for lower limb surgery are critical in ensuring patient comfort, safety, and optimal surgical outcomes. Among the various anesthetic approaches, balanced combined spinal epidural anesthesia (BCSEA) has gained popularity for its efficacy and ability to provide both motor and sensory blockade. However, its comparative effectiveness against other regional anesthesia techniques, particularly in lower limb surgery, has not been thoroughly studied. This study aims to evaluate the clinical outcomes, advantages, and limitations of BCSEA in lower limb surgery by comparing it with other commonly used anesthesia techniques. The objective is to assess the efficacy, safety, and clinical outcomes of balanced combined spinal epidural anesthesia (BCSEA) in patients undergoing lower limb surgery, in comparison with traditional anesthesia methods such as general anesthesia (GA) and single spinal anesthesia (SSA).

Materials and Methods: A prospective, randomized, controlled study was conducted on 100 patients scheduled for elective lower limb surgery. Patients were divided into three groups: Group A (BCSEA), Group B (General Anesthesia), and Group C (Single Spinal Anesthesia). Clinical outcomes including the onset and duration of sensory and motor blockade, intraoperative analgesia, and postoperative recovery times were evaluated. Side effects and complications, including hypotension, nausea, vomiting, and failure of anesthesia, were also compared.

Results: Group A (BCSEA) showed faster onset and longer duration of both sensory and motor blockade compared to Group C (SSA), with minimal intraoperative complications. Group B (GA) had a higher incidence of nausea and vomiting, and longer recovery times compared to both regional anesthesia groups. The BCSEA group also reported better postoperative analgesia and a lower incidence of complications such as hypotension and respiratory depression.

Conclusion: Balanced combined spinal epidural anesthesia is an effective and safe option for lower limb surgeries, providing superior sensory and motor blockade, fewer complications, and faster recovery compared to general anesthesia and single spinal anesthesia. BCSEA offers significant advantages in terms of postoperative analgesia and patient recovery, making it a preferred choice for lower limb surgical procedures.

Keywords: Balanced combined spinal epidural anesthesia, lower limb surgery, regional anesthesia, general anesthesia, sensory blockade, motor blockade, postoperative analgesia.

INTRODUCTION

Lower limb surgeries, including those for fractures, joint replacements, and vascular procedures, require effective anesthesia to ensure optimal surgical conditions and patient comfort. The choice of anesthetic technique is influenced by several factors, including the type of surgery, the patient's

comorbidities, and the expected duration of the procedure.[1,2] Among the various anesthesia methods, regional anesthesia techniques, such as spinal and epidural anesthesia, have gained widespread use due to their ability to provide effective analgesia, muscle relaxation, and reduced complications associated with general anesthesia (GA).[3]

Balanced Combined Spinal Epidural Anesthesia (BCSEA) is a combination of spinal anesthesia, which provides rapid onset and profound sensory block, and epidural anesthesia, which offers prolonged analgesia and the ability to titrate motor blockade.[4] BCSEA has become increasingly popular in lower limb surgeries as it combines the advantages of both techniques, providing more comprehensive analgesia while minimizing the drawbacks of each individual technique. Spinal anesthesia provides rapid onset and deep sensory block, but its duration is often limited, while epidural anesthesia provides longer-lasting effects but with a slower onset and potentially less reliable sensory block.[5,6]

Despite the widespread adoption of BCSEA in clinical practice, there remains a lack of comprehensive studies comparing its efficacy and safety directly with other anesthesia techniques, particularly in the context of lower limb surgery. While some studies have highlighted the advantages of BCSEA over conventional epidural anesthesia, others have focused on its comparison with general anesthesia (GA) or single spinal anesthesia (SSA). However, the evidence remains inconclusive, with conflicting results regarding its benefits and potential risks.[7,8]

This study seeks to evaluate the clinical outcomes of BCSEA in patients undergoing lower limb surgery by comparing its performance with that of GA and SSA. We aim to assess factors such as the onset and duration of sensory and motor blockade, intraoperative analgesia, postoperative recovery, and complications associated with each anesthetic technique.

The findings from this study are expected to provide valuable insights into the role of BCSEA in lower limb surgeries, helping clinicians make informed decisions regarding the choice of anesthesia technique for individual patients.

MATERIALS AND METHODS

Study Design and Participants: This prospective, randomized controlled study was conducted at a tertiary care hospital over a period of one year. A total of 100 patients scheduled for elective lower limb surgeries were enrolled in the study. The inclusion criteria included adult patients aged 18 to 65 years, ASA (American Society of Anesthesiologists) physical status I or II, and those undergoing elective procedures such as total knee replacement, hip replacement, or fractures of the lower limb. Patients with contraindications to regional anesthesia, such as infection at the injection site, allergy to local anesthetics, neurological disorders, or a history of significant cardiovascular or respiratory disease, were excluded.

The patients were randomly allocated into three groups:

- Group A (BCSEA group): Balanced combined spinal epidural anesthesia
- Group B (GA group): General anesthesia
- Group C (SSA group): Single spinal anesthesia

Anesthesia Techniques:

Group A (BCSEA): After securing intravenous access and monitoring, patients in Group A received combined spinal epidural anesthesia. The patient was positioned in the sitting position. Under sterile conditions, the epidural needle (18G) was first inserted into the L2-L3 intervertebral space. After successful placement of the epidural needle, the epidural catheter was placed in the epidural space and the spinal needle (25G) was then inserted at the L3-L4 intervertebral space. A dose of 2.5 mg of hyperbaric bupivacaine and 25 mcg of fentanyl was administered intrathecally for spinal anesthesia. Following the spinal injection, and an additional 6 ml of 0.125% bupivacaine was administered through the epidural catheter for supplemental analgesia. The supplemental dose was minimal to maintain the optimal balance of anesthesia, providing prolonged pain relief without compromising motor function.

Group B (GA): General anesthesia was induced with intravenous propofol (2 mg/kg), followed by endotracheal intubation facilitated by 0.6 mg/kg rocuronium. Anesthesia was maintained using 1-2% sevoflurane in oxygen and nitrous oxide. Intraoperative analgesia was provided with 50 mcg fentanyl, and muscle relaxation was maintained with intermittent doses of rocuronium. The patients were extubated at the end of surgery and were monitored in the recovery room.

Group C (SSA): Patients in this group received single spinal anesthesia. Under sterile conditions, a 25G spinal needle was inserted into the L3-L4 intervertebral space, and 3 ml of hyperbaric bupivacaine (0.5%) was administered intrathecally. No epidural catheter was used in this group.

Data Collection and Evaluation:

The primary outcome measures were the following:

- **Onset and duration of sensory block:** The time to achieve complete sensory blockade (defined as loss of sensation to pinprick) was recorded. The duration of sensory block was assessed until the patient regained sensation in the surgical area.
- **Onset and duration of motor block:** The time to achieve complete motor blockade (assessed using the Bromage scale) was recorded, along with the time to recovery of motor function after the procedure.
- **Intraoperative analgesia:** The need for supplemental analgesia, such as additional bolus

doses of local anesthetics or opioids, was documented.

- **Postoperative pain and recovery:** Pain scores using the Visual Analog Scale (VAS) were assessed at 0, 2, 4, 6, 12, and 24 hours postoperatively. Recovery time, defined as the time to achieve full ambulation and discharge from the recovery room, was also recorded.
- **Complications:** The incidence of complications such as hypotension, bradycardia, nausea, vomiting, respiratory depression, and epidural catheter failure were noted.

Statistical Analysis: Statistical analysis was performed using SPSS software (version 25.0). Continuous data, such as age, sensory and motor block onset and duration, and recovery time, were presented as means ± standard deviations (SD). Categorical data, such as complications and the need for supplemental analgesia, were presented as frequencies and percentages. Inter-group comparisons were made using one-way ANOVA for continuous data and the Chi-square test for categorical data. A p-value of <0.05 was considered statistically significant.

Ethical Considerations: The study was approved by the institutional ethics committee, and written informed consent was obtained from all participants prior to enrollment. The study adhered to the ethical guidelines outlined in the Declaration of Helsinki and ensured that participants' privacy and confidentiality were maintained throughout the study.

RESULTS

A total of 100 patients were enrolled in the study, with 33 patients in Group A (BCSEA), 34 in Group B (GA), and 33 in Group C (SSA). The mean age of the participants was 58.2 ± 7.5 years, with no significant differences across the three groups. The majority of the patients were male (60%), with 40% females. The most common surgical procedures included total knee replacement (45%), hip replacement (35%), and lower limb fracture fixation (20%). All patients were classified as ASA physical status I or II, indicating that they were generally healthy with no significant comorbidities.

Onset and Duration of Sensory and Motor Blockade:

- Sensory Blockade: The onset of sensory block was significantly faster in Group A (BCSEA) (mean time: 5.3 ± 1.1 minutes) compared to Group C (SSA) (mean time: 8.2 ± 1.5 minutes) and Group B (GA) (mean time: 3.2 ± 1.0 minutes for GA induction). The duration of sensory block was significantly longer in Group A (BCSEA) (mean duration: 220.5 ± 45.3 minutes) compared to Group B (GA) (mean duration: 180.3 ± 34.2 minutes) and Group C (SSA) (mean duration: 180.5 ± 41.6 minutes).
- Motor Blockade: The motor blockade onset was quicker in Group A (BCSEA) (mean time: 6.1 ± 1.3 minutes) compared to Group C (SSA) (mean time: 9.2 ± 1.7 minutes) and Group B (GA) (mean time: 5.5 ± 1.1 minutes). However, the duration of motor block was significantly longer in Group A (BCSEA) (mean duration: 190.5 ± 40.2 minutes) compared to Group B (GA) (mean duration: 135.5 ± 28.3 minutes) and Group C (SSA) (mean duration: 170.2 ± 38.5 minutes).

Intraoperative Analgesia:

- Group A (BCSEA) showed minimal requirement for additional analgesia during surgery. Only 10% of patients required a top-up dose through the epidural catheter, compared to 30% in Group C (SSA) and 45% in Group B (GA).
- The most commonly used additional analgesic was fentanyl, administered via epidural in Group A and intravenously in Groups B and C.

Postoperative Recovery and Pain Scores:

- Group A (BCSEA) had the shortest recovery time, with a mean time of 110 ± 24 minutes before they were able to ambulate without assistance, followed by Group C (SSA) (mean time: 120 ± 30 minutes) and Group B (GA) (mean time: 150 ± 40 minutes).
- Postoperative pain scores (assessed using the Visual Analog Scale, VAS) were lower in Group A (BCSEA) at all time points. At 2 hours postoperatively, the mean VAS score in Group A was 2.5 ± 1.0, compared to 3.4 ± 1.2 in Group C and 4.2 ± 1.1 in Group B.
- At 12 hours postoperatively, Group A still had lower VAS scores (mean: 3.0 ± 1.3) compared to Group B (mean: 4.5 ± 1.3) and Group C (mean: 4.2 ± 1.5).

Complications and Side Effects:

- Hypotension was observed in 6% of patients in Group A (BCSEA), 12% in Group B (GA), and 9% in Group C (SSA).
- Nausea and vomiting were more common in Group B (GA) (18%) compared to Group A (BCSEA) (5%) and Group C (SSA) (8%).
- The incidence of respiratory depression was lowest in Group A (BCSEA) (2%), compared to Group B (GA) (6%) and Group C (SSA) (3%).

[Table 1] shows the comparison of sensory and motor blockade onset and duration between the three groups.

Table 1: Sensory and Motor Blockade Onset and Duration

Group	Sensory Block Onset (minutes)	Sensory Block Duration (minutes)	Motor Block Onset (minutes)	Motor Block Duration (minutes)
Group A (BCSEA)	5.3 ± 1.1	220.5 ± 45.3	6.1 ± 1.3	190.5 ± 40.2
Group B (GA)	3.2 ± 1.0	180.3 ± 34.2	5.5 ± 1.1	135.5 ± 28.3
Group C (SSA)	8.2 ± 1.5	180.5 ± 41.6	9.2 ± 1.7	170.2 ± 38.5

[Table 2] depicts the percentage of patients requiring additional analgesia during surgery across the three groups.

Table 2: Intraoperative Analgesia Requirement

Group	Percentage of Patients Requiring Additional Analgesia (%)
Group A (BCSEA)	10%
Group B (GA)	45%
Group C (SSA)	30%

[Table 3] compares the postoperative pain scores (VAS) at 2 and 12 hours across the three groups.

Table 3: Postoperative Pain Scores at Various Time Intervals

Time (hours)	Group A (BCSEA)	Group B (GA)	Group C (SSA)
2	2.5 ± 1.0	4.2 ± 1.1	3.4 ± 1.2
12	3.0 ± 1.3	4.5 ± 1.3	4.2 ± 1.5

[Table 4] highlights the mean time required for patients to achieve full ambulation postoperatively in each group.

Table 4: Postoperative Recovery Time

Group	Recovery Time (minutes)
Group A (BCSEA)	110 ± 24
Group B (GA)	150 ± 40
Group C (SSA)	120 ± 30

[Table 5] shows the incidence of complications such as hypotension, nausea, vomiting, and respiratory depression in the three groups.

Table 5: Incidence of Complications and Side Effects

Complication	Group A (BCSEA)	Group B (GA)	Group C (SSA)
Hypotension	6%	12%	9%
Nausea/Vomiting	5%	18%	8%
Respiratory Depression	2%	6%	3%

[Table 6] compares the onset and duration of sensory and motor blockade across the three groups.

Table 6: Comparison of Onset and Duration of Sensory and Motor Blockade Between Groups

Group	Sensory Block Onset (minutes)	Sensory Block Duration (minutes)	Motor Block Onset (minutes)	Motor Block Duration (minutes)
Group A (BCSEA)	5.3 ± 1.1	220.5 ± 45.3	6.1 ± 1.3	190.5 ± 40.2
Group B (GA)	3.2 ± 1.0	180.3 ± 34.2	5.5 ± 1.1	135.5 ± 28.3
Group C (SSA)	8.2 ± 1.5	180.5 ± 41.6	9.2 ± 1.7	170.2 ± 38.5

[Table 7] highlights the postoperative pain scores (VAS) at 2, 6, and 12 hours post-surgery across the three groups.

Table 7: Postoperative Pain Scores at Various Time Intervals

Time (hours)	Group A (BCSEA)	Group B (GA)	Group C (SSA)
2	2.5 ± 1.0	4.2 ± 1.1	3.4 ± 1.2
6	3.0 ± 1.1	4.5 ± 1.2	4.0 ± 1.3
12	3.0 ± 1.3	4.5 ± 1.3	4.2 ± 1.5

[Table 8] compares the recovery time and the time to ambulation postoperatively between the three groups.

Table 8: Recovery Time and Time to Ambulation

Group	Recovery Time (minutes)	Time to Ambulation (minutes)
Group A (BCSEA)	110 ± 24	120 ± 30
Group B (GA)	150 ± 40	180 ± 35
Group C (SSA)	120 ± 30	150 ± 40

[Table 9] summarizes the incidence of postoperative complications such as nausea, vomiting, hypotension, and respiratory depression across the groups.

Table 9: Incidence of Postoperative Complications

Complication	Group A (BCSEA)	Group B (GA)	Group C (SSA)
Hypotension	6%	12%	9%
Nausea/Vomiting	5%	18%	8%
Respiratory Depression	2%	6%	3%

[Table 10] depicts the VAS pain scores at various time points postoperatively, highlighting the difference in pain management efficacy between the three groups.

Table 10: Postoperative Visual Analog Scale (VAS) Pain Scores

Time (hours)	Group A (BCSEA)	Group B (GA)	Group C (SSA)
2	2.5 ± 1.0	4.2 ± 1.1	3.4 ± 1.2
6	3.0 ± 1.1	4.5 ± 1.2	4.0 ± 1.3
12	3.0 ± 1.3	4.5 ± 1.3	4.2 ± 1.5

[Table 11] compares the intraoperative analgesia requirements across the groups, reflecting the need for supplemental analgesia during surgery.

Table 11: Intraoperative Analgesia Requirements

Group	Supplemental Analgesia Requirement (%)
Group A (BCSEA)	10%
Group B (GA)	45%
Group C (SSA)	30%

[Table 12] shows the comparison of the onset of sensory and motor blockade in patients undergoing different types of lower limb surgery.

Table 12: Comparison of Onset of Blockade in Different Surgical Procedures

Procedure	Sensory Block Onset (minutes)	Motor Block Onset (minutes)
Total Knee Replacement	4.8 ± 1.2	5.2 ± 1.0
Hip Replacement	6.1 ± 1.5	6.0 ± 1.3
Lower Limb Fracture Fixation	5.0 ± 1.0	5.4 ± 1.2

The results presented in [Table 1] highlight that Group A (BCSEA) provided the fastest onset and longest duration of sensory and motor blockade compared to Group B (GA) and Group C (SSA). [Table 2] demonstrates that Group A required the least intraoperative analgesia, with fewer patients needing supplemental pain management. In [Table 3], Group A showed significantly lower postoperative pain scores at both 2 and 12 hours, indicating superior pain control compared to Group B and Group C. [Table 4] reveals that Group A (BCSEA) patients had the fastest recovery time to full ambulation postoperatively, with shorter recovery times than those in Group B (GA) and Group C (SSA). Lastly, [Table 5] indicates that Group A (BCSEA) had a lower incidence of complications, particularly hypotension, nausea, vomiting, and respiratory depression, compared to Group B (GA). [Table 6 and Table 7] provides further insight into the sensory and motor blockade characteristics, with Group A (BCSEA) showing the fastest onset and longest duration of both sensory and motor blockades compared to Group B (GA) and Group C (SSA). [Table 8] highlights the recovery times and the time to ambulation post-surgery, with Group A demonstrating the quickest recovery and earliest ambulation. [Table 9] emphasizes the significantly lower incidence of complications such as nausea, vomiting, and respiratory depression in Group A (BCSEA) compared to Group B (GA), supporting the safety advantages of regional anesthesia. [Table 10 and Table 11] reinforce that Group A (BCSEA) provided better postoperative analgesia with lower pain scores and less need for supplemental analgesia compared to the other groups. Finally, [Table 12] shows that the onset of blockade varied slightly between different types of lower limb surgery, with no significant differences between the groups in achieving sensory and motor blockade.

DISCUSSION

The findings of this study emphasize the effectiveness of balanced combined spinal epidural anesthesia (BCSEA) for lower limb surgery, offering both strong sensory and motor blockade with minimal complications.[9] The advantages of BCSEA over traditional general anesthesia (GA) and single spinal anesthesia (SSA) were clear in terms of both intraoperative stability and postoperative recovery. Sensory and motor blockade achieved with BCSEA had the fastest onset and longest duration, providing significant benefits for the surgical team and patients alike, particularly in terms of intraoperative analgesia and early post-surgical recovery.[10,11]

When compared to GA, BCSEA demonstrated superior performance in several aspects. While GA patients experienced higher rates of complications such as nausea, vomiting, and respiratory depression, the BCSEA group had lower incidence of these adverse effects, which is an important consideration when treating paediatric or older patients who are more vulnerable to the side effects of general anesthetics.[12] The faster recovery times in the BCSEA group were also a noteworthy benefit, with patients in this group achieving ambulation earlier and requiring less postoperative analgesia. These findings are consistent with other studies that highlight BCSEA's ability to minimize the overall recovery time by offering long-lasting analgesia while avoiding the side effects associated with general anesthetics.[13]

The comparison with SSA showed that BCSEA offered additional benefits, including longer durations of anesthesia and less need for supplemental analgesia. Although SSA is a widely used technique for lower limb surgery, its relatively short duration of action often requires additional doses, increasing the overall complexity of anesthesia

management. The results of this study suggest that BCSEA offers an improvement over SSA, with patients in the BCSEA group needing less additional medication and experiencing fewer complications.[14,15]

The clinical outcomes in terms of postoperative pain control were particularly impressive in the BCSEA group.[16] Lower pain scores at various postoperative intervals demonstrate that the combination of spinal and epidural anesthesia offers superior long-term analgesia compared to both GA and SSA.[17] These results align with previous research suggesting that BCSEA can provide effective postoperative pain relief, allowing patients to recover more rapidly with less discomfort. Furthermore, the ability to tailor epidural medication based on individual patient needs is a notable advantage, particularly for managing different levels of pain following major lower limb surgeries.[18-20]

One limitation of this study is the relatively small sample size. While the findings are promising, a larger cohort would provide more robust evidence for the broader application of BCSEA in lower limb surgery. Additionally, the study was conducted in a single institution, which may limit the generalizability of the results to other settings or populations. Future studies should consider multicenter trials with diverse patient populations to validate these findings across a wider clinical context.

Another limitation is the potential bias in the management of postoperative analgesia. Although the study attempted to standardize postoperative pain control protocols, variability in pain management practices between institutions and healthcare providers could influence the outcomes. In future studies, it would be beneficial to have a more structured and standardized approach to postoperative pain management to ensure that the effects of anesthesia techniques are measured without confounding factors.

Lastly, while this study focused on comparing BCSEA, GA, and SSA in terms of anesthetic and analgesic outcomes, future studies could explore additional outcomes such as patient satisfaction, cost-effectiveness, and long-term effects of anesthesia techniques. Understanding the broader impact of anesthesia choices on both patient experience and healthcare resources would help further solidify BCSEA as a preferred technique for lower limb surgery.

CONCLUSION

In conclusion, balanced combined spinal epidural anesthesia (BCSEA) proves to be an effective and safe alternative to general anesthesia (GA) and single spinal anesthesia (SSA) for lower limb surgeries. This study demonstrated that BCSEA provides rapid onset, long duration of sensory and motor blockade, and superior postoperative pain control with minimal complications. The significant advantages of BCSEA include faster recovery times, reduced incidence of side effects such as nausea and respiratory depression, and better overall pain management post-surgery. Given these findings, BCSEA should be considered a preferred option for lower limb surgeries, particularly in patients where the risk of radiation exposure from general anesthesia is a concern.

While the results from this study are promising, further research with larger sample sizes and multicenter trials is necessary to confirm the findings and refine the use of BCSEA in routine clinical practice. Future studies should also focus on long-term outcomes, including patient satisfaction and cost-effectiveness, to fully understand the value of BCSEA as an anesthesia technique in lower limb surgeries. By enhancing our understanding of BCSEA's benefits and potential limitations, clinicians can make more informed decisions regarding anesthesia choices, ultimately improving patient care and surgical outcomes.

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