Scientific Research Publishing

Open Journal of Anesthesiology, 2026, 16(2), 41-55
https://www.scirp.org/journal/ojanes
ISSN Online: 2164-5558
ISSN Print: 2164-5531

Value of Ultrasound Assessment of the Inferior Vena Cava and the Subclavian Vein in Hemodynamic Monitoring during Spinal Anesthesia

Francois Stephane Kona Ngondo[1,2], Ferdinand Ndom Ntock[1], Christela Iroume[1], Serge Ngouatna[1], Ben Ousman Djoubairou[3,4], Tchatat Reine[1], Albert Ludovic Amengle[1], Roddy Stephan Bengono Bengono[1], Junette Arlette Metogo Mbengono[3,5], Bonaventure Jemea[1], Paul Owono Etoundi[1], Jacqueline Ze Minkande[1]

[1]Faculty of Medicine and Biomedical Sciences, University of Yaoundé I, Yaoundé, Cameroon
[2]Department of Anesthesia and Critical Care, Regional Military Hospital No. 1, Yaoundé, Cameroon
[3]Faculty of Medicine and Pharmaceutical Sciences, University of Douala, Douala, Cameroon
[4]Department of Neurosurgery, Regional Military Hospital No. 1, Yaoundé, Yaoundé, Cameroon
[5]Department of Anesthesia and Critical Care, Douala General Hospital, Douala, Cameroon
Email: *stephkona@yahoo.fr

How to cite this paper: Kona Ngondo, F.S., Ndom Ntock, F., Iroume, C., Ngouatna, S., Djoubairou, B.O., Reine, T., Amengle, A.L., Bengono, R.S.B., Metogo Mbengono, J.A., Jemea, B., Etoundi, P.O. and Ze Minkande, J. (2026) Value of Ultrasound Assessment of the Inferior Vena Cava and the Subclavian Vein in Hemodynamic Monitoring during Spinal Anesthesia. *Open Journal of Anesthesiology*, **16**, 41-55.
https://doi.org/10.4236/ojanes.2026.162005

Received: January 19, 2026
Accepted: February 24, 2026
Published: February 27, 2026

Abstract

Introduction: Spinal anesthesia is a locoregional anesthetic technique used for interventions below the umbilicus. Ultrasound monitoring of the inferior vena cava and the subclavian vein can reduce the incidence of hypotension following spinal anesthesia. The objective of our study was to evaluate the hemodynamic status following spinal anesthesia using ultrasound of the inferior vena cava and subclavian vein. **Methods:** We conducted a blinded randomized clinical study from December 2024 to July 2025, a duration of eight months, in the anesthesia unit of the Yaoundé Military Hospital. We included patients with anesthesia risk ASA I and ASA II and excluded patients with cardiovascular comorbidities, pregnant women, and those undergoing interventions with bleeding potential. We divided the participants into two groups—standard and ultrasound-guided—using a 1:1 sequence. Our dependent variables were hypotension, vasopressor dosage used, quantity of fluid before and after induction, diameters of the inferior vena cava and right subclavian vein during inspiration and expiration, collapsibility indices, and variability. Data were entered into CS Pro version 8.0 and analyzed using SPSS version 27.0. **Results:** A total of 80 patients were recruited for the study and divided into two groups: 40 in the ultrasound-guided group and 40 in the standard group. The sex ratio was 6.18. The mean age was 35.51 ± 14.02 years; most surgeries performed were orthopedic (42.5%), and most patients were classified as ASA 1 (93.8%). Ultrasound measurements were as follows: mean Dmin IVC 1.7 ± 0.4 cm, mean Dmax IVC 2.0 ± 0.3 cm, mean IVCCI 15.3 ± 11.5%, Dmin SCV on spontaneous breathing 0.9 ± 0.3 cm, Dmax SCV on spontaneous breathing 1.0 ± 0.3 cm, spontaneous SCVCI 9.7 ± 8.0%. Variability index SCV 0.1 ± 0.1%, Dmin SCV on deep breathing 0.8 ± 0.2 cm, Dmax SCV on deep breathing 1.1 ± 0.3 cm, SCVCI on deep breathing 25.0 ± 9.0%, SCV variability index on deep breathing 0.3 ± 0.1%. In the study population, hypotension occurred in 18.8% (n = 15), with 22.5% (n = 9) in the ultrasound-guided group versus 15% (n = 6) in the standard group (p = 0.390). The total volume of crystalloid during the intervention was 100 ± 99 ml (0 - 500 ml) in the ultrasound-guided group versus 1174.3 ± 565.7 ml (240 - 3000 ml), p < 0.001. The total dose of ephedrine used in the two groups was 9.0 ± 3.4 mg, with 8.9 ± 3.3 mg in the ultrasound-guided group versus 9.2 ± 3.8 mg in the standard group (p = 0.408). **Conclusion:** Ultrasound measurements of the inferior vena cava and subclavian vein are beneficial for monitoring the hemodynamic state following spinal anesthesia. Our study showed a higher proportion of hypotension in the ultrasound-guided group, with no statistically significant difference between the two groups. It permits individualized fluid management based on the needs of each patient.

Keywords

Spinal Anesthesia, Hemodynamic Monitoring, Hypotension,
Ultrasound-Guided, Inferior Vena Cava, Subclavian Vein

1. Introduction

Spinal anesthesia (SA) is a locoregional anesthetic technique in which a local anesthetic (LA) is injected into the cerebrospinal fluid (CSF), in direct contact with the nerve roots. It is an anesthetic technique frequently used for infra-umbilical surgeries [1]. Its advantages include technical simplicity, rapid onset, and low cost [1]. Despite these benefits, hypotension and bradycardia are the most common and predominant adverse effects. Thus, post-spinal anesthesia hypotension (PSAH) is the most frequent complication, with a prevalence ranging from 15% to 33% [2]-[4] in the general population and up to 65% in the specific context of cesarean section [5]. Hypotension may lead to adverse postoperative events such as myocardial infarction, postoperative delirium, and acute kidney injury, as well as an increased 30-day postoperative mortality after non-cardiac surgery [6]-[8].

Fluid resuscitation, in the prevention and management of PSAH, aims to increase stroke volume and improve vital organ perfusion and oxygen delivery [9]. Predicting fluid responsiveness, or determining whether fluid administration will result in the expected significant increase in cardiac output, remains a major concern for clinicians [10]. Various invasive techniques, such as invasive arterial pressure monitoring, pulmonary artery catheterization, PiCCO®, and Vigileo®, have been described to assess preload and other components of hemodynamic status. However, their widespread use remains controversial because of their high cost and relatively high complication rates [11]. Other non-invasive methods include non-invasive blood pressure monitoring, the passive leg-raising test, and ultrasound.

Ultrasound is a useful non-invasive tool that is increasingly used by anesthesiologists in the operating room, with a short learning curve. Its advantages include reliability, portability, ease of use, and the absence of complications. It allows the measurement of several parameters, including the inferior vena cava (IVC), which has been used in intensive care and the perioperative period as a hemodynamic assessment tool [12] [13]. Ultrasonographic assessment of the inferior vena cava collapsibility index (IVC-CI) and the subclavian vein collapsibility index (SCV-CI) represents a simple, non-invasive technique for evaluating intravascular volume status [13] [14].

In low-resource countries, more than half of anesthesia-related maternal deaths are caused by post-spinal anesthesia hypotension. Hemodynamic management during spinal anesthesia relies mainly on strategies such as empirical prophylactic fluid loading and/or the prophylactic use of vasopressors to reduce the incidence of PSAH. This approach is not always patient-tailored and is primarily based on monitoring heart rate (HR), mean arterial pressure (MAP), and systolic arterial pressure (SAP) [15] [16]. The incidence of deaths related to PSAH is highest in these settings due to limited resources for optimizing perioperative management [15]. Therefore, implementing point-of-care ultrasound in perioperative management could improve patient care. Goal-directed fluid therapy may allow the appropriate use of fluids, vasopressors, and inotropes, leading to better outcomes [17].

The objective of our study was to evaluate the contribution of IVC and SCV monitoring to hemodynamic management during spinal anesthesia. We hypothesized that IVC and SCV monitoring would be beneficial for optimizing hemodynamic management in patients undergoing spinal anesthesia.

2. Patients and Methods

After obtaining ethical approval from the Ethics Committee of the Faculty of Medicine of the University of Yaoundé I (FMSB) and administrative authorization from the Military Hospital of Region No. 1 (HMR No. 1), we conducted a single-blind randomized clinical trial over a period of eight (8) months in the Department of Anesthesiology of the Military Hospital of Region No. 1 in Yaoundé (HMR1).

All patients aged over 18 years undergoing surgery under spinal anesthesia, classified as ASA physical status I or II, were eligible for inclusion. Exclusion criteria were: body mass index (BMI) > 30 kg/m^2; pregnancy; cardiovascular diseases such as systemic arterial hypertension, heart failure, or unstable angina; presence of a pacemaker; pulmonary arterial hypertension; mean arterial pressure (MAP) < 65 mmHg; cardiac arrhythmias; diabetes mellitus; acute kidney injury; poor ultrasonographic visualization of the inferior vena cava and/or subclavian vein; and potentially hemorrhagic surgical procedures.

2.1. Pre-Spinal Anesthesia Period

After welcoming the patient in the preoperative area, the fasting duration was calculated, and the patient was instructed to remain at rest for 5 minutes. Baseline parameters were then recorded.

Pre-anesthetic fluid administration:

Fluid administration before anesthesia was performed according to the intervention group.

In the standard group, without ultrasound guidance, preoperative fasting deficits were corrected according to the 4-2-1 rule, with half of the calculated fluid requirement administered 30 minutes before the initiation of spinal anesthesia.

Ultrasound-guided group:

Ultrasound assessment of the right subclavian vein (SCV) was performed as follows:

- Right SCV diameters were measured using a high-frequency linear array transducer (6 - 13 MHz) in M-mode. To obtain the optimal transverse image of the vein, the probe was positioned inferior to the proximal portion of the mid-clavicle, perpendicular to the long axis of the SCV, in the sagittal plane at the level of the deltopectoral triangle. The collapsibility index was calculated during spontaneous and deep breathing. Dynamic changes in venous diameter over time were recorded using M-mode to identify and quantify the minimum and maximum venous diameters during a respiratory cycle. Once the target vein was identified, three scans were obtained for each patient. The maximum (dSCV_max) and minimum (dSCV_min) anteroposterior diameters of the SCV at the end of expiration and inspiration were recorded within the same respiratory cycle, during both normal and deep breathing. The SCV collapsibility and variability indices were calculated using the following formulas:
- Collapsibility index: (Dmax – Dmin)/Dmax * 100
- Variability index: (Dmax – Dmin)/((Dmax + Dmin)/2) * 100

The measurement of the inferior vena cava was performed as follows:

- The patient was relaxed in the supine position and breathing spontaneously for 5 minutes. A 3.5 -5 MHz curvilinear probe was placed longitudinally in the subxiphoid position, as for cardiac imaging, and then oriented toward the liver, proximal to the drainage of the common hepatic vein into the inferior vena cava (IVC). Once adequate visualization was obtained, the IVC was measured in time–motion (M-mode) at 1 - 2 cm caudal to the hepatic vein–IVC junction or 3 - 4 cm distal to the junction between the IVC and the right atrium, using a subxiphoid transabdominal long-axis view [18]. Measurements were obtained over a single respiratory cycle, with the diameter measured between the two inner walls. The minimum diameter (IVC-Dmin) and maximum diameter (IVC-Dmax) were calculated using M-mode ultrasound, and the IVC collapsibility index (CI) was determined. Three measurements were taken at one-minute intervals, and the mean value was considered as the IVC-CI. A threshold value of 40% was defined. Accordingly:

- Patients were considered euvolemic when the IVC-CI was < 40% and/or the minimum IVC diameter was > 1.10 cm.
- Patients were considered hypovolemic when the IVC-CI was > 40% and/or the minimum IVC diameter was < 1.10 cm.

Only hypovolemic patients received a 3 mL/kg crystalloid bolus (Ringer's lactate or 0.9% saline) over a 10-minute period, after which changes in IVC diameter were reassessed. Identical fluid boluses were administered until an IVC-CI < 40% and/or a minimum IVC diameter > 1.10 cm was achieved. Spinal anesthesia was then performed.

2.2. Intraoperative Period: Induction of Spinal Anesthesia

The patient was then transferred to the operating room. Standard positioning and monitoring were established using a multiparameter monitor. After disinfection of the lumbar region and identification of the L3-L4 interspace, a lumbar puncture was performed using a Quincke spinal needle, and 12.5 mg of 0.5% isobaric bupivacaine was administered. Adjuvants such as fentanyl and/or morphine were added to the bupivacaine and injected intrathecally over 10 seconds once free flow of cerebrospinal fluid was confirmed. After injection, patients were immediately positioned supine with a 30˚ head-up tilt. The sensory block level was assessed using the pinprick test, and motor block was evaluated using the Bromage score. Surgical procedures were initiated only once the patient was stable.

Intraoperative resuscitation

Standard group:

In the event of hypotension following spinal anesthesia, resuscitation was conducted according to the following protocol:

- In cases of hypotension and/or bradycardia, ephedrine 5 mg or atropine 0.1 mg/kg, respectively, was administered. Hemodynamic parameters were reassessed every 3 minutes.
- After two doses of the aforementioned medications with persistent arterial hypotension, a crystalloid infusion of 3 mL/kg was administered over 10 minutes, followed by reassessment.
- Maintenance fluid administration after fasting correction was continued according to the 4-2-1 rule, taking insensible losses into account and the losses (2 ml/kg/h) due to surgical trauma (3 ml/kg/h) because we only included surgeries with minor trauma.

Ultrasound-guided group:

IVC and subclavian vein (SCV) measurements were performed at 5, 10, 15, 30, 45, 60, 75, and 90 minutes after the induction of spinal anesthesia. Resuscitation was conducted according to the following protocol:

- In the event of hypotension during surgery, if the IVC minimum diameter was ≥ 1.10 cm and/or the IVC-CI was < 40%, hypotension was attributed to vasoplegia, and patients received 5 mg of ephedrine.

- Conversely, if the IVC minimum diameter was < 1.10 cm and/or the IVC-CI was $> 40\%$, hypotension was attributed to hypovolemia, and a 3 mL/kg crystalloid bolus (Ringer's lactate or 0.9% saline) was administered over 10 minutes, followed by reassessment of the IVC diameter variation.

3. Data Analysis

Data entry was performed using CSPro software version 8.0. Data analysis was conducted using SPSS software version 22.0. Graphs were generated using SPSS version 22.0 and Microsoft Excel 2016. Consecutive sampling with 1:1 random allocation was used. Each patient was randomly assigned to one of the two study groups corresponding to the protocols under investigation. Both groups included an equal number of patients.

Sample size:

Sample size was calculated using OpenEpi software based on the Kelsey *et al.* formula. Parameters included a two-sided significance level $(1 - \alpha)$ of 95%, statistical power $(1 - \beta)$ of 80%, a non-exposed/exposed ratio of 1, an expected outcome proportion among exposed participants of 34% (the percentage of patients who developed hypotension after spinal anesthesia in the first study by Ni *et al.*, 2022, to evaluate the power of preoperative IVCCI for predicting hypotension after induction of spinal anesthesia), and an odds ratio of 10. The total sample size with continuity correction was 68 participants, comprising 34 exposed and 34 non-exposed subjects.

A p-value < 0.05 was considered statistically significant for all analyses.

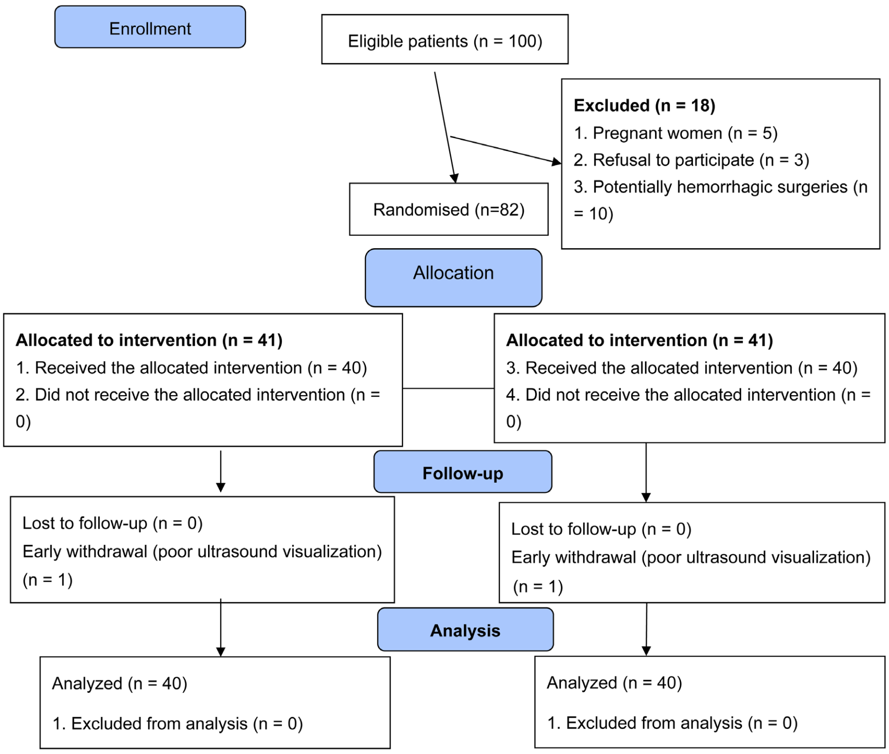

Figure 1. CONSORT flow diagram.

4. Results

During the study period, 100 patients were enrolled, of whom 20 were excluded. Forty patients were allocated to the ultrasound-guided group and forty to the standard group (see Figure 1).

Table 1. Demographic and clinical characteristics according to the intervention group.

Variables	Overall, N = 80.	Ultrasound-guided N = 40[1]	Standard N = 40[1]	p-value[2]
Age (years)				0.174
Mean ± SD	35.51 ± 14.02	33.38 ± 11.33	37.7 ± 16.3	
Age groups				0.108
15 - 29 years	31 (38.8%)	17 (42.5%)	14 (35.0%)	
30 - 59 years	42 (52.5%)	21 (52.5%)	21 (52.5%)	
≥60 years	7 (8.75%)	2 (5.00%)	5 (12.5%)	
BMI (kg/m^2)				0.361
Mean ± SD	25.0 ± 2.9	24.7 ± 2.6	25.3 ± 3.2	
Sex				0.330
Male	69 (86.3%)	33 (82.5%)	36 (90.0%)	
Female	11 (13.8%)	7 (17.5%)	4 (10.0%)	
Type of surgery				0.099
Orthopedic	34 (42.5%)	19 (47.5%)	15 (37.5%)	
Digestive	26 (32.5%)	15 (37.5%)	11 (27.5%)	
Urologic	18 (22.5%)	5 (12.5%)	13 (32.5%)	
Gynecologic	1 (1.25%)	1 (2.50%)	0 (0%)	
Vascular	1 (1.25%)	0 (0%)	1 (2.50%)	
ASA score				0.055
ASA I	75 (93.8%)	40 (100.0%)	35 (87.5%)	
ASA II	5 (6.25%)	0 (0%)	5 (12.5%)	

Table 2. Preoperative fasting characteristics and preoperative parameters according to the intervention group.

Variables	Overall N = 80[1]	Ultrasound-guided N = 40 [1]	Standard N = 40[1]	p-value[2]
Duration of liquid fasting (h)				0.243
Mean ± SD	12.2 ± 8.2	12.4 ± 10.6	12.1 ± 4.8	
Duration of solid fasting (h)				0.915
Mean ± SD	12.8 ± 4.9	12.7 ± 5.3	13.0 ± 4.6	

Continued

Baseline SBP (mmHg)				0.606
Mean ± SD	126.6 ± 11.1	125.7 ± 11.0	127.5 ± 11.2	
Baseline DBP (mmHg)				0.578
Mean ± SD	76.8 ± 12.0	77.7 ± 11.7	75.9 ± 12.4	
Baseline MBP (mmHg)				0.908
Mean ± SD	93.4 ± 9.9	93.7 ± 10.1	93.1 ± 9.7	
Baseline HR (beats/min)				0.033
Mean ± SD	79.3 ± 14.1	83.1 ± 15.7	75.5 ± 11.3	

Table 3. Spinal anesthesia procedural characteristics according to the intervention group.

Variables	Global N = 80 [1]	échoguidée N = 40[1]	Standard N = 40[1]	p-value[2]
Needle type				0.172
Cutting needle	63 (78.8%)	29 (72.5%)	34 (85.0%)	
Pencil-point needle	17 (21.3%)	11 (27.5%)	6 (15.0%)	
Needle gauge				0.241
G25	71 (88.8%)	37 (92.5%)	34 (85.0%)	
G24	3 (3.75%)	0 (0%)	3 (7.50%)	
G22	5 (6.25%)	2 (5.00%)	3 (7.50%)	
G27	1 (1.25%)	1 (2.50%)	0 (0%)	
Introducer				>0.999
Yes	14 (17.5%)	7 (17.5%)	7 (17.5%)	
No	66 (82.5%)	33 (82.5%)	33 (82.5%)	
Puncture site				0.263
L4 - L5	72 (90.0%)	38 (95.0%)	34 (85.0%)	
L3 - L4	8 (10.0%)	2 (5.00%)	6 (15.0%)	
Sensory block level				0.231
T6-below T10	56 (70.0%)	26 (65.0%)	30 (75.0%)	
T4-below T6	18 (22.5%)	12 (30.0%)	6 (15.0%)	
Above T10	6 (7.50%)	2 (5.00%)	4 (10.0%)	
Bromage score				>0.999
Bromage 3	77 (96.3%)	39 (97.5%)	38 (95.0%)	
Bromage 2	3 (3.75%)	1 (2.50%)	2 (5.00%)	

Table 4. Pre-induction inferior vena cava ultrasound characteristics - Ultrasound-guided group.

Variables	N = 40
Dmin IVC (cm)	
Mean ± SD	1.7 ± 0.4
Min – Max	0.6 - 2.4
Dmax IVC (cm)	
Mean ± SD	2.0 ± 0.3
Min – Max	1.0 - 2.7
IVC collapsibility index (%)	
Mean ± SD	15.3 ± 11.5
Min – Max	3.0 - 54.5
IVC variability index	
Mean ± SD	0.2 ± 0.2
Min – Max	0 - 0.8
IVC Dmax/collapsibility index	
Mean ± SD	0.2 ± 0.2
Min – Max	0 - 0.8

Table 5. Pre-induction ultrasound characteristics of the subclavian vein during deep breathing.

Variables	N = 40
Dmin SCV during deep breathing (cm)	
Mean ± SD	0.8 ± 0.2
Min – Max	0.2 - 1.5
Dmax **VSC deep breathing (cm)**	
Mean ± SD	1.1 ± 0.3
Min – Max	0.4 - 1.9
Collapsibility Index VSC Deep Breathing (%)	
Mean ± SD	25.0 ± 9.0
Min – Max	2.4 - 42.9
Index of Variability VSC Deep Breathing (%)	
Mean ± SD	0.3 ± 0.1
Min – Max	0 - 0.5

Table 6. Pre-induction ultrasound characteristics of the subclavian vein during quiet breathing.

Variables	N = 40
SCV Dmin during quiet breathing (cm)	
Mean ± SD	0.9 ± 0.3
Min – Max	0.3 - 1.7
SCV Dmax during quiet breathing (cm)	
Mean ± SD	1.0 ± 0.3
Min – Max	0.3 - 1.8
SCV collapsibility index during quiet breathing (%)	
Mean ± SD	9.7 ± 8.0
Min – Max	1.8 - 47.3
SCV variability index during quiet breathing (%)	
Mean ± SD	0.1 ± 0.1
Min – Max	0 - 0.6

Table 7. Intraoperative complications according to the intervention group.

Variables	Overall N = 80[1]	Ultrasound-guided N = 40 [1]	Standard N = 40[1]	p-value[2]
Occurrence of arterial hypotension				0.390
Yes	15 (18.8%)	9 (22.5%)	6 (15.0%)	
Nausea				>0.999
Yes	6 (7.50%)	3 (7.50%)	3 (7.50%)	
Bradycardia				0.359
Yes	5 (6.25%)	1 (2.50%)	4 (10.0%)	
Pruritus				0.359
Yes	5 (6.25%)	4 (10.0%)	1 (2.50%)	
Vomiting				>0.999
Yes	2 (2.50%)	1 (2.50%)	1 (2.50%)	
Shivering				>0.999
Yes	1 (1.25%)	1 (2.50%)	0 (0%)	

The most frequently encountered complications in both groups were arterial hypotension in 15 patients (18.8%), bradycardia in 5 patients (6.25%), and nausea in 6 patients (7.50%). The incidence of hypotension in the ultrasound-guided group was 9 cases (22.5%) compared with 6 cases (15.0%) in the standard group, with no statistically significant difference between the groups.

The mean dose of ephedrine was 9.0 ± 3.4 mg in both groups, 8.9 ± 3.3 mg in the ultrasound-guided group, and 9.2 ± 3.8 mg in the standard group. The median dose of atropine was similar in the standard group and the ultrasound-guided group, at 0.5 [0.5 - 0.6] mg.

Table 8. Total atropine and ephedrine doses.

Variables	Overall N = 80[1]	Ultrasound-guided N = 40[1]	Standard N = 40[1]	p-value[1]
Total atropine dose (mg)				>0.999
Median [Q1 - Q3]	0.5 [0.5 - 0.6]	0.5 [0.5 - 0.5]	0.5 [0.5 - 0.6]	
Min – Max	0 - 0.6	0 - 0.5	0 - 0.6	
Total ephedrine dose (mg)				0.948
Moyenne ± DS	9.0 ± 3.4	8.9 ± 3.3	9.2 ± 3.8	
Min – Max	0 - 15.0	0 - 15.0	0 - 15.0	

The distribution of fluids throughout the procedure is illustrated in Figure 2.

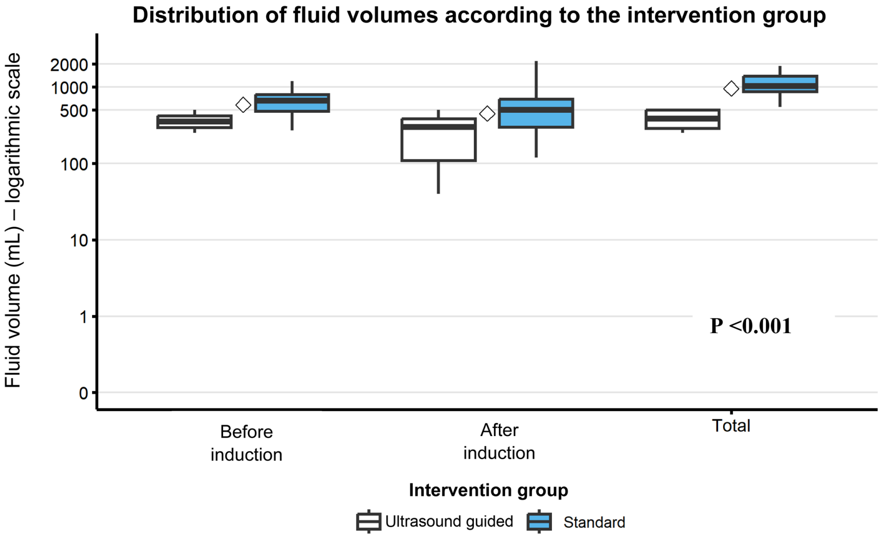

Figure 2. Distribution of fluid volume according to the intervention group and induction time (mL).

5. Discussion

The mean age was 35.51 ± 14.02 years, with extremes ranging from 19 to 80 years. The most represented age group was 39 - 59 years, with no significant association between the two groups. These findings are similar to those reported by Yang *et al.*, who reported a mean age of 36.36 ± 7.15 years [19]. In contrast, other studies reported a higher mean age, around 49 - 59 years [12] [13] [20], which may be explained by the inclusion of patients with cardiovascular comorbidities in those studies.

Regarding the type of surgery, orthopedic procedures were the most frequent (42.5%), a finding comparable to that of Roy *et al.*, who reported a rate of 39% [21]. In our study, this may be explained by the high prevalence of traumatic conditions in younger populations and by the fact that the study was conducted in a military hospital.

In our study, the mean IVC collapsibility index (IVC-CI) was 15.3 ± 11.5%. This value was similar to that reported by Sumit *et al.*, with a mean IVC-CI of 16.14 (9.79 - 23.18) [22]. In contrast, Ni *et al.* reported a mean IVC-CI of 40.7 ± 6.9%, and Eeshwar *et al.* reported a mean value of 33.64 ± 14.9% in ASA I and II patients[12] [20]. This discrepancy may be explained by the fact that, in our study as well as in that of Sumit *et al.*, patients with cardiovascular diseases were excluded, suggesting an influence of cardiovascular conditions—particularly hypertension—and their treatments on vascular morphology. Moreover, in spontaneously breathing patients, voluntary respiratory effort varies among individuals and affects the ability of respiratory variations in IVC diameter to predict fluid responsiveness. It has been shown that breathing patterns can influence IVC diameter and venous return.

The overall incidence of hypotension was 15 cases (18.8%). In the ultrasound-guided group, hypotension occurred in 9 patients (22.5%) compared with 6 patients (15.0%) in the standard group, with no statistically significant difference. These results differ from those reported in other studies, which showed higher incidences ranging from 23% to 45% [12] [20] [22]. This difference may be related to larger sample sizes in those studies and to the inclusion—except in the study by Sumit *et al.*—of hypertensive patients, who may be at higher risk of hypotension due to baroreceptor dysregulation.

The total volume of crystalloid administered throughout the procedure was 100 ± 99 mL (minimum 0, maximum 500 mL) in the ultrasound-guided group versus 1174.3 ± 565.7 mL (minimum 240, maximum 3000 mL) in the standard group, with a statistically significant difference between the two groups. In the study by Ni *et al.*, the mean total volume in the standard and ultrasound-guided groups was 345 (285 - 670) mL and 330 (0 - 560) mL, respectively. The mean post-induction volume in the ultrasound-guided group was 0 (0 - 0) mL versus 0 - 335 mL in the standard group, with a significant difference between groups [12]. The similarity of findings in the ultrasound-guided groups may be explained by ultrasound-guided fluid management; however, in our study, the fluid protocol in the standard group differed, as we applied the 4-2-1 rule and accounted for insensible losses.

The total ephedrine dose was 9.0 ± 3.4 mg in both groups, with mean doses of 8.9 ± 3.3 mg in the ultrasound-guided group and 9.2 ± 3.8 mg in the standard group, with no significant difference. In the study by Ni *et al.*, the frequency of vasoactive drug use was compared and was higher in the standard group (17 cases, 27%) than in the ultrasound-guided group (7 cases, 11.9%), with a significant difference between the two groups [12].

Study limitations

- Only patients classified as ASA physical status I - II, without comorbidities, were included in the study.
- The single-blind randomization design may constitute a potential source of bias.
- All measurements were performed by a single operator to improve measurement precision; however, the presence of intra-observer variability cannot be excluded.

6. Conclusion

In our study population, ultrasound-derived indices of the subclavian vein (SCV) and inferior vena cava (IVC) were lower than those reported in the literature. Although the incidence of hypotension was higher in the ultrasound-guided group, this difference was not statistically significant. In contrast, the volume of fluids administered and the dose of ephedrine used were higher in the standard group compared with the ultrasound-guided group.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Cabos, C. and Fuzier, R. (2020) Rachianesthésie: Où en sommes-nous en 2020? *Anesthésie & Réanimation*, **6**, 523-533. https://doi.org/10.1016/j.anrea.2020.09.003

[2] Carpenter, R.L., Caplan, R.A., Brown, D.L., Stephenson, C. and Wu, R. (1992) Incidence and Risk Factors for Side Effects of Spinal Anesthesia. *Anesthesiology*, **76**, 906-916. https://doi.org/10.1097/00000542-199206000-00006

[3] Hartmann, B., Junger, A., Klasen, J., Benson, M., Jost, A., Banzhaf, A., *et al.* (2002) The Incidence and Risk Factors for Hypotension after Spinal Anesthesia Induction: An Analysis with Automated Data Collection. *Anesthesia & Analgesia*, **94**, 1521-1529. https://doi.org/10.1213/00000539-200206000-00027

[4] Tarkkila, P. and Isola, J. (1992) A Regression Model for Identifying Patients at High Risk of Hypotension, Bradycardia and Nausea during Spinal Anesthesia. *Acta Anaesthesiologica Scandinavica*, **36**, 554-558. https://doi.org/10.1111/j.1399-6576.1992.tb03517.x

[5] Shitemaw, T., Jemal, B., Mamo, T. and Akalu, L. (2020) Incidence and Associated Factors for Hypotension after Spinal Anesthesia during Cesarean Section at Gandhi Memorial Hospital Addis Ababa, Ethiopia. *PLOS ONE*, **15**, e0236755. https://doi.org/10.1371/journal.pone.0236755

[6] Bijker, J.B. and Gelb, A.W. (2012) Review Article: The Role of Hypotension in Perioperative Stroke. *Canadian Journal of Anesthesia/Journal canadien d'anesthésie*, **60**, 159-167. https://doi.org/10.1007/s12630-012-9857-7

[7] Hofhuizen, C., Lemson, J., Snoeck, M. and Scheffer, G. (2019) Spinal Anesthesia-Induced Hypotension Is Caused by a Decrease in Stroke Volume in Elderly Patients.

Local and Regional Anesthesia, **12**, 19-26. https://doi.org/10.2147/lra.s193925

[8] Monk, T.G., Bronsert, M.R., Henderson, W.G., Mangione, M.P., Sum-Ping, S.T.J., Bentt, D.R., *et al.* (2015) Association between Intraoperative Hypotension and Hypertension and 30-Day Postoperative Mortality in Noncardiac Surgery. *Anesthesiology*, **123**, 307-319. https://doi.org/10.1097/aln.0000000000000756

[9] Marik, P.E., Cavallazzi, R., Vasu, T. and Hirani, A. (2009) Dynamic Changes in Arterial Waveform Derived Variables and Fluid Responsiveness in Mechanically Ventilated Patients: A Systematic Review of the Literature. *Critical Care Medicine*, **37**, 2642-2647. https://doi.org/10.1097/ccm.0b013e3181a590da

[10] Boyd, J.H., Forbes, J., Nakada, T., Walley, K.R. and Russell, J.A. (2011) Fluid Resuscitation in Septic Shock: A Positive Fluid Balance and Elevated Central Venous Pressure Are Associated with Increased Mortality. *Critical Care Medicine*, **39**, 259-265. https://doi.org/10.1097/ccm.0b013e3181feeb15

[11] Minto, G., Scott, M.J. and Miller, T.E. (2015) Monitoring Needs and Goal-Directed Fluid Therapy within an Enhanced Recovery Program. *Anesthesiology Clinics*, **33**, 35-49. https://doi.org/10.1016/j.anclin.2014.11.003

[12] Ni, T., Zhou, Z., He, B. and Zhou, Q. (2022) Inferior Vena Cava Collapsibility Index Can Predict Hypotension and Guide Fluid Management after Spinal Anesthesia. *Frontiers in Surgery*, **9**, Article 831539. https://doi.org/10.3389/fsurg.2022.831539

[13] Ceruti, S., Anselmi, L., Minotti, B., Franceschini, D., Aguirre, J., Borgeat, A., *et al.* (2018) Prevention of Arterial Hypotension after Spinal Anaesthesia Using Vena Cava Ultrasound to Guide Fluid Management. *British Journal of Anaesthesia*, **120**, 101-108. https://doi.org/10.1016/j.bja.2017.08.001

[14] Liu, Y., Han, Z., Wang, J., Wang, Q. and Qie, X. (2024) Inferior Vena Cava Collapsibility Index for Predicting Hypotension after Spinal Anesthesia in Patients Undergoing Total Knee Arthroplasty. *Die Anaesthesiologie*, **73**, 735-742. https://doi.org/10.1007/s00101-024-01468-4

[15] Carpentier, J.P., Banos, J.P., Brau, R., Malgras, G., Boye, P., Dubicq, J., *et al.* (2001) Pratique et complications de la rachianesthésie en milieu tropical africain. *Annales Françaises d'Anesthésie et de Réanimation*, **20**, 16-22. https://doi.org/10.1016/s0750-7658(00)00329-4

[16] Binam, F., Lemardeley, P., Blatt, A. and Arvis, T. (1999) Pratiques anesthésiques à Yaoundé (Cameroun). *Annales Françaises d'Anesthésie et de Réanimation*, **18**, 647-656. https://doi.org/10.1016/s0750-7658(99)80152-x

[17] Bartha, E., Arfwedson, C., Imnell, A., Fernlund, M.E., Andersson, L.E. and Kalman, S. (2013) Randomized Controlled Trial of Goal-Directed Haemodynamic Treatment in Patients with Proximal Femoral Fracture. *British Journal of Anaesthesia*, **110**, 545-553. https://doi.org/10.1093/bja/aes468

[18] Wallace, D.J., Allison, M. and Stone, M.B. (2010) Inferior Vena Cava Percentage Collapse during Respiration Is Affected by the Sampling Location: An Ultrasound Study in Healthy Volunteers. *Academic Emergency Medicine*, **17**, 96-99. https://doi.org/10.1111/j.1553-2712.2009.00627.x

[19] Wang, B., Hui, K., Xiong, J., Yang, C., Cao, X., Zhu, G., *et al.* (2024) Effect of Subclavian Vein Diameter Combined with Perioperative Fluid Therapy on Preventing Post-Induction Hypotension in Patients with ASA Status I or II. *BMC Anesthesiology*, **24**, Article No. 138. https://doi.org/10.1186/s12871-024-02514-9

[20] Eeshwar, M., Chari, A., Gaude, Y.K. and Kordcal, A.R. (2024) Estimating the Usefulness of Inferior Vena Cava Collapsibility Index and Caval Aorta Index to Predict Hypotension after Spinal Anaesthesia in Adult Patients Undergoing Elective Surgery in

a Tertiary Care Hospital. *Journal of Anaesthesiology Clinical Pharmacology*, **41**, 140-144. https://doi.org/10.4103/joacp.joacp_338_23

[21] Roy, S., Kothari, N., Goyal, S., Sharma, A., Kumar, R., Kaloria, N., *et al.* (2023) Preoperative Assessment of Inferior Vena Cava Collapsibility Index by Ultrasound Is Not a Reliable Predictor of Post-Spinal Anesthesia Hypotension. *Brazilian Journal of Anesthesiology* (*English Edition*), **73**, 385-392. https://doi.org/10.1016/j.bjane.2022.04.001

[22] Chowdhury, S.R., Baidya, D.K., Maitra, S., Singh, A.K., Rewari, V. and Anand, R.K. (2022) Assessment of Role of Inferior Vena Cava Collapsibility Index and Variations in Carotid Artery Peak Systolic Velocity in Prediction of Post-Spinal Anaesthesia Hypotension in Spontaneously Breathing Patients: An Observational Study. *Indian Journal of Anaesthesia*, **66**, 100-106. https://doi.org/10.4103/ija.ija_828_21