Original Article *Egyptian Journal of Health Care, 2018 EJHC Vol.9 No.4*

Correlation between Invasive and Noninvasive Arterial Blood Pressure Monitoring in Pediatric Cardiac Surgical Patients

***Belal Ibrahim Ibrahim Mohamed, **Mohamed Ahmed A. Sultan, ***Mohamed-Adel Fatouh El- Gamal, ****Hanaa H. El-Sayed Ahmed**

*B.Sc of Nursing, ** Intensive and Emergency department, faculty of medicine, Mansoura University, *** Cardiothoracic department, faculty of medicine, Mansoura University, **** Critical care & Emergency Nursing department, faculty of Nursing Mansoura University

Abstract

Background: Blood pressure (BP) is a basic hemodynamic monitoring index that is a core vital sign used as a basis for diagnosis, management and treatment of patients postoperatively. Measurement of blood pressure can be accomplished invasively or non-invasively. Accurate blood pressure measurement is critical in which the inaccuracies may delay treatment of serious conditions. Several studies have indicated a significant relation between invasive and noninvasive arterial blood pressure measurement. Therefore, the **aim of this study** is to investigate correlation between invasive and noninvasive arterial blood pressure monitoring in pediatric cardiac surgical patients in Intensive Care Unit at Children Hospital, Mansoura University. **Material and Methods**: A comparative research design was used to carry outconvenient sample the research on fifty pediatric cardiac surgical patients in Intensive Care Unit at Children Hospital, Mansoura University. Two tools were used to collect data about correlation between invasive and noninvasive arterial blood pressure measurements. **Results**: the findings showed a significant correlation between invasive and noninvasive arterial blood pressure pre and postoperatively in pediatric cardiac surgical patients. Six equations were inferred from our results to calculate invasive arterial blood pressure from noninvasive ABP (systolic, diastolic and mean ABP pre and postoperatively). **Conclusion**: Invasive arterial blood pressure can be calculated by inference from noninvasive arterial blood pressure using the calculated equations pre and postoperatively. **Recommendation**: Further research studies are required to measure correlation between invasive and noninvasive arterial blood pressure with different sites as brachial and femoral arteries as well as replication of this study on a large probability sample.

Key words: Arterial blood pressure, Invasive arterial blood pressure, Noninvasive arterial blood pressure calculated invasive ABP, pediatric cardiac surgical patients.

Introduction

Pediatric cardiac surgery (PCS) is indicated when patients don’t respond to traditional medical management, or when disease progression is evident. PCS is performed for many reasons as repair of acquired cardiac lesions and congenital abnormalities. So, PCS is required for the following cases as atrial septal defect (ASD), ventricular septal defect (VSD), tetralogy of fallot (TOF) and tricuspid and pulmonary atresia **(Barron, Jones, & Mussa, 2018)**. This surgery can be performed through opening patient's chest cavity. After the heart is stopped, the patient is linked to heart lung machine that maintains the blood circulating during surgery. The heart begins to beat again after the pediatric cardiac surgical patient (PCSP) is weaned from the heart lung machine. Finally; postoperatively the PCSPs are transferred to pediatric cardiac intensive care unit (PCICU) **(Siemens, Sangaran, Hunt, Murdoch, & Tibby, 2018)**.

Pediatric cardiac surgical patients may have many and serious complications postoperatively which may be fetal for their life. These complications may be due to surgery itself and cardiopulmonary bypass or anesthesia procedures **(Kaplow, 2015; Nishimura et al., 2017)**. The postoperative complications may involve many systems as cardiovascular, respiratory, neurological, gastrointestinal and renal systems. Cardiovascular and hematologic systems complications are the most common as dysrhythmias, myocardial ischemia and deep venous thrombosis. Moreover, hemodynamic instability especially arterial blood pressure (ABP) is the common changeable parameter postoperatively. Thus, postoperative phase is the most significant and critical period for PCSPs **(Benoit et al., 2017; Sharma, Sisodia, Devgarha, & Mathur, 2016)**.

Arterial blood pressure describes the function of the blood flow rate and resistance of the arterial circulation. Blood circulates through the arterial tree by a vigor and enormous force generated by the left ventricle. So, ABP is a fluctuating wave for each cardiac cycle with a minimum and maximum values **(Koohi, 2017; Secomb, 2016).** Maximum pressure occurs when the heart is completely contracted, and it is called systolic arterial blood pressure (SABP). Conversely, pressure drops to its minimum value during the heart relaxation period, which is called diastolic arterial blood pressure (DABP). The average ABP at each cardiac cycle is estimated and called mean arterial blood pressure (MABP). ABP can be monitored by two methods noninvasively and invasively **(Gao, 2016; Koohi, 2017; Kucewicz-Czech, Krzych, & Ligowski, 2017)**.

Noninvasive arterial blood pressure (NIABP) aneroid sphygmomanometers and oscillometric automated devices are the most used devices in NIABP monitoring. They are quicker and simpler than invasive arterial pressure (IABP) and need less expertise. Continuous NIABP is usually monitored in PCSPs who need frequent ABP monitoring due to vasoactive agents administration **(Shein & Clark, 2017).** Additionally, automated devices are the most convenient devices in NABP monitoring in PCICU. Its measurements are fully automated, not require specialist training, have a good reliability, and are norm to ABP measurements for PCSPs. NIABP measurement methods are more commonly used in routine nursing assessment and monitoring **(Duncombe, Voss, & Harris, 2017).**

However, IABP measurement is oftentimes deemed the golden standard of ABP measurement. Because it is a continuous beat-to-beat pressure measurement, close monitoring of PCSPs on vasoactive agents. Moreover, it provides pulse waveform analysis that is very important for hemodynamic parameters. Additionally, IABP reduces the risk of tissue injury and neuropraxias in PCSPs who require frequent arterial blood sampling. IABP is more accurate than NABP, especially in the extremely hypotensive or the PCSPs with dysrhythmias **(Renner et al., 2016)**. On the other hand, IABP is accompanied with increased risks, cost, and need for technical expertise for inseration and management. IABP is commonly executed in theatres and PCICUs using an arterial catheter (AC) **(Hebal et al., 2018)**.

Arterial catheter is used for PCSPs intraoperatively and postoperatively for diagnostic and therapeutic decisions. AC is inserted into a peripheral artery most commonly the radial artery. The catheter is connected via flushing system to a pressure transducer. Otherwise, arterial catheterization has huge risks as bleeding and hematoma. In addition, accidental deccanulation can lead to rapid and significant blood loss in PCSPs and thrombosis of small and large blood vessels. Further risks are intrarterial drug infusion, site infection and limb ischemic necrosis that should be considered during arterial catheterization **(Lin et al., 2017; Maaji, Kumar, Kumar, & Gulati, 2017)**.

Pediatric critical care nurses (PCCNs) have a key role for PCSPs postoperatively management. Their role includes PCS cardiovascular parameter monitoring and hemodynamic stability. Maintaining of hemodynamic stability especially ABP is the main nursing goal for PCCNs postoperatively. Additionally, PCCNs have a significant role in dealing with AC and its care, to prevent its complications. Also accuracy of recording readings and notifying physician if there is any abnormality are duties of them **(Silverman, Kurtz, & Draper, 2016)**.There were no national research conducted on the three ABP parameters (SABP, DABP, MABP) in pediatric patients undergoing cardiac surgery and the correlation between IABP and NIABP monitoring. Thereby, the aim of the study is to investigate correlation between IABP, NIABP monitoring in PCSPs in ICU at Children Hospital.

Significance of the study

Pediatric cardiac surgery is considered important in resolving many cardiac problems and has many complications that may be serious for PCSPs as cardiovascular complications. ASD and VSD were reported to account for 28.5% and 28.2% of 312 PCSPs respectively at pediatric cardiology clinic and inpatient department in El Fayoum University hospital **(Atwa & Safar, 2014)**. Also, percentage of mortality among all patients, was 4.8% and hospitalization due to chest infection was 48.2% **(Atwa & Safar, 2014).**

Most of these patients have hemodynamic instability and ABP changes so ABP monitoring is crucial for PCSPs postoperatively. Measurement of ABP can be accomplished both invasively and non-invasively. The radial artery is the most common site for arterial cannulation **(Gu, Tie, Liu, & Zeng, 2014)**. **Bernd, Azriel, and Ulrich (2002)** studied 19,617 radial arterial patients for complications and risk factors of peripheral arterial catheters used for hemodynamic monitoring in anesthesia and intensive care medicine. They stated that the occlusion of the artery was considered the most common complication as it occurred in the range of 1.5% to 35% with mean 19.7 of inserted catheter. Also, they reported that pseudo aneurysm, sepsis and local infection with means 0.09, 0.13 and 0.72 respectively. Moreover, **Hebal et al. (2017)** who assessed the pediatric arterial catheters complications and associated risk factors for two hundred twenty-eight children. They highlighted that complications of pediatric radial artery catheter as line malfunctions, bleeding, multiple complications, infiltration and hematoma with percentages (59, 16, 11, 8 and 4%) respectively.

So, we tried to study noninvasive measuring of arterial blood pressure in PCSPs to avoid complications of invasive arterial catheters. The present study was conducted in attempt to establish the correlation between IABP and NIABP monitoring in PCSPs.

Aim of the Work

The study aimed to investigate any correlation between invasive and noninvasive arterial blood pressure monitoring pre and postoperatively in pediatric cardiac surgical patients in Intensive Care Units.

Research questions

To fulfill the aim of the current study the following research questions were formulated:

Q1: Is there any correlation between IABP and NIABP measurement?

Q2: Which technique is more reliable in monitoring ABP for PCSPS?

Subjects and Methods

Research design

A comparative research design was used to examine the correlation between invasive and noninvasive arterial blood pressure in pediatric cardiac surgery patients.

Setting

This study was carried out in cardiothoracic surgery, ICU of Children Hospital at Mansoura University. The ICU involves 10 beds. Each bed has a ventilator, a bedside cardiac monitor with its elements (ECG cable, pulse oximeter, capnograph, temperature probes and CVP monitoring), two infusion pumps, two syringe pumps and an arterial flushing system.

Subjects

A convenient sample of 50 PCSPs undergoing cardiothoracic surgery were included in the present study. Whose families were willing to participate voluntarily and gave a written consent were recruited in the study. Children aged from 1-6 years, undergoing cardiac surgery who had recently (first day insertion) radial catheter were involved in the study. On the other hand, PCSP who had different arterial line (femoral or brachial), dysrhythmias, arm injuries, wounds, edema and subcutaneous tissue infection and anomalies of aortic arch or bleeding tendency were excluded from the study.

Tools

Two tools were developed by researcher to collect the data of study after reviewing the related literature

Tool I: Preoperative PCSPs Assessment Sheet

This tool was divided into two parts

Part A: Patients' Demographic and Relevant Health Information

This part included patients' demographic and relevant health information that involved patient's name, gender, age, medical and surgical history.

Part B: Variables that Affect Blood Pressure Reading

This part included patient's arm circumference (cm), patient's weight (kg), patient's height (cm), heart rate (beats/min), patient's diagnosis, type of surgery, history of blood pressure disease and serum investigation as prothrombin time (Pt), INR, hematocrit level, white blood cell counts, hemoglobin level, red blood cell counts, platelet counts, albumin and creatinine values.

Tool II: Postoperative PCSPs Assessment Sheet:

Invasive and Non-invasive Arterial Blood Pressure Readings Record

This part involved invasive and noninvasive arterial blood pressure readings hourly along 12 hours for each PCSP postoperatively.

Pilot study

A pilot study was carried out before starting data collection on 10% of the sample (5 out 55 PCSPs) who were excluded from the study subjects to test the tools clarity, feasibility, objectivity and consistency and detect its ambiguity. Based on the findings of the pilot study, necessary modifications were done accordingly. Some items have been added and others were rephrased to be clear and understood.

Protection & human rights

An Ethical consideration approval was obtained from the Scientific Research Ethical Committee of the Faculty of Nursing, Mansoura University. Approval and acceptance was obtained from the hospital administrative personnel based on the official letter after explanation of the aim and nature of the study. Informed written consent were obtained from the responsible member of the family before the beginning of the study after explanation of the purpose and nature of the study. The researcher discussed with the participants' families that there were no risks or hazards related to the study. Each participant's family was informed that their child's participation in the study was voluntary and they could withdraw at any stage without any responsibility. Finally, confidentiality and anonymity of each subject were assured through the collected data and were assured through coding of all data.

Results

Table 1 shows the socio-demographic characteristics of the PCSPS. The majority of the study cardiac patients were within mean age value of 2.39±1.57. Moreover, the majority of the sample were males 68%. Also, PCSPS who had medical past history were 16%. While the PCSPs with surgical past history was 14% and the PCSPS who were free from medical and surgical past history 70%.

Table 2: shows the comparison between postcanulation NIABP and IABP. There were non statically significant between NIABP, IABP readings regarding SABP, DABP and MABP with p values (0.86, 0.7 and 0.2) respectively.

Table 3: shows the correlation between heart rate (HR), NIABP and IABP thought 12 hours postoperatively. The current readings illustrated that there were non-significant correlation between HR and NIABP readings with p values of 0.734, 0.712 and 0.901 respectively. In the same line there were non-significant correlation between HR & IABP regarding DABP & MABP readings with p values of 0.794 & 0.141 respectively. On other hand there was a positive correlation between HR and invasive SABP with p value of 0.048*.

Table 4: reflects the mean of IABP and NIABP readings postoperatively each hour throughout 12 hours. The current readings illustrated that there were statistically nonsignificant difference in most of the study hours. Otherwise, there were a statistically significant difference in SABP at 9, 10 hours of the study period with p values of 0.024**, 0.042* respectively. In the same line there were an extremely significant difference in SABP at hour 8 with p value of 0.001***. Data revealed that there was a significant difference between DABP of invasive and noninvasive ABP at the first hour of the study period with p value of 0.020**.

Table 5: describes the preoperative postcanulation correlation between IABP & NABP. The data shows an extremely significant correlated for SABP, DABP and

MABP with p value of 0.001**for all. From current data of the study the following equations were inferred to estimate invasive SABP, DABP and MABP. The first equation of SABP is Y= 61.9+ (0.4*x) (y= invasive& x= noninvasive), the equation of DABP is Y= 28.36+ (0.54*x) and the equation of MABP is Y= 30.65+ (0.62*x).

Table 6: shows the correlation between invasive and noninvasive ABP readings postoperatively allover 12 hours. The current result shows a highly statically significant correlation for SABP, DABP and MABP with p value of 0.001*** for all. Moreover, the current data of the study stated the following equations to estimate invasive SABP, DABP and MABP. The first equation of SABP is Y=12.55+ (0.87*x) (y= invasive& x= noninvasive), the equation of DABP is Y= 30.9+ (0.55*x) and the equation of MABP is Y=24.96+ (0.71*x).

Table 1: Distribution of the studied patients according to their socio-demographic and history relevant data (n-50)

Parameters	**Item**	**n= 50**	
		No	**%**
Gender	Male	34	68
	Female	16	32
Past medical history	Medical	8	16
	Surgical	7	14
	None	35	70
Age	Mean	±SD	
	2.39	1.57	

SD: standard deviation

Table 2:comparison between NIABP and IABP monitoring

Parameters	**n=50**					
	Postcanulation Invasive		**Postcanulation Non invasive**		**t**	**P**
	Mean	**±SD**	**Mean**	**±SD**		
SABP	102.50	14.79	102.08	20.33	0.17	0.86
DABP	60.66	11.89	60.12	13.31	0.33	0.7
MABP	78.44	11.96	76.58	12.95	1.3	0.2

SD: standard deviation **P**: probability Test used: **T**: test **SABP**: Systolic arterial blood pressure **DABP**: Diastolic arterial blood pressure **MABP**: Mean arterial blood pressure (*****) statistically significant at $p \leq 0.05$
(******) extremely statistically significant at $p \leq 0.001$

Table 3: Correlation between HR, NIABP and IABP readings all over 12 hours postoperatively

Parameters		**Postoperative (n=50)**					
		Invasive			**None-Invasive**		
		SABP	**DABP**	**MABP**	**SABP**	**DABP**	**MABP**
HR	R	0.081	0.011	0.061	0.014	0.015	0.005
	P	***0.048**	0.794	0.141	0.734	0.712	0.901

R: Pearson Correlation coefficient **P**: Probability **HR**: heart rate **SBP**: Systolic blood pressure **DBP**: Diastolic blood pressure **MAP**: Mean arterial blood pressure (*****) statistically significant at $p \leq 0.05$ (******) extremely statistically significant at $p \leq 0.001$

Table 4: Mean of invasive and noninvasive arterial blood presssure readings postoperatively throughout 12 hours.

Hours	Parameters	Postoperative Invasive n=50		Postoperative non invasive n=50		t	P
		Mean	±SD	Mean	±SD		
Hour 1	SABP	116.92	14.84	116.92	13.31	0	1.000
	DABP	69.34	10.95	66.12	13.61	2.400	**0.020****
	MABP	86.08	17.16	86.62	13.39	0.248	0.805
Hour 2	SABP	115.46	17.36	114.38	15.18	0.782	0.438
	DABP	67.68	11.98	66.48	13.05	0.724	0.473
	MABP	87.82	12.93	85.32	14.02	1.855	0.070
Hour 3	SABP	112.86	15.86	115.30	15.87	1.693	0.097
	DABP	66.50	12.21	66.02	13.56	0.332	0.741
	MABP	85.72	12.75	85.58	13.06	0.110	0.9013
Hour 4	SABP	113.16	16.93	115.20	15.67	1.556	0.126
	DABP	66.88	10.34	66.24	13.42	0.463	0.645
	MABP	85.68	12.85	86.06	13.02	0.329	0.744
Hour 5	SABP	111.10	15.89	114.06	15.16	1.990	**0.052***
	DABP	65.84	10.48	65.82	13.14	0.014	0.989
	MABP	84.94	12.36	84.32	12.67	0.438	0.663
Hour 6	SABP	111.42	15.46	111.90	12.67	0.448	0.656
	DABP	68.12	10.45	66.44	11.75	1.191	0.239
	MABP	85.14	12.39	82.74	11.18	1.766	0.084
Hour 7	SABP	111.42	14.60	113.94	14.05	1.975	**0.054***
	DABP	66.64	9.28	68.40	12.01	1.415	0.163
	MABP	85.72	11.17	85.84	12.21	0.111	0.912
Hour 8	SABP	108.86	14.83	112.82	12.44	3.690	**0.001*****
	DABP	66.52	11.49	65.42	12.59	0.657	0.515
	MABP	83.34	11.98	84.90	11.17	1.400	0.168
Hour 9	SABP	109.86	14.66	113.10	13.42	2.337	**0.024***
	DABP	67.18	10.29	66.52	13.81	0.399	0.692
	MABP	84.18	12.25	85.76	13.71	0.874	0.386
Hour 10	SABP	110.30	15.51	113.58	16.40	2.088	**0.042***
	DABP	68.00	10.39	65.92	13.54	1.844	0.071
	MABP	83.94	11.07	84.68	12.94	0.756	0.453
Hour 11	SABP	109.72	17.98	112.28	15.62	1.563	0.125
	DABP	68.24	10.95	67.30	14.75	0.754	0.455
	MABP	85.02	12.42	84.62	14.12	0.361	0.719
Hour 12	SABP	106.86	15.66	108.98	15.27	1.461	0.150
	DABP	64.06	11.03	62.88	14.24	0.919	0.363
	MABP	80.48	12.92	79.84	14.79	0.697	0.489

SD: standard deviation **P:** probability **Test used:** T-test
SABP: Systolic arterial blood pressure **DABP**: Diastolic arterial blood pressure
MAP: Mean arterial blood pressure
(*) statistically significant at p ≤ 0.05 **(**)** extremely statistically significant at p ≤ 0.001

Table 5: Correlation preoperative postcanulation correlation between invasive and noninvaive ABP

Parameters		Postcannulation invasive versus noninvasive n=50	Equations
SABP	r	0.547	Y= 61.9+0.4*x
	P	**0.001*** **	
DABP	r	0.601	Y= 28.36+0.54*x
	P	**0.001*** **	
MABP	r	0.676	Y= 30.65+0.62*x
	P	**0.001*** **	

R: Pearson's correlation coefficient **P:** Probability
SABP: Systolic arterial blood pressure **DABP**: Diastolic arterial blood pressure

Table 6: Correlation betwwen invasive versus noninvasive arterial blood pressure postoperatively every hor all over 12 hour (n-50)

Parameters		Postoperative (Invasive versus None-invasive) n=50	Equations
SABP	r	0.802	Y= 12.55+0.87*x
	P	**0.001*** **	
DABP	r	0.670	Y= 30.9+0.55*x
	P	**0.001*** **	
MABP	r	0.723	Y= 24.96+0.71*x
	P	**0.001*** **	

R: Pearson's correlation **coefficient** **P**: Probability **MABP**: Mean arterial blood pressure
SABP: Systolic blood pressure **DABP**: Diastolic blood pressure
(*) statistically significant at $p \leq 0.05$ **(**)** extremely statistically significant at $p \leq 0.001$

Discussion

The current study found that the majority of studied patients were males with no past medical or surgical history and the most of them had undergone open CS. This result was supported with the result of **Fischer et al. (2012)** who stated that the majority of their patients undergoing CS were males.

The present research findings illustrated that NIABP readings of systolic, diastolic and mean arterial blood pressure are enough accurate & reliable as IABP with positive significant correlation for all parameters. These findings were compatible with the result of **Lin et al. (2017)** who concluded that NIABP by TL-300 was comparable with IABP intraoperatively is more accurate. Moreover, **Shoji, Nakagomi, Okada, Ohno, and Kobayashi (2017)** illustrated that there was a strong correlation between oscillometric (sphygmocor XCEL) and IABP. Also,this result supported with result of **Joffe, Duff, Guerra, Pugh, and Joffe (2016)** who showed a significant correlation between IABP & NIABP in critically ill children. Moreover, **Garnier, Van Der Spoel, Sibarani-Ponsen, Markhorst, and Boer (2012)** supported this point by using Nexfin in the pediatric setting without an indication for IABP readings. Additionally, **McCann, Hill, Thomas, Zurakowski, and Laussen (2005)** who studied the Vasotrac system correlation with IABP monitoring in anesthetized children. They found that this system was a reliable alternative to cuff and direct ABP readings during routine surgical cases.

On the other hand, this result was in contrast with the result of **Sheshadri, Tiwari, Nagappa, and Venkatraghavan (2017)** who reported that NIABP inflation causes a transient reactive rise in IABP. In the same line, **Joffe et al. (2016)** concluded that NIABP was not accurate enough compared with IABP in critically ill children especially who received inotropes or vasoactive agents. Additionally, **Ribezzo et al. (2014)** reported that noninvasive techniques cannot be regarded as a reliable alternative to direct readings.

From the previous findings of the current study the following equations were estimated to calculate IABP by inferences from NIABP preoperatively and postoperatively. First, preoperative equations include SABP equation: Y= 61.9+ (0.4*x), DABP equation: Y= 28.36+ (0.54*x) and MABP equation: Y= 30.65+ (0.62*x) in which (y = noninvasive & x = invasive). Second, postoperatively equations involved SABP equation: Y=12.55+ (0.87*x), DABP equation: Y= 30.9+ (0.55*x) and DABP equation: Y=24.96+ (0.71*x) in which (y = noninvasive & x = invasive).

Finally, the current research results showed that NIABP readings are enough accurate as IABP with positive significant correlation to invasive systolic, diastolic and mean ABP readings. Thus, we can reduce using invasive procedure for blood pressure monitoring and use noninvasive procedure to decrease its complications as bleeding, infection, cost and pain. This can be achieved by using the estimated equations in the current study.

Conclusion

Based on the findings of the current study, it can be concluded that there was a positive correlation (extremely significant) between invasive and noninvasive ABP preoperatively. Also, there was a positive correlation (extremely significant) between invasive and noninvasive ABP postoperatively. IABP can be calculated by inference from NIABP using the estimated equations pre & postoperatively

Recommendations

Selecting the appropriate cuff size for PCSPs to measure NIABP. Selecting the appropriate technique of IABP care and its monitoring for PCSPs. Using the six equations preoperatively and postoperatively to calculate invasive (SABP, DABP, MABP).Meeting between nurses and supervisors regularly could be considered to evaluate practice and find ways for its improvement regarding ABP monitoring. Updating information about noninvasive ABP measurement methods to learn the best methods to decrease complications of invasive procedures. Future studies are required to investigate the reliability of estimated six equations preoperatively and postoperatively. Further researches are required to investigate correlation between invasive and noninvasive ABP with different sites as brachial and femoral arteries.

Summary

The present study revealed the following main findings:

The present study reflected a non-significant difference in most hours of the study period for the mean IABP and NIABP readings postoperatively throughout 12 hours. There was a positive correlation (extremely significant) between invasive and noninvasive ABP preoperatively. There was a positive correlation (extremely significant) between invasive and noninvasive ABP postoperatively. Six equations preoperatively and postoperatively were inferred.

Based on the study findings the following are recommended:

- Equip the PCCNs effectively with knowledge & skills to deal with PCSPs.

- Integrate the theory with the practice for PCCNs to narrow the gap in relation to new devices of ABP monitoring.

- Engage PCCNs in the up-to-dated workshops & conferences to expand their knowledge & skills related to ABP monitoring.

- Periodical meeting between PCCNs and supervisors could be considered to evaluate their practice and find ways for their improvement.

- Similar studies are recommended to include large sample size in other settings which use NIABP methods to confirm these findings.

- Future studies are required to investigate the reliability of the estimated six equations preoperatively and postoperatively.

- Further research are required to investigate correlation between IABP and NIABP with different sites as brachial and femoral arteries.

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