Effect of head of bed elevation on intra-abdominal pressure measurement among mechanically ventilated critically ill patients

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Abstract:

Background: *Intra-abdominal pressure (IAP) measurement is used to detect intra-abdominal hypertension (IAH), which may predispose patients to certain physiological derangements of the splanchnic circulation. The patient does not need to be in the supine position for continuous measurement of IAP. Hence, this study evaluated the impact of differing head of bed elevations (HOB) on bladder pressure when used as a surrogate IAP measurement in severely intubated patients.* ***Aim of the study:*** *The aim of the study was to determine the effect of head of bed elevation on intra-abdominal pressure measurement among mechanically ventilated patients.* ***Materials and Method: Research design:*** *the design of this study was a quasi-experimental.* ***Setting:*** *this study was conducted at the general ICU of Damanhur Medical Institute.* ***Subjects:*** *A convenience sample of 60 mechanically ventilated patients was involved.* ***Tool:*** *this study used an assessment tool which consists of four parts; part I: it was used to identify characteristics and clinical data of patients. Part II: this part was used to identify ventilator data. Part III: it was used to identify vital signs which include pulse, temperature systolic, diastolic and mean blood pressure. Part IV: this part was used to identify IAP measurements.* ***Methods:*** *Body mass index (BMI), vital signs, ventilator parameters and Intra- abdominal pressure (IAP) were assessed at different head of bed elevation angles; supine, 15°, 30°and 45°.* ***Results:*** *IAP was found to be increased significantly with increases in HOB angle. Moreover, it was increased significantly, specifically at 45°. Age and BMI positively correlated with IAP with significant differences.* ***Conclusion:*** *There was no difference in the measurement values of IAP: supine position, HOB elevation 15° and 30°. There was a difference in the measurement at 45° position.*

Key words: Head of bed elevation, intra-abdominal pressure measurement, mechanically ventilated patients.

Introduction:

Measuring hemodynamic parameters is considered the most crucial duty of nurses who work in intensive care units (Urden et al., 2021). The significance of intra-abdominal pressure (IAP) as a physiologic variable in critically ill patients is recognized more and more. Regarding this, intra-abdominal pressure is one of those elements that might affect other measurements and ignoring it could result in inaccuracies in the calculation and recording of unrealistic hemodynamic values (Xu et al., 2021).

The steady-state pressure within the abdominal cavity that results from the compromise of the viscera and abdominal wall is known as intra-abdominal pressure. Additionally, IAP fluctuates in response to the respiratory cycle and abdominal wall resistance (Chien et al., 2021).

Adults have usual intra-abdominal pressure (IAP) levels up to 5 mmHg. However, in patients with disorders without pathophysiological importance, such as obesity, IAP levels may range from 10 to 15 mmHg, whereas critically ill patients are expected to have IAP values between 5 and 7 mmHg. (Luckianow et al., 2012).

Intra-abdominal pressure (IAP) measurement is used to detect intra-abdominal hypertension (IAH), which may predispose patients to certain physiological derangements of the splanchnic circulation, as well as the cardiovascular, respiratory, and renal systems; such derangements are referred to as the abdominal compartment syndrome (ACS) (Lee 2012).

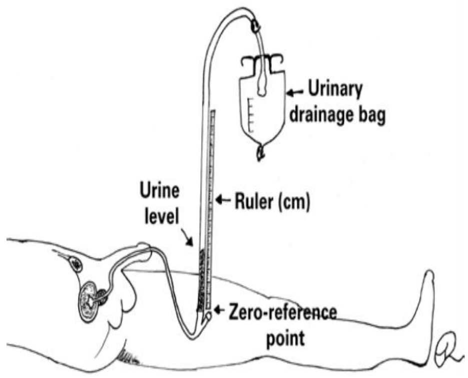
The term intra-abdominal hypertension (IAH) refers to an increase in IAP above 12 mmHg. Intra- abdominal pressure values up to 5 mmHg are considered physiological for adults, but in patients suffering from illnesses values of 5-7 mmHg are critically expected for sick patients (Chien et al. 2021 and Annika et al. 2019).

Persistent IAP 20 mmHg and above may gradually cause intra-compartment syndrome and related organ dysfunction or failure (Kirkpatrick et al., 2013 and Inneke et al., 2020). Patients with abdominal lesions or illnesses that exacerbate the patient's overall condition have shown a link between organ malfunction and elevated IAP. Incidence of complications caused by abdominal pressure fluctuations in critically ill patients with acute abdomen is high and needs to be increased IAP measurement request (Lee 2012 and Wise et al., 2017).

There are different methods for measuring IAP (e.g., intra-vesical, intra-gastric, intra-rectal); while each method has advantages, each is also prone to error due to inherent characteristics. Intermittent IAP measurement with indwelling bladder catheters (Figure 1) is a simple measurement method commonly used in clinical practice. Furthermore, placing a Foley catheter in the bladder has long been the gold standard for determining IAP (Milanesi and Aquino, 2016).

Recently, continuous IAP monitoring techniques have been recommended in intensive care units. This technique uses a connected three-way catheter to send continuous IAP records to a bedside monitor. This reduces maintenance work and enables continuous display. Despite these advantages, practical use is limited due to the need to return the patient to the supine position for standardized measurements (Bodnar 2018).

The patient does not need to be in the supine position for continuous measurement of IAP, but it is advisable to interpret IAP. However, supine position in patients in the intensive care unit is a significant risk factor for ventilator related pneumonia. (Christopher et al.2016).



(Figure I): Intra-abdominal pressure measurement using indwelling bladder catheter
(Milanesi and Aquino, 2016).

Keeping the patient in a stilt bed position is an integral part of the "ventilator bundle" of many institutions to prevent ventilator-related pneumonia (Klompas et al., 2016). There is evidence in the literature that body position affects IAP measurement, but it is not clear the degree to which commonly used head of bed (HOB) elevations affect IAP measurements.

The possible solution to this dilemma could be determined as a correction value that would allow the interpretation to elevate head of bed IAP values. So, this study evaluated the impact of differing HOB elevations on bladder pressure when used as a surrogate IAP measurement in intubated patients.

Aim of the Study

The aim of the study is to determine the effect of head of bed elevation on intra-abdominal pressure measurement among mechanically ventilated patients

The Study question:

The study question was; what is the effect of head of bed elevation on intra-abdominal pressure?

Materials and Method

Materials

Research design

This study is a quasi-experimental, quantitative, and used uncontrolled pretest-posttest designs. Data are collected before and after repositioning of studied patient in pretest-posttest study designs, and the changes can be quantified by calculating the change in the group.

Setting:

This study was conducted at the general ICU of Damanhur Medical Institute which has 15 beds.

Subjects:

A convenience sample of 60 mechanically ventilated patients was taken using incidental sampling technique. Subjects in this study were involved according the following inclusion criteria, age > 18 years old, mechanically ventilated patient and having indwelling urine catheter in place. They were excluded according to the following exclusion criteria, unable to change position, neurogenic bladder, bladder rupture, hematuria, heart failure and pulmonary edema, pregnancy, morbid obesity and acute abdominal patients.

Tool:

This study used assessment sheet developed by the researcher which consists of four parts:

Part I: This part was used to identify characteristics and clinical data of patients including; age, sex, medical diagnosis, past medical history, date of intensive care unit (ICU) admission and date of starting mechanical ventilation.

Part II: This part was used to identify ventilator parameters which include; tidal volume (Vt), respiratory rate (RR), Positive inspiratory pressure (PIP) and dynamic lung compliance. In addition peripheral oxygen saturation (SPO_2) was evaluated.

Part III: This part was used to identify vital signs which include; temperature (Temp), heart rate (HR), systolic (SBP), diastolic (DBP) and mean arterial pressure (MAP).
MAP = (SBP + 2DBP)/3

Part IV: This part was used to identify IAP measurement, abdominal perfusion pressure (APP) and filtration gradient (FG). APP was calculated according to the consensus formula: APP= MAP– IAP. FG was calculated according to the consensus formula: FG=MAP– 2×IAP.

Methods:

- An official letter from faculty of nursing, Damanhour University was sent to the hospital authorities in Damanhour Medical Institute and approval to conduct this study was obtained after providing explanation of the aim of the study.
- The tool of the present study was developed after reviewing the related literature. The tool was submitted to a Jury of 7 experts in critical care nursing, to assess clarity and content validity and all necessary modifications were done accordingly.
- A pilot study was carried out on 6 patients (10 % from the study sample) to test the clarity and applicability of the research tool and they were excluded from the study. Pilot study revealed that further modifications are not needed.

Data collection

Firstly, the researcher fulfilled part I by obtaining needed data of patient's characteristics including age, date of admission, medical diagnosis, past medical history, date of ICU admission, date of starting mechanical ventilation. Then, the researcher started to assess body mass index (BMI), which was calculated using the following formula: BMI= weight/height (m^2). While, the weight of female patients was calculated by using the following formula: weight= (knee height × 1.01) + (arm circumference × 2.81) - 66.04 and their height were calculated using the_following formula: height = (1.83 × knee height) - 0.24 × age) + 84.88.

The weight of male patients was calculated by using the following formula: weight = (knee height × 1.19 + arm circumference × 3.21-86.8). And their heights were calculated by using the following formula: height = (2.02 × knee height – 0.04 × age + 64.19. Moreover, the calculation of BMI ranging from (16 – 18.5) was considered thin, (18.5 – 25) was normal, (25 – 30) was overweight and (30 – 40) was obese. (Ferreira et al., 2014).

After that, the researcher started to assess vital signs; Pulse, systolic and diastolic blood pressure, mean arterial pressure and body temperature at different head of bed elevation angles supine, 15°, 30° and 45°. Moreover, ventilator data were assessed at the same time.

The intra-abdominal pressure (IAP) measurement was done through urinary bladder using manometer, a three- way stopcock with extension tube, blood set, syringe 50 ml and 0.9% NaCl fluid. Measurements were made with the steps: set the zero point by drawing a parallel line simpisis pubis to the lateral direction, then pull the axillary line median, connect the blood sets and a three-way to Foley catheter patients, fill the syringe with liquid NaCl 0.9% at 35 ml, the contents manometer with liquid NaCl 0.9% to zero by turning the three way towards manometer, cap toward the patient, turn back three way towards patients, cap toward manometer, enter the fluid NaCl 0.9% 25 ml, cap askew wait 30-60 seconds. Readings were taken at the end of expiration.

The researcher measured Intra-abdominal pressure (IAP) at different head of bed elevation angles supine, 15°, 30° and 45°. However, in order to make the right clinical decision about the patient, the patient's condition must be constant from one measurement to the next. (Desie et al., 2012). In addition, abdominal perfusion pressure (APP) and filtration gradient (FG) were calculated as, APP and FG have been proposed as more accurate predictor of visceral perfusion and a potential endpoint for resuscitation (Elatroush et al., 2015)

Ethical considerations:

- Written informed consent was obtained from head nurses for intervention in this study after appropriate explanation of the study purpose.
- Written informed consent was obtained from patients' family for their participation and right to refuse of their patients' participation in the study was assured. Patients' privacy was respected.
- Anonymity and data confidentiality were assured during implementation of the study

Statistical analysis:

- The raw data were coded and transformed into coding sheets. The results were checked. Then, the data were entered into the Statistical Package for Social Sciences (SPSS) version 18 using personal computer. Output drafts were checked against the revised coded data for typing and spelling mistakes. Finally, analysis and interpretation of data were conducted.
- The following statistical measures were used:
- Descriptive statistics including frequency and distribution were used to describe different characteristics of subjects.
- F test (ANOVA) was used to compare IAP measurements at supine position, HOB elevations 15°, 30° and 45°.

Results:

Based on table I, it can be seen that the age of nearly one third of the patients is in the range between 41-50 years and as many as 15 patients (25%). By sex, more than half of patients are male, as many as 35 patients (58.3%). Based on BMI, as many as 37 patients (61.7 %) were obese. Based on past medical history, it was found that cardiovascular disorders affected nearly two thirds of patients (63.3%). Moreover, nearly one third of the patients diagnosed with respiratory disorders or neurological disorders (38.3% and 35%) respectively. On the other hand, 38% of the studied patients were diagnosed with Respiratory disorders.

The data for the effect of different head of bed (HOB) angles on intra- abdominal bladder pressure measurements are summarized in Table II. Table II illustrates the mean IAP, APP and FG at each HOB angle. IAP was found to be increased significantly with increases in HOB angle (F= 6.6, p=<0.001*). Moreover, it is increased significantly specifically at HOB angle increases of 45° compared to supine position (p_1=<0.001).

Age and BMI were significant in this study, whereas age and BMI positively correlate with IAP with significant differences (Table III). Whereas, they negatively correlated with FG significantly. Furthermore, we could not detect significant interactions between age and APP. It can be noticed that BMI negatively correlates with APP significantly.

The effect of different head of bed (HOB) angles on ventilator parameters was summarized in Table IV, which shows that Vt and dynamic lung compliance were increased significantly with all of different HOB angles. While respiratory rate (RR) and PIP decreased with most different HOB angles. RR significantly decreased the difference at 15°and 30°. While PIP decreased significantly at 30° and 45°. In relation to: increased significantly 15°, 30°, and 45°.

In relation to the effect of head of bed angles on vital signs was summarized in table IV. It can be noticed that SBP increased significantly with increases in HOB angles. Moreover, it increased significantly at 45°. Considering changes in spo_2, it increased significantly with all head of body angles 15°, 30°, and 45°.

Discussion

Intra-abdominal pressure measurement is one of the most important hemodynamic monitoring that needs to be performed in the intensive care unit to identify patients at risk for intra-abdominal hypertension and subsequent abdominal compartment syndrome. The intra-abdominal pressure varies greatly depending on body position and bed head height (Samimian et al., 2021)

In this study IAP was found to be increased significantly with increases in HOB angle. Moreover it is increased significantly specifically at HOB angle of 45°. This result matched with the study by (Cresswell et al., 2012).

IAP value at HOB height 30° was higher than its value at supine position. Moreover, the result is at the same line with the study of (Rooban et al., 2012) as IAP was affected by repositioning from the supine position to the HOB altitude of 30°. However, IAP measurements increase on average at the elevation angle of HOB position 30° rather than in the supine position.

The results of this study are also consistent with the study by (Monica et al., 2021). It is a study was conducted to compare the results of IAP measurements at 0-45° angles. The results showed that an increase in IAP was significantly associated with an increase in HOB elevation, with a significant change in the position of HOB elevation> 20°.

The results of this study also showed that BMI and age were significant in this model, whereas age and BMI positively correlates with IAP with significant difference (Table III). Whereas, they were negatively correlates with FG significantly. Furthermore, we could not detect significant interactions between age and abdominal pressure perfusion (APP). While, it was found that BMI negatively correlates with APP significantly. Previous studies reported that obesity which was defined as body mass index (BMI) >30 kg/m2 was a risk factor for IAH in mixed ICU patients (Kim et al., 2012 and Devansh et al. 2021). Body mass index (BMI) has been found to affect IAP in hospitalized patients (Holodinsky, 2013).

In the current study, we did not evaluate the effect of position on lung functions. However, this study examined the effect of position on respiratory rate (RR), Vt, PIP, SPo_2 and dynamic lung compliance. Considering, changes in spo_2, dynamic lung compliance and tidal volume (Vt) they were increased significantly with all of head of body angles 15°, 30°, and 45°. Moreover, it was found that RR and PIP decreased at most of different HOB angles. RR significantly decreased differences at 15°, 30°. While, PIP decreased significantly at 30° and 45°.

This finding may be related to the favorability of deep breaths in elevated head of bed, and overcomes the tendency to airway closure related to changes in lung compliance and lower pressure of the abdominal organs in relation to the diaphragm. (Martinez et al., 2015).

These results are in consistent with other similar studies compared effect of different head of bed elevations on end expiratory lung volumes and found that HOB elevation increased vital capacity and improved lung volume and there was a greater decrease in forced vital capacity (FVC) in supine position. This decrease may be attributed to decreased dynamic lung compliance and increased resistance to pulmonary blood flow, resulting from reduced functional residual capacity (FRC) in this position.

In supine position, anatomical changes occur in the pharynx, such as the reduction of its diameter, which increases the upper airway resistance. The cephalic displacement of the diaphragm due to increased abdominal pressure, and the increased intra-thoracic blood volume, are also factors that result in reduced lung volume at rest and justify an increase in airway resistance in this body position. Moreover, supine decreased breathing frequency 2.73 breaths/min on average. (Martinez et al., 2015 and Mezidi and Guérin, 2018).

Considering vital signs, it was found that SBP increased significantly with increases in HOB angles and it increased significantly at 45°. While, MAP increased not significantly with changes in head of bed elevations angel. This result is in the contrary with finding of previous studies showed that sitting BP is significantly lower than the supine blood pressure (Walawalkar 2014 and Islam 2018).

Changes in systolic pressure in the present study may be related to stress or pain which results from increased frequency of changing position. This result is in the contrary with a study conducted by (Samimian et al., 2021). It was a cross-sectional descriptive-analytic study to determine intra-abdominal pressure and its related factors in the human patient in particular centers.

The results of this study showed that there was a significant relationship between the frequency of intra-abdominal pressure and the mean arterial pressure. So consideration of this variable as well as its influencing factors should be considered. In another study conducted by (Moghaddam 2019) in this study, the effects of changes at different positions (0°, 15°, 30°, 45°degrees) on the mean arterial pressure were evaluated. There was a significant difference between the mean arterial pressures of all of the fourth measurements.

Conclusion

According to the results of this study, the patient's body position changing from supine to higher positions lead to increase of intra-abdominal pressure. There was no difference in the measurement values IAP supine position, HOB elevation 15° and 30°. But, there was a difference in the measurement position value (IAP) at HOB elevation 45°. HOB elevations 15° and 30° are safe positions for the measurement of IAP So that, it can be used as evidence-based positions measurement of IAP using HOB elevation 15° or 30° to prevent aspiration.

Recommendations

Based on the results of the present study, the following recommendations are suggested:

Recommendations regarding clinical practice:

- Nursing management protocol for IAP measurement should be applied in clinical practice as a routine of unit care.

- Strategies for updating nurses' knowledge and enhancing their practice should be developed.

Recommendations regarding education and training:

- Nursing students' curriculum should be focused on the vital role of intra-abdominal pressure monitoring.
- The teaching and training programs about intra-abdominal pressure measurement should be performed through workshop, seminars, conferences, group discussion.

Recommendations regarding administration:

- Hospital budget should be directed to provide the needed equipment and supplies for application of intra-abdominal pressure measurements.
- Administrators should check regularly the adherence of nurses regarding implementation of intra-abdominal pressure measurements and detection of compartment syndrome.
- Evidence based guidelines mentors should be present in health-care systems

Recommendations regarding research:

- Further studies are needed to evaluate different methods of intra-abdominal pressure measurements.

- Studies with large sample size are needed to evaluate effect of head of bed elevation on intra-abdominal pressure measurement among mechanically ventilated patients.

Limitation of the study:

- The patients who would not endure an elevation in HOB or flat position were excluded in our study. Unfortunately, many of these patients were at high risk for IAH/ACS. Furthermore, the small size of the sample was limitation in this study. So, the results of the study cannot be generalized.

Table I: Distribution of studied patients according to age, sex and clinical data:

Patients' data	No.	%
Age (Years)		
18–30	6	10
31–40	11	18.3
41–50	15	25
51–60	16	26
>60	12	20
Sex		
Male	35	58.3
Female	25	41.7
Past medical history #		
Non	8	13.3
Cardiovascular	38	63.3
Endocrine	16	26.7
Renal	8	13.3
Hepatic	6	10
BMI		
Thin (16 – 18.5)	10	16.7
Normal (18.5 – 25)	8	13.3
Overweight (25 – 30)	5	8.3
Obese (30 – 40)	37	61.7
Diagnosis #		
Respiratory disorders	23	38.3
Cardiovascular disorders	4	6.7
Endocrine disorders	5	8.3
Renal disorders	12	20
Neurological disorders	21	35
GIT disorders	11	18.3

#: More than one answer

Table II: Mean of intra- abdominal pressure, APP and FG at different HOB angles:

	head of bed angles				**F Test**	**P_2**
	Supine	**15°**	**30°**	**45°**		
	Mean ± SD.	**Mean ± SD.**	**Mean ± SD.**	**Mean ± SD.**		
IAP	13 ± 8	13 ± 7.9	13.2 ± 8.1	14.1 ± 8.6	6.6*	<0.001*
P_1		1.000	1.000	<0.001*		
% change		0.5 ± 3.6	1 ± 17.2	7.9 ± 14.1		
APP	77.6 ± 24.4	76.4 ± 20.6	77.3± 19.4	79.8 ± 29	1	0.392
P_1		1.000	1.000	1.000		
% change		-0.21 ± 10.36	2.78 ± 20.13	3.47 ± 20.98		
FG	62.1 ± 28.7	59.4 ± 26.1	61.5 ± 24.7	66.5 ± 33.5	2	0.115
P_1		1.000	1.000	1.000		
% change		-1.7 ± 17.8	4.0 ± 28.1	35.18 ± 183.4		

F: F test (ANOVA) with repeated measures p_1: p value for association between each studied position and supine. p_2: p value for association between the studied positions *: Statistically significant at $p \le 0.05$
intra- abdominal pressure (IAP), abdominal perfusion pressure (APP) and filtration gradient (FG).

Table III: Relationship between FG, APP and IAP with age and BMI at head of bed angles

	Age		BMI	
	r	p	r	p
FG				
Supine	-0.239	0.065	-0.141	0.281
15°	-0.276*	0.033*	-0.204	0.118
30°	-0.248	0.056	-0.208	0.111
45°	-0.076	0.563	-0.387*	0.002*
IAP				
Supine	0.282*	0.029*	0.497*	<0.001*
15°	0.282*	0.029*	0.498*	<0.001*
30°	0.257*	0.047*	0.569*	<0.001*
45°	0.276*	0.032*	0.505*	<0.001*
APP				
Supine	-0.077	0.557	-0.147	0.264
15°	-0.067	0.613	-0.271*	0.036*
30°	-0.053	0.689	-0.268*	0.038*
45°	-0.018	0.889	-0.301*	0.020*

r: Pearson coefficient *: Statistically significant at $p \leq 0.05$. intra- abdominal pressure (IAP), abdominal perfusion pressure (APP) and filtration gradient (FG).

Table IV: Mean and standard deviation of ventilator parameters at head of bed angles:

Ventilator parameters	Head of bed angles				Test	P_2
	Supine	15°	30°	45°		
	Mean ± SD.	Mean ± SD.	Mean ± SD.	Mean ± SD.		
vt	425.2±150.1	436.4±142.7	480.1±149.9	461.8±149.8	Fr=95.398 *	<0.001*
P_1		<0.001*	<0.001*	<0.001*		
R.R	24.60 ± 5.8	23.87 ± 5.9	22.93 ± 5.3	24.53 ± 5.6	F=15.918*	<0.001*
P_1		0.009*	<0.001*	1.000		
Spo2	94.3 ± 8	96 ± 2.5	97.2 ± 2.6	96.5 ± 3.4	Fr=70.42*	<0.00*
P_1		0.015*	<0.001*	<0.001*		
PIP	27.72 ± 5.8	26.98 ± 5.8	25.40 ± 5.5	26.25 ± 5.4	F=18.671*	<0.001*
P_1		0.127	<0.001*	0.001*		
Dynamic lung compliance	39.69 ±20.3	42.36 ±20.0	46.64 ±22.0	43.70 ±21.7	F=35.482*	<0.001*
P_1		0.001*	<0.001*	<0.001*		

Fr: **Friedman test F: F test (ANOVA) with repeated measures** p_1: p value for association between each studied position and supine. p_2: p value for association between the studied positions. *: Statistically significant at $p \leq 0.05$.Tidal volume (Vt), respiratory rate (RR), Positive inspiratory pressure (PIP) and dynamic lung compliance and oxygen saturation SPO_2 was evaluated.

Table V: Mean of vital signs at head of bed angles:

Vital signs	Head of bed angles				Test	P_2
	Supine	15°	30°	45°		
	Mean ± SD.	Mean ± SD.	Mean ± SD.	Mean ± SD.		
SBP	117.7 ±21.26	118.2 ±20.54	118.5 ±18.58	121.5 ±20.98	F=5.21*	0.00*
P_1		1.000	1.000	0.000*		
DBP	75.2 ± 15.2	75 ± 15	76.2 ± 13.8	77.8 ± 14.3	F=1.03	0.38
P_1		**1.000**	**1.000**	**1.000**		
MAP	90.7 ± 21.3	89.4 ± 16.4	90.5 ± 15.6	93.9 ± 25	F=1.80	0.15
P_1		1.000	1.000	1.000		
Temp	37.4 ± 1.1	37.6 ± 0.6	37.6 ± 0.6	37.7 ± 0.7	Fr=26.1	0.12
P_1		**1.00**	**1.000**	**1.000**		
H.R	94.2 ± 19	93.7 ± 18.6	93 ± 18.1	94.4 ± 19.1	F=0.94	0.42
P_1		1.000	1.000	1.000		

Fr: **Friedman test F: F test (ANOVA) with repeated measures** p_1: p value for association between each studied position and supine. p_2: p value for association between the studied positions. *: Statistically significant at $p \leq 0.05$. Temperature (Temp), heart rate (HR), systolic (SBP), diastolic (DBP) and mean blood pressure (MAP).

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