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Impact of Needle Bevel Orientation on Hemodynamic Stability and Quality of Spinal Anesthesia for Cesarean Section: A Prospective Randomized Study

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ABSTRACT:

Introduction: Maternal arterial hypotension is the most common complication of spinal anesthesia for cesarean section, potentially compromising maternal and fetal safety. The objective of this study was to evaluate whether a simple technical modification, the orientation of the needle bevel, could reduce the incidence of this hypotension.

Methods: A prospective, randomized, comparative study was conducted on 100 parturients (ASA I-III) undergoing emergency cesarean section. Patients were divided into two groups: Group I (n=54) received spinal anesthesia with a conventional cephalad bevel orientation, and Group II (n=46) with a caudad orientation. All participants received 10 mg of hyperbaric bupivacaine and 25 mcg of fentanyl. The primary endpoint was the incidence of hypotension (defined as SBP < 100 mmHg or a drop > 20% from baseline).

Results: The incidence of hypotension was significantly lower in the caudad orientation group (10.8%) compared to the cephalad orientation group (38.8%, p = 0.039). Ephedrine consumption was reduced by over 70% in the caudad group (3.0 ± 1.8 mg vs 11.9 ± 4.2 mg, p < 0.05). Furthermore, 78.3% of patients in the caudad group required no vasopressors, compared to 37% in the cephalad group (p < 0.05). The sensory block level was lower (T5 vs T3) and had a slower onset (time to T6: 10 vs 6 min) in the caudad group, while remaining clinically effective.

Conclusion: Caudad orientation of the needle bevel is a simple, effective, and cost-free technique to improve the safety of obstetric spinal anesthesia. It significantly reduces the incidence of maternal hypotension and vasopressor consumption, at the cost of a slightly slower onset of the anesthetic block.

KEYWORDS: Spinal Anesthesia, Cesarean Section, Hypotension, Obstetric Anesthesia, Needle Orientation, Bupivacaine, Patient Safety.

INTRODUCTION

Spinal anesthesia (SA) has established itself as the gold standard anesthetic technique for both elective and emergency cesarean sections, owing to its simplicity, rapid onset of action, and superior safety profile compared to general anesthesia (GA). By avoiding airway manipulation, SA has drastically reduced anesthesia-related maternal mortality.

Nevertheless, SA is not without risks. Its most frequent and feared complication is maternal arterial hypotension, with an incidence ranging from 30% to over 80% depending on the studies and definitions used. This hypotension, resulting from the sympathetic block induced by the local anesthetic, can lead to unpleasant maternal symptoms (nausea, vomiting) and, more seriously, to uteroplacental hypoperfusion.

The prevention and treatment of post-SA hypotension are therefore a central concern in obstetric anesthesia. Current strategies rely on preventive fluid loading (co-loading), left lateral tilt, and the use of vasopressors either prophylactically or for treatment. However, these approaches are not always sufficient, and vasopressors themselves are not without side effects.

We hypothesized that a simple modification of the injection technique, namely the orientation of the needle bevel, could modulate the distribution of the anesthetic and, consequently, the hemodynamic profile. A cephalad orientation (towards the head), conventionally used, could direct the flow of anesthetic towards the upper thoracic segments, causing an extensive sympathetic block and marked hypotension. Conversely, a caudad orientation (towards the feet) could confine the anesthetic to the lower segments, limiting the extent of the sympathetic block while ensuring sufficient analgesia for surgery.

The primary objective of this study was to compare the incidence of maternal arterial hypotension during spinal anesthesia for cesarean section, using a cephalad versus caudad bevel orientation.

MATERIALS AND METHODS

Study Design and Ethics

This prospective, randomized, comparative, and single-blind (patient) study was conducted in the obstetric operating room of the Mother and Child University Hospital Abderrahim Harouchi (Casablanca, Morocco) over a six-month period, from January 1, 2025, to June 30, 2025. The protocol was approved by the institutional ethics committee. Informed oral consent was obtained from each participant before inclusion.

Study Population

Inclusion criteria were: parturients aged 18 years or older, classified as American Society of Anesthesiologists (ASA) I, II, or III, scheduled for an emergency cesarean section under spinal anesthesia. Exclusion criteria included patient refusal, contraindications to spinal anesthesia (coagulation disorders, infection at the puncture site, intracranial hypertension, known allergy to local anesthetics), pre-existing hemodynamic instability, and severe spinal deformities.

Randomization and Anesthetic Procedure

After inclusion, patients were randomized using a system of sealed opaque envelopes into two groups: Group I (Cephalad, n=54) and Group II (Caudad, n=46). All patients were pre-hydrated with 500 mL of crystalloids. The procedure was performed in the sitting position. After local skin anesthesia, the lumbar puncture was performed at the L3-L4 or L4-L5 space. After reflux of clear cerebrospinal fluid (CSF), 10 mg of 0.5% hyperbaric bupivacaine mixed with 25 mcg of fentanyl were injected. The patient was then immediately placed in the supine position with a left uterine displacement.

RESULTS

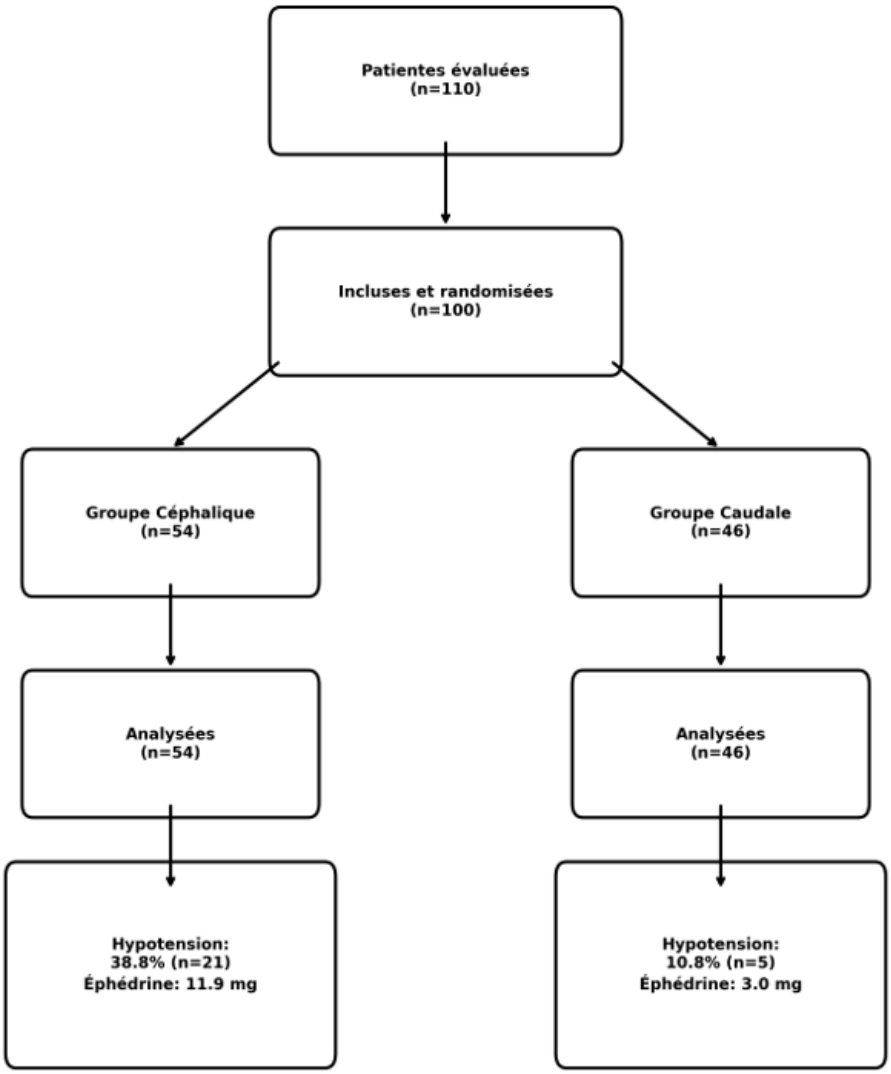
Population Characteristics

Of the 110 patients assessed, 100 were included and randomized. Patient characteristics were comparable between the two groups.

Table 1: Demographic and Clinical Characteristics of Patients

Characteristic	Cephalad Group (n=54)	Caudad Group (n=46)	p-value
Age (years)	26.7 ± 5.1	25.6 ± 4.8	0.31
Weight (kg)	75.3 ± 10.2	73.9 ± 9.8	0.52
Height (cm)	164 ± 6	163 ± 5	0.45
BMI (kg/m²)	28.0 ± 3.5	27.8 ± 3.1	0.78
ASA Classification	30/22/2	26/18/2	0.91
Gestational Age (weeks)	38.5 ± 1.2	38.7 ± 1.1	0.49

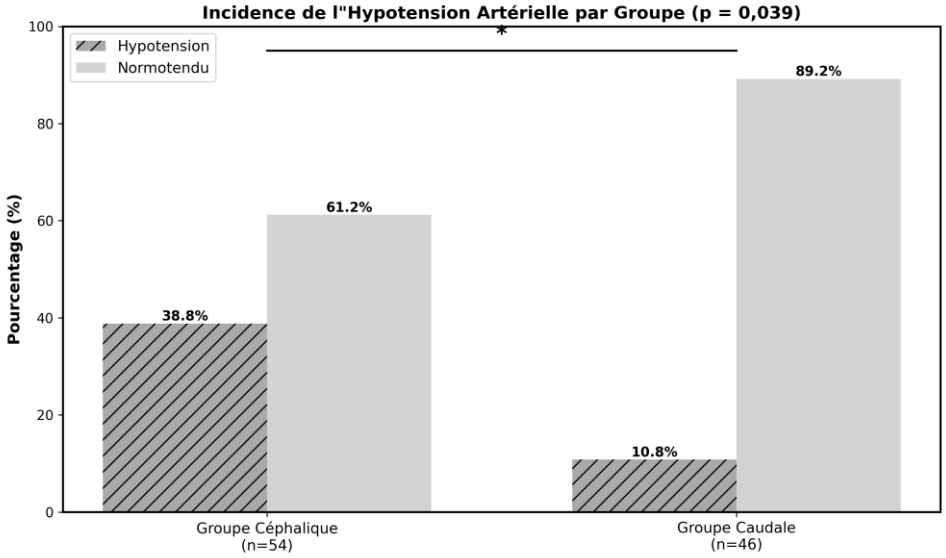
Figure 1: Study Flow Diagram



Primary Endpoint: Incidence of Hypotension

The incidence of arterial hypotension was significantly lower in the caudad orientation group. Twenty-one patients (38.8%) in the cephalad group developed hypotension, compared to only five patients (10.8%) in the caudad group ($p = 0.039$). The relative risk of hypotension in the cephalad group compared to the caudad group was 3.59 (95% CI [1.45 - 8.88]).

Figure 2: Incidence of Arterial Hypotension by Group (p = 0.039)



Secondary Endpoints

The better hemodynamic stability of the caudad group was confirmed by significantly reduced vasopressor consumption.

Table 2: Vasopressor Use and Anesthetic Block Characteristics

Parameter	Cephalad Group (n=54)	Caudad Group (n=46)	p-value
Patients requiring ephedrine	21 (38.8%)	5 (10.8%)	0.039
Total ephedrine dose (mg)	11.9 ± 4.2	3.0 ± 1.8	< 0.001
Patients without vasopressor	20 (37.0%)	36 (78.3%)	< 0.001
Maximum sensory level (median)	T3 [T5-T2]	T5 [T7-T3]	< 0.001
Time to reach T6 (min)	6 ± 2	10 ± 3	< 0.001
Maximum Bromage score (median)	4	4	0.85
Nausea/Vomiting	12 (22.2%)	4 (8.7%)	0.08

Figure 3: Mean Ephedrine Dose Administered (p < 0.001)

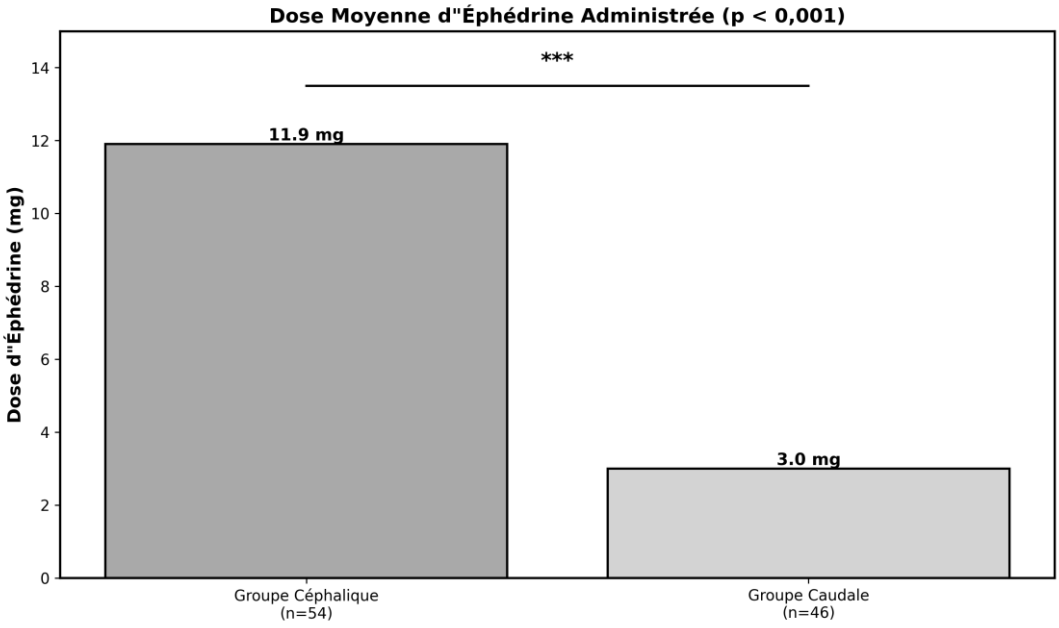


Figure 4: Hypotension Treatment Strategies

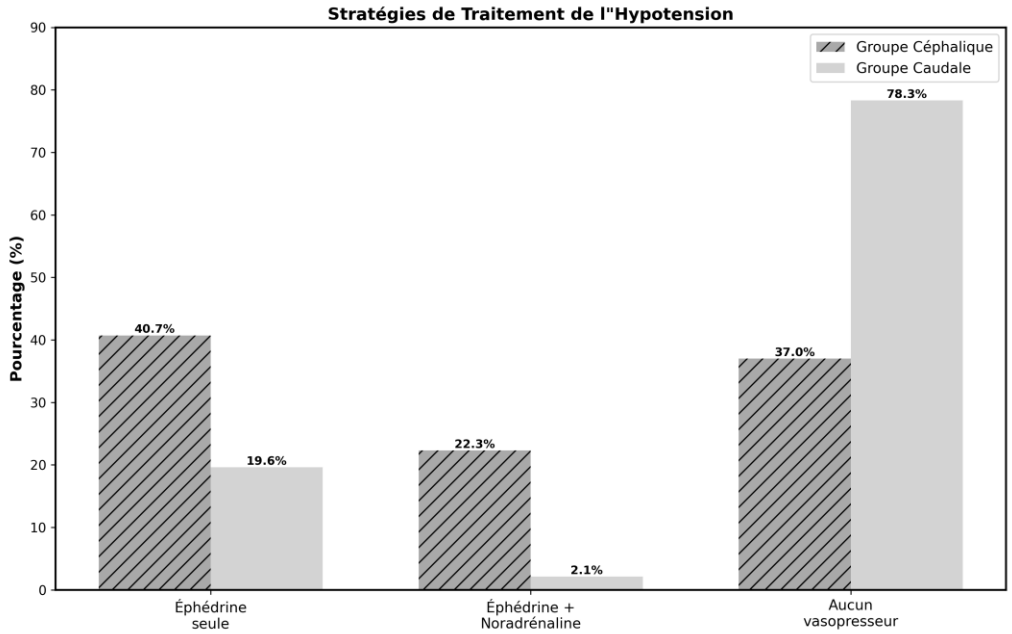
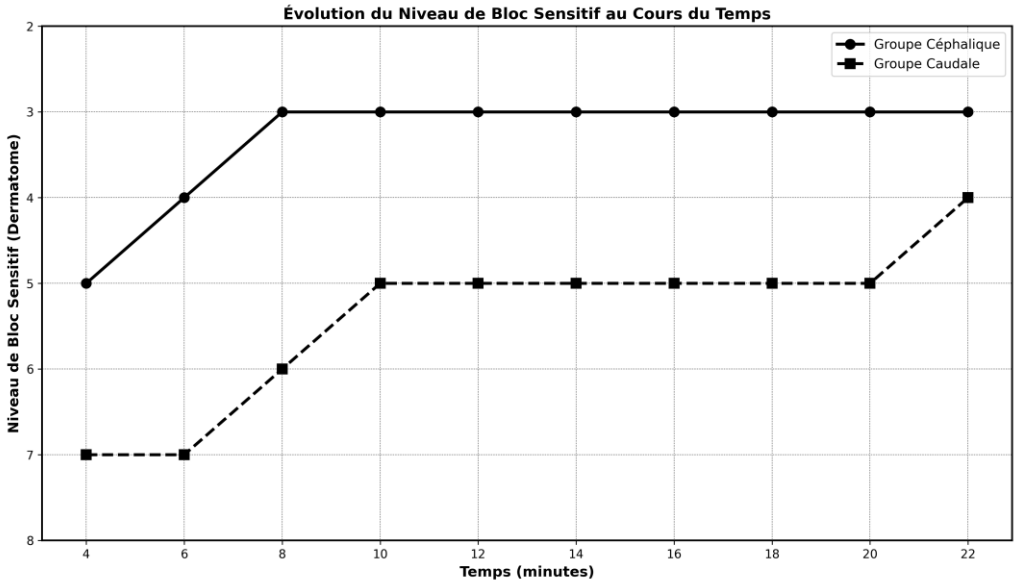


Figure 5: Evolution of Sensory Block Level Over Time



DISCUSSION

Analysis of Main Results and Comparison with Literature

The results of this prospective, randomized study convincingly demonstrate that a simple technical modification – the caudad orientation of the spinal needle bevel – significantly reduces the incidence of maternal arterial hypotension during cesarean section. The nearly 75% reduction in incidence (from 38.8% in the cephalad group to 10.8% in the caudad group) represents a substantial improvement in procedural safety, with a number needed to treat (NNT) of only 3.6 to prevent one case of hypotension. This finding is of great clinical relevance, as it proposes a simple, cost-free, and easily applicable intervention to mitigate the most common complication of this anesthetic technique.

The incidence of hypotension in our control group (cephalad), at 38.8%, is consistent with the existing literature, although it is in the lower range. Studies report incidences ranging from 33% to over 80%. This wide variability is explained by differences in the definition of hypotension (a drop in SBP of 20%, 25%, or 30% from baseline, or an absolute value < 90 or 100 mmHg), fluid loading protocols (crystalloids vs. colloids, co-loading vs. pre-loading), and the use of prophylactic vasopressors. A recent meta-analysis by Kinsella et al. (2018) highlighted this heterogeneity, making direct comparisons difficult. Nevertheless, our main result – the drastic reduction in hypotension with a caudad orientation – is a new and robust finding within our study population. To our knowledge, this is the first prospective randomized study to evaluate this specific impact in obstetric anesthesia.

Pathophysiological Mechanisms and CSF Dynamics

The underlying mechanism for our observations is most likely related to a modification of the distribution of the hyperbaric anesthetic in the cerebrospinal fluid (CSF). Our secondary results corroborate this hypothesis: the sensory block was significantly less extensive (median level T5 vs. T3) and had a slower onset in the caudad group. The caudad orientation of the Quincke-type needle bevel likely directs the initial jet of the anesthetic solution downwards into the dural sac, thus limiting its cranial spread by CSF currents and the effect of gravity on the hyperbaric solution.

By confining the anesthetic to the lower lumbar and sacral segments, this technique spares the cardio-accelerator sympathetic fibers (T1-T4) and the splanchnic vasoconstrictor fibers (T5-L1) to a greater extent. The sympathetic block is therefore less extensive, which better preserves vascular tone and hemodynamic stability. This observation is consistent with the work of She et al. (2021), who demonstrated that the distribution of the sensory block is a major determinant of hemodynamic stability. Similarly, Zhang et al. (2017) showed that the level of sensory block after spinal anesthesia is an independent predictor of hypotension in parturients.

The literature on fluid dynamics in the subarachnoid space is complex, but it is accepted that the direction and speed of injection are important determinants of block distribution. MRI modeling studies have shown that CSF flow is pulsatile and influenced by respiration and the cardiac cycle. The direction of the initial jet can interact with these flows to determine the final dispersion of the agent. Our study provides strong clinical evidence to support the concept that bevel orientation is a first-order technical factor, easily controllable by the anesthesiologist, to control this dispersion.

Clinical Implications and Patient Safety

The massive reduction in vasopressor consumption is a major clinical benefit. Ephedrine, although effective, is not without side effects. Studies have shown that ephedrine can increase maternal and fetal heart rate, and may be associated with fetal acidosis through its action on beta-adrenergic receptors. Phenylephrine, a selective alpha-1 vasopressor, is increasingly favored because it better maintains fetal pH, but it can induce maternal reflex bradycardia and a decrease in cardiac output. The fact that nearly 80% of patients in the caudad group required no pharmacological intervention to maintain their blood pressure is a strong argument in favor of this technique. This simplifies anesthetic management, reduces costs, and, most importantly, minimizes fetal exposure to drugs. This observation is particularly important in light of the work of Ngan Kee et al. (2009), who demonstrated the fetal metabolic effects of vasopressors.

A potential concern could be that this less extensive block is insufficient for surgery. However, our results are reassuring: a T5 level was reached in the caudad group, which is considered adequate for a cesarean section, as the visceral peritoneum is innervated up to T5. Ousley et al. (2012) demonstrated that anesthesiologists consider a block up to T5 to be sufficient for most cesarean sections. No patient in our study required supplemental analgesia or conversion to general anesthesia. The longer onset time (10 minutes to T6) must be taken into account by the practitioner, who will have to wait a few extra minutes before authorizing the surgical incision. This slight inconvenience seems a very acceptable compromise given the major gain in terms of hemodynamic safety.

CONCLUSION

In conclusion, caudad orientation of the needle bevel during spinal anesthesia for cesarean section is a simple, effective, and cost-free technical modification that dramatically reduces the incidence of maternal arterial hypotension and vasopressor consumption. It allows for achieving anesthesia of sufficient quality for surgery while significantly improving the safety of the procedure. Given these compelling results, this technique merits consideration as a standard practice in obstetric anesthesia. Larger multicenter studies are needed to confirm these findings and evaluate their impact on neonatal outcomes.

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DECLARATIONS

Ethical Compliance Statement

This study was approved by the ethics committee of the Mother and Child University Hospital Abderrahim Harouchi. Oral consent was obtained from all patients before their inclusion.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Data Availability

The raw data used in this study are available from the corresponding author upon reasonable request.

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