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Research Article

The Effect of Anesthesia Method on Hemodynamics during Abdominal Hysterectomy: A Comparative Analysis

Polishchuk Liudmyla* and Tkachenko Ruslan

Department of Obstetric, Gynecology and Reproductology, Shupyk National Healthcare University of Ukraine, Ukraine

***Corresponding Author:** Polishchuk Liudmyla, Department of Obstetric, Gynecology and Reproductology Shupyk National Healthcare, University of Ukraine, Ukraine.

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Abstract

Background: Hemodynamic stability during surgery is critical for preventing perioperative complications. The choice of anesthesia (general vs. spinal) significantly impacts hemodynamic parameters due to differences in physiological mechanisms, including the effects of anesthetics, analgesics, or sympathetic nervous system blockade. However, the influence of various anesthesia techniques, including low-opioid general anesthesia, on hemodynamics during abdominal hysterectomy remains insufficiently studied.

Methodology: This study analyzed data from 118 women (aged 35-65 years) divided into three groups: multimodal low-opioid general anesthesia (MMA, n = 47), spinal anesthesia with hyperbaric bupivacaine (SA, n = 33), and adjuvant spinal anesthesia (ASA, n = 38). Hemodynamic parameters (blood pressure, heart rate, stroke volume, systemic vascular resistance) were evaluated at seven stages: preoperatively, pre-induction, post-induction, during the traumatic phase of surgery, and 1, 3, and 6 hours postoperatively.

Results: The SA and ASA groups demonstrated a 23-28% reduction in systolic and diastolic blood pressure compared to MMA ($p < 0.001$), with a 33-fold lower risk of hypertension (OR = 33.0). However, the ASA group exhibited significant bradycardia (heart rate decreased by 27-32%), requiring atropine correction in 23.6% of cases. Central hemodynamic analysis revealed lower stroke volume (SV) and systemic vascular resistance (SVR) in the SA and ASA groups due to sympathetic blockade. Partial recovery of SV (+9.38%) and SVR (+28.02%) in ASA was attributed to dexmedetomidine's alpha-adrenergic effects. Hemodynamic parameters normalized in all groups 6 hours postoperatively.

Conclusion: Spinal anesthesia, particularly with adjuvants, ensures more stable hemodynamics compared to MMA, reducing intra-operative complications (e.g., myocardial ischemia) and enhancing patient safety, especially in high-risk cardiovascular patients.

Keywords: Abdominal Hysterectomy; Spinal Anesthesia; Multimodal Anesthesia; Hemodynamics; Dexmedetomidine, Opioids; Eras Protocol

Introduction

Abdominal hysterectomy is one of the most common gynecological operations, and ranks second in frequency of performance after cesarean section. According to Harvey SV et al. annually in the USA alone, about 600 thousand hysterectomies are performed [1]. Despite the achievements of modern medicine and pharmacology, the problem of antinociceptive protection of patients from acute surgical pain remains unresolved in anesthesiology and surgery [2]. Inadequate nociceptive protection can change the endocrine response of the patient by increasing the level of catecholamines and cortisol and can enhance autonomic reflexes, causing hypertensive crisis or vagal syndrome, which can lead to serious complications during and after surgery [3].

Adequate analgesia is one of the main components of anesthetic care for patients. It is well known that high-quality analgesia in the perioperative period improves the psychological and physiological status of the patient, provides earlier activation and helps reduce the frequency of postoperative complications (cardiovascular, thromboembolic, infectious, etc.). Since excessive dependence on opioids for intra- and postoperative pain control is associated with opioid dependence and hyperalgesia, multimodal analgesia is central [4]. Multimodal analgesia within the framework of the Enhanced Recovery After Surgery (ERAS) program for gynecological surgery has demonstrated a decrease in opioid consumption [5], a decrease in the frequency of postoperative nausea and vomiting, as well as a reduction in the length of hospital stay, which reduces economic costs [6]. Therefore, today the search for effective strategies to reduce perioperative opioid use and reduce opioid-related harm continues, which include multimodal analgesia and the implementation of the ERAS protocol.

Hemodynamic stability during surgery is critical to prevent complications such as hypotension, tachycardia, myocardial or renal ischemia, which can impair short- and long-term outcomes [7]. Tracheal intubation during general anesthesia can cause hemodynamic changes that can be life-threatening, especially in elderly patients with cardiac disease [8]. During intubation, epipharyngeal and parapharyngeal areas are stimulated, leading to sympathoadrenal stimulation and, consequently, to significant increases in serum catecholamine levels, blood pressure (BP), and heart rate (HR). These increases can lead to myocardial infarction and arrhythmias in patients [9]. Therefore, hemodynamic stabilization in the perioperative period is a key aspect of patient safety, especially in the presence of cardiovascular pathologies or endocrine pathology [10].

Depending on the patient's condition, general or spinal anesthesia (GA or SA) may be chosen for abdominal hysterectomy [11]. The advantages of general anesthesia for this procedure include patient satisfaction and surgeon comfort, as the operation can last a long time, while the advantages of SA include reduced bleeding and faster postoperative recovery [12,13].

The choice of anesthesia (general or spinal) significantly affects hemodynamic parameters through various physiological mechanisms due to the action of anesthetics, analgesics, or the development of sympathetic nervous system blockade. To ensure prolonged duration of sensory block, reduce intrathecal dose of local anesthetic, prolong analgesia, and reduce its side effects, the combination of bupivacaine with adjuvants has been proposed. Various drugs are used as adjuvants, such as fentanyl, sufentanil, morphine, clonidine, and dexmedetomidine [14]. However, the effect of different anesthesia options, including low-opioid general anesthesia, on the hemodynamics of the patient during abdominal hysterectomy is still poorly understood. Therefore, the purpose of this study was to compare methods of multimodal low-opioid anesthesia and spinal anesthesia options, including those with the addition of adjuvants, regarding the impact on hemodynamic parameters in patients with abdominal hysterectomy.

Materials and Methods

The studies presented in the work were carried out at the Kyiv City Center for Reproductive and Perinatal Medicine, which is a branch of the National University of Healthcare of Ukraine during 2023-2024. in compliance with the basic biotic provisions of the Council of Europe Convention on Human Rights and Biomedicine.

Inclusion criteria for the study

- Age from 35 to 65 years ;
- performing a planned abdominal hysterectomy;
- Pfannenstiel incision;
- The physical condition of the patients corresponded to ASA class I - II;
- Informed consent of the patient to participate in the study.

Exclusion criteria from the study

- Age up to 35 years and after 65 years;
- ASA > 3;
- Diabetes mellitus;
- Hyperthyroidism;
- Upper midline or lower midline laparotomy;
- The patient's refusal to participate in the study at any stage.

The study sample consisted of 118 patients who were randomly divided into 3 groups depending on the type of anesthesia used.

Group 1 (n = 47) - surgery was performed under multimodal low-opioid general inhalation anesthesia (MMA) with sevoflurane with fentanyl against the background of total myoplegia with mechanical ventilation. Group 2 (n = 33) - abdominal hysterectomy (AH) was performed under spinal anesthesia with hyperbaric bupivacaine (SA), and patients in group 3 (n = 38) had surgery under spinal anesthesia with intrathecal administration of adjuvants - adjuvant spinal anesthesia (ASA).

Systemic and central hemodynamic parameters were assessed at 7 stages : preoperatively, before induction, after induction, during the traumatic phase of surgery, and 1, 3, and 6 hours after surgery. Student's t- test and Fisher's exact test were used for statistical analysis ($p < 0.05$ was considered significant).

Demographic data (age , BMI, height) and physical condition of patients according to ASA did not reveal significant differences, which allowed us to consider groups with different methods of analgesia as statistically homogeneous.

AH in patients of group 1 was performed under multimodal low-opioid general anesthesia (M MA) with artificial lung ventilation (MVL) and sevoflurane inhalation. 15 min before the operation, the patients were administered i.v. paracetamol 1000 mg, and 5 min before the operation, dexketoprofen 50 mg and dexamethasone 4 mg i.v. For induction of anesthesia, propofol was used - 1.5-2.0 mg/kg + ketamine - 12.5 mg and fentanyl at a dose of 2.0-2.5 mg/kg. Tracheal intubation was performed after the administration of atracurium besylate - 0.3 mg/kg. MVL was performed in the volume-controlled oxygen - air mixture with a tidal volume of 6-8 ml/kg in the normoventilation mode. Maintenance of anesthesia was provided by inhalation of sevoflurane 2.0-2.5 vol % until a minimum alveolar concentration of 0.9 ± 0.1 vol %. Intravenous infusion of fentanyl at a rate of 1.5-2 mg/kg/h and ketamine at a rate of 0.45-0.5 mg/kg/h was used to maintain intraoperative analgesia.

Spinal anesthesia with bupivacaine (SA) (group 2) was used in 33 patients. Puncture of the subdural space was performed under aseptic conditions through a median approach at the level of L3 - L4 in the sitting position. After identification of the subdural space, a solution of 0.5 % hyperbaric bupivacaine at a dose of 16 mg. For additional sedation, propofol was administered at a rate of 3.0-4.0 mg/kg/h i.v. In women of group 3, adjuvant spinal anesthesia (ASA) was administered in addition to the 0.5% solution. % hyperbaric bupivacaine - 16 mg, adjuvants - morphine hydrochloride - 100 mg and fentanyl - 20 mg in combination with dexamethasone 4 mg were injected into the subarachnoid space. All patients in this group received additional sedation with dexmedetomidine : an initial bolus at a dose of 1.0 mg/kg over 10 min , followed by maintenance of the sedation level by continuous infusion at a rate of 0.5-0.7 mg/kg/h.

Registration of central and systemic hemodynamic parameters was carried out using non-invasive esCCO (Estimated Continuous Cardiac Output) technology, which is implemented in the Vismo PVM-2701 monitor (Nihon Kohden, Japan).

Results

The comparative analysis of the differences in the indicators of central and systemic hemodynamics showed that after the induction and development of anesthesia, statistically significant differences were observed between the groups, which indicated the existing influence of the applied anesthesia options. Thus, during SAB and ASA , in contrast to MMZA, a significant decrease in blood pressure was observed, mainly due to ABP, which decreased by 23.28% ($t = 7.89$; $p < 0.001$) and 28.41% ($t = 7.42$; $p < 0.001$), respectively, which naturally reflected in the decrease in SBP in these groups by 23.86% ($t = 7.12$; $p < 0.001$) and 23.16% ($t = 6.78$; $p < 0.001$). It should be noted that these changes in blood pressure indicators indicate, first of all, the normalization of hemodynamics at the 3rd stage, during CA, because these indicators approached the preoperative state (Figure 1).

Analysis of the presence of significant differences between groups using Fisher's exact test showed that in the groups where SAB and ASA were performed there were significantly more patients with normal blood pressure (Table 1) in contrast to patients who underwent MMSA. The risk of developing hypertension in the MMSA group was 33 times higher than in SAB ($p < 0.001$). This indicates certain advantages of both ASA and SAB in terms of their effect on hemodynamics and its more stable indicators when using spinal anesthesia in general.

Also, significant differences between the groups were recorded when analyzing the dynamics of heart rate in different groups (Fig. 2), which was manifested by a significant decrease in heart rate in the ASA group compared to groups 1 and 2 immediately after the development of anesthesia (stage 3). Thus, the heart rate in this group at this stage was significantly lower by 32.77% compared to group 1 and by 27.9% compared to the SAB group. It should be noted that 9 patients (23.6%) of this group had significant bradycardia less than 55 beats/min, and in 3 (7.8%) of them, even below 45 beats/min, which required correction with atropine sulfate.

In our opinion, a sufficiently significant decrease in heart rate is primarily associated with the negative chronotropic effect of dexmedetomidine, the infusion of which at this stage was carried out at a rate of 10 mg /kg (Figure 1, Table 1, Figure 2, Table 2).

Analyzing the changes in UOS in different groups, we found that, unlike the patients in the SAB group, in groups 1 and 3, there were no significant changes in stage 3 compared to stages 1 and 2 of the study, while in group 2, a lower UOS was observed by 16.78% ($t = 7.12$; $p < 0.001$) compared to group 1 and by 22.47% ($t = -2.56$; $p < 0.05$) compared to group 3. The lack of significant dynamics of UOS in patients in the ASA group can be explained by an increase in diastolic duration and a larger end-diastolic volume due to

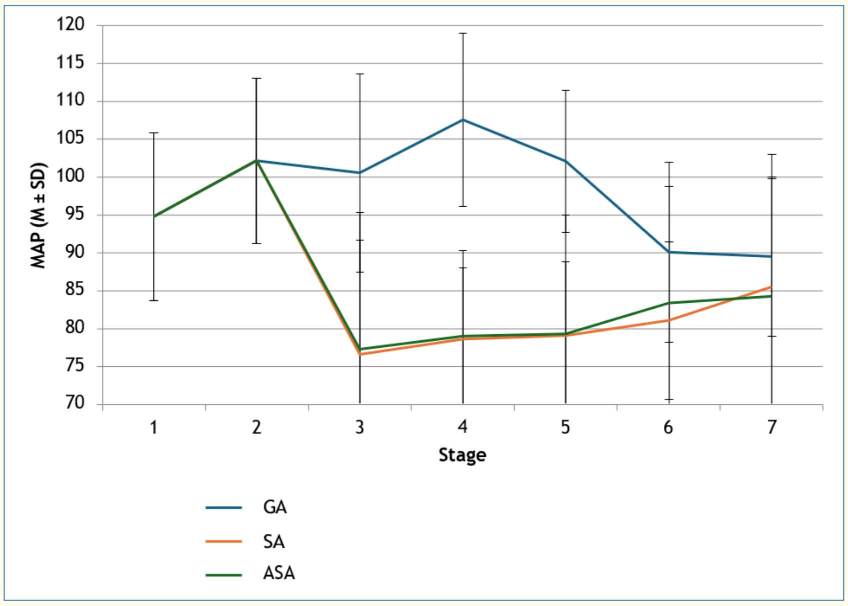

Figure 1: Dynamics of MAP in the study groups.

Group	SBP < 100 mmHg	Normal BP	SBP >150 mmHg	Total
1 (MMA)	13 (27.6%)	19 (40.5%)	15 (31.9%)	47 (100%)
2 (SA B)	7 (21.2%)	26 (78.8%)	0	33 (100%)
3 (A S A)	5 (13.1%)	31 (81.7%)	2 (5.2%)	38 (100%)
p	$P_{1-2} = 0.47$ $P_{1-3} = 0.2$ $P_{2-3} = 0.56$	$P_{1-2} = 0.001$ $P_{1-3} = 0.001$ $P_{2-3} = 0.78$	$P_{1-2} = 0.001$ $P_{1-3} = 0.03$ $P_{2-3} = 0.49$	
OR	$OR_{1-2} = 1.43$ $OR_{1-3} = 1.93$ $OR_{2-3} = 1.35$	$OR_{1-2} = 0.18$ $OR_{1-3} = 0.15$ $OR_{2-3} = 0.83$	$OR_{1-2} = 33 , 0$ $OR_{1-3} = 8.44$ $OR_{2-3} = 0.0$	

Table 1*:* Frequency of arterial hypo- and hypertension in different groups , (n /%).

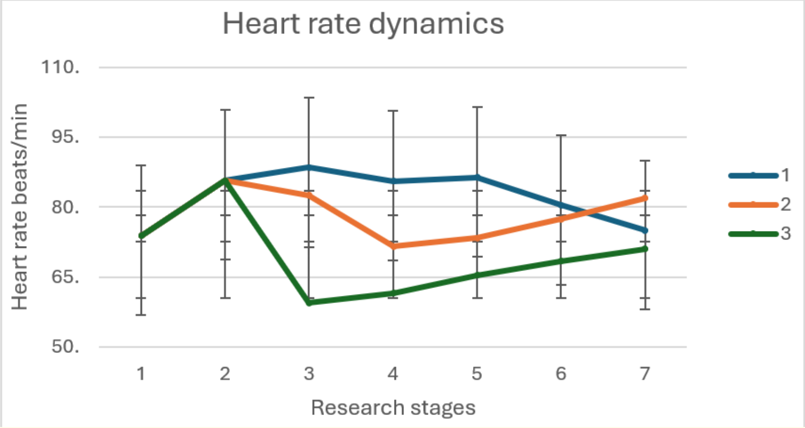

Figure 2: Heart rate dynamics in different groups.

Note: OR - Odds ratio.

Research stage	Group	UOS , ml	HOS , l/min	SI , $l/min/m^2$	ZPOS , $dyn×s×cm^{-5}$
1 (n = 81)	1 - 3	74.9 (6.7)	5.7 (0.9)	3.2 (0.4)	1358.5 (159.2)
2 (n = 118)	1 - 3	75.9 (6.9)	6.3 (0.7)	3.6 (0.6)	1344.4 (186.1)
3 (n = 47)	1	71.5 (5.9)	6.3 (0.9)	3.4 (0.4)	1291.2 (216.3)
(n = 33)	2	59.5 (8.9)*	4.9 (1.1)*	2.6 (0.8)*	891.2 (376.1)*
(n = 38)	3	73.0 (7.6)#	4.8 (1.1) †	3.0 (0.8) † #	1091.4 (406.6) † #
4 (n = 47)	1	69.5 (4.1)	5.3 (0.7)	2.9 (0.6)	1770.1 (190.0)
(n = 33)	2	60.8 (9.1)*	4.3 (1.7)*	2.5 (0.9)*	970.0 (290.8)*
(n = 38)	3	66.5 (7.1) † #	4.6 (1.5) †	3.1 (1.0)#	1191.0 (302.7) † #
5 (n = 47)	1	70.3 (3.7)	5.7 (0.9)	3.4 (0.6)	1401.6 (270.9)
(n = 33)	2	62.6 (10.7)*	4.7 (1.9)*	2.7 (1.0)*	1001.2 (372.9)*
(n = 38)	3	67.6 (8.7)#	4.7 (1.4) †	3.1 (1.0)	1281.9 (298.5)#
6 (n = 45)	1	72.3 (6.4)	5.8 (0.9)	3.2 (0.4)	1357.5 (290.1)
(n = 33)	2	69.3 (8.4)	5.4 (0.9)	2.9 (0.9)	1257.5 (271.1)
(n = 38)	3	65.3 (8.8) † #	4.5 (0.9) † #	3.0 (0.7)	1314.5 (171.9)
7 (n = 45)	1	73.6 (5.5)	5.7 (0.7)	3.1 (0.5)	1300.2 (277.1)
(n = 33)	2	70.7 (11.5)	5.8 (1.0)	3.0 (0.7)	1323.4 (297.1)
(n = 38)	3	72.3 (7.5)	5.2 (0.9) † #	3.0 (0.7)	1283.4 (288.4)

Table 2: Changes in central hemodynamic parameters at the stages of the study in patients of different groups, M (SD).
Notes: * - $p < 0.05$ between groups 1 and 2 ; † - $p < 0.05$ between groups 1 and 3 ; # - $p < 0.05$ between groups 2 and 3.

bradycardia against the background of bolus administration of dexmedetomidine compared to patients in group 2.

During the traumatic stage of the study (stage 4) and 1 hour after the operation (stage 5), we did not observe any significant dynamics in terms of systemic hemodynamics indicators compared to the previous stage, which also indicated the stability of hemodynamics against the background of various anesthesia options. Thus, at stage 4, compared to group 1, the SAB group maintained significantly lower ABP (by 32.57%) and SBP (by 26.95%), and in patients of group 3 by 34.75% and 26.58%, respectively, while no statistically significant differences in these indicators were observed between groups 2 and 3.

A more significant intergroup difference at stage 4 was observed among the indicators of central hemodynamics. Thus, significantly lower indicators of UOS , HOS and ZPOS remained in the SAB and ASA groups compared to group 1, however, it was noteworthy that ASA, unlike SAB, was accompanied by significantly higher indicators of UOS, SI and ZPOS, which to some extent also indicated the absence of significant gemodynamic fluctuations in patients of group 3, unlike SAB. Thus, the UOS was 9.38% higher than in group 2 ($t = -3.12$; $p < 0.01$), and the SI and ZPOS were 24.0% ($t = -3.45$; $p < 0.001$) and 22.78% ($t = -3.78$; $p < 0.001$), respectively (Table 2).

1 hour after the completion of the operation, the above-mentioned trends persisted. Thus, in patients of group 2, compared with the MMZA group, significantly lower central hemodynamic indicators were maintained, and the most significant difference between these groups was in the indicators of ZPOS by 28.56% ($t = 5.89$; $p < 0.001$) and SI by 20.59% ($t = 3.78$; $p < 0.01$). It should be noted that at this stage, a significantly significant difference between groups 1 and 3 among the indicators of central hemodynamics was observed only in the side of the HOS, which was significantly lower by 17.54% ($t = 3.45$; $p < 0.001$). The described phenomena are explained by the residual blockade of the SNS , which was observed in groups 2 and 3.

Comparative analysis of differences in central hemodynamic parameters between the SAB and ASA groups showed that at this stage there was a significantly higher UOS by 7.99% ($t = -2.34$; $p < 0.05$) and ZPOS by 28.02% ($t = -3.78$; $p < 0.001$), which was most likely due to the alpha - adrenergic effect of dexmedetomidine infusion.

3 hours after surgery, the most pronounced changes in systemic hemodynamic parameters were observed between groups 1 and 3, especially BP and HR, which were lower by 12.12% ($t = 3.12$; $p < 0.01$) and 14.93% ($t = 3.01$; $p < 0.01$).

We did not find any significant difference in these indicators between groups 1 and 2 and 2 and 3, except for heart rate, which at this stage was significantly lower by 14.93% ($t = 3.45$; $p < 0.001$) than in group 1 and by 11.63% ($t = 3.45$; $p < 0.001$) compared to the SAB group, which may indirectly indicate greater effectiveness of analgesia, but confirmation of this hypothesis should be provided by a comparative analysis of the course of the postoperative period.

Analyzing the differences between the indicators of central hemodynamics, we observed the absence of statistically significant differences at this stage in patients of groups 1 and 2. As for patients who underwent ASA, 3 hours after the operation they maintained significantly lower indicators of UOS and HOS compared to groups 1 and 2 (Table 2).

6 hours after surgery (stage 7 of the study), we did not find any significant differences between all comparison groups , indicating the restoration of hemodynamic parameters to baseline values in all groups.

Discussion

The results of the study demonstrate significant differences in hemodynamic parameters depending on the chosen method of anesthesia during abdominal hysterectomy. The groups with spinal anesthesia (SAH and ASA) showed more stable blood pressure (BP) compared to the group with multimodal low-opioid general anesthesia (MMGA). This is consistent with the literature, where spinal anesthesia is associated with a lower risk of hypertensive reactions due to blockade of the sympathetic nervous system [11]. The decrease in systolic and diastolic BP in the SAH and ASA groups by 23-28 % confirms the effectiveness of this method in minimizing the body's stress response, which is especially important for patients with cardiovascular pathologies.

An important aspect is the significant bradycardia observed in the ASA group, where the heart rate was reduced by 27-32 % compared with the other groups. This effect is probably related to the use of dexmedetomidine, which has a pronounced chronotropic effect [15,16]. Although bradycardia required correction with atropine in some patients, the inclusion of dexmedetomidine in the ASA protocol may be justified to achieve deep analgesia and reduce opioid doses in the postoperative period.

Central hemodynamic analysis revealed that the spinal anesthesia group had lower stroke volume (SV) and systemic peripheral vascular resistance (SPR) compared with the MMSA group. This may be due to sympathetic blockade, which reduces peripheral vascular resistance and cardiac workload [17]. However, in the ASA group, there was a partial recovery of SVR and SPR, which is likely due to the alpha - adrenergic stimulatory effect of dexmedetomidine, which compensated for the effects of spinal anesthesia.

The hemodynamic stability in the SAB and ASA groups suggests their benefits for patients at increased risk of cardiovascular complications. Reducing BP and heart rate fluctuations may reduce the likelihood of intraoperative myocardial or renal ischemia, which is supported by other studies [18,19]. In addition, the use of adjuvants in spinal anesthesia (ASA) allows for prolonged analgesia and a reduced dose of local anesthetics, which reduces the risk of toxic effects.

Conclusion

Modern anesthetic management for abdominal hysterectomy should focus on methods that minimize the stress response. Spinal anesthesia, especially with the use of adjuvants, provides more stable hemodynamic parameters compared to multimodal low-opioid general anesthesia (MMGA), which reduces the risk of intraoperative complications (myocardial ischemia, renal) and maintains patient safety, especially within the ERAS protocol. The introduction of such approaches into clinical practice may improve the safety and effectiveness of treatment , in particular in patients with concomitant cardiac pathologies.

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Conflict of Interests

Authors declare that they have no conflict of interests.

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