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International Journal of Current Research
Vol. 9, Issue, 11, pp.60620-60625, November, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

TO STUDY THE ROLE OF PERFUSION INDEX IN ASSESSING EFFICACY OF SPINAL ANAESTHESIA

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ARTICLE INFO

Article History:
Received 18th August, 2017
Received in revised form
09th September, 2017
Accepted 19th October, 2017
Published online 30th November, 2017

Key words:
Spinal anaesthesia,
PI (perfusion index).

ABSTRACT

Spinal anesthesia, also referred to as central neuraxial blockade is produced when a local anesthetic agent is injected into the subarachnoid space. It induces sympathectomy leading to selective vasodilatation of lower limbs. Perfusion index (PI) is a valuable objective during anesthetic practice to find out noninvasive methods for predicting the effect of anesthesia at our institution we studied the role of PI in assessing the efficacy of spinal anesthesia in 100 patients, scheduled for lower abdominal surgeries. In our study we found that when perfusion index in toe increases continuously from baseline at various intervals, there was simultaneous drop in mean blood pressure. PI in the lower limbs (increase of 602.98% at 20 minutes) has a strong negative correlation with the mean arterial pressure (decrease of 19.67% at 20 minutes) as per our results ($p < 0.01$). We correlated mean sensory block time with PI from baseline to 20 minutes, PI increased even at 1 minute after SAB but no statistically significant correlation could be found ($p > 0.05$) between time of onset of block and PI values.

Citation: Manish Choudhary, Pardeep Kumar, Vivek Batra, Mamta Dubey and Bhargava, A. K. 2017. "To study the role of perfusion index in assessing efficacy of spinal Anaesthesia", *International Journal of Current Research*, 9, (11), 60620-60625.

INTRODUCTION

Spinal anaesthesia, also referred to as central neuraxial blockade is produced when a local anaesthetic agent is injected into the subarachnoid space. Spinal anaesthesia acts mainly at spinal nerve roots, although some effect is possible at the cord itself. It requires a small volume of local anaesthetic, virtually devoid of systemic pharmacologic effect, to produce profound, reproducible sensory analgesia. (Brown, 2010) There are many choices of drugs to produce spinal anaesthesia: procaine, lidocaine, mepivacaine, tetracaine, ropivacaine, (*S*)-enantiomer of levobupivacaine and bupivacaine. (Brown, 2010) Spinal anaesthesia induces sympathectomy leading to selective vasodilatation of lower limbs. Clinical signs of sympathectomy (warm, dry feet) may be used to confirm correct block placement. Quantitative bedside assessments of sympathectomy induced vasodilatation following regional anaesthesia include cutaneous temperature changes (Stevens *et al*., 2006; Galvin *et al*., 2006), leg-toe temperature gradients (Stevens *et al*., 2006) and change in blood pressure (Van de Velde *et al*., 2006). More sophisticated assessments of vasodilatation have been reported using laser Doppler flowmetry (Kano *et al*., 1994) but this requires expensive equipment. Perfusion index (PI) (calculated as the ratio of the pulsatile blood flow to the nonpulsatile blood in peripheral tissue) (Hales *et al*., 1989) can be measured non-invasively. PI can be used to assess peripheral perfusion dynamics due to changes in peripheral vascular tone (Lima *et al*., 2002; Zaramella *et al*., 2005; Mowafi *et al*., 2009; Ginosar *et al*., 2009; Takahashi *et al*., 2010). It is a valuable indicator during anaesthetic practice to predict the hemodynamic responses to anaesthetic drugs, techniques and intra operative stimuli. As spinal anaesthesia often causes hypotension mainly as a result of decreased systemic vascular resistance due to blockade of preganglionic sympathetic fibres (Hanns *et al*., 2005), which may increase PI via the toe, study of the same can detect proper onset of spinal anaesthesia. Detection of a spike in PI is a sign to the physician of the successful onset of anaesthesia. Conversely, no increase in PI in a patient given spinal anaesthesia may be an early warning of anaesthetic failure. As an objective indicator of pain levels in patients (Hager *et al*., 2004), PI has been used to determine proper management of pain, especially in patients unable to communicate their discomfort to the clinician. It is assumed that peripheral tissue is the first tissue bed to be sacrificed in shock and the last to be reperfused in resuscitation (Chien *et al*., 2007; Poeze *et al*., 2005). The peripheral perfusion index (PI) is derived from the photoelectric plesthysmographic signal of pulse oximetry and has been shown to reflect changes in peripheral perfusion (Lima *et al*., 2002; Galvin *et al*., 2006). Because a pulse oximeter is almost universally available in the operating room

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and intensive care unit, this ratio can be used to monitor perfusion in these circumstances. We thus undertook this study to evaluate the role of perfusion index in assessing the efficacy of spinal anaesthesia.

MATERIALS AND METHODS

It was a prospective Observational Study done on 100 patients from November2013 to October 2015. The sample size of minimum 100 patients was estimated in order to obtain a 95% confidence interval for PI with a precision of 0.25 and an estimated standard deviation of 1.5. Patients with age between 18-70 years, both male and female, presenting for lower abdominal surgeries were included in the study. Exclusion criteria included patients with medical co-morbidities like hypertension, diabetes mellitus, liver, cardiac or neurological disease; pre-existing haematologic or coagulation disorder; infection of skin over the back; neuropathy; presence of spinal deformity; patient receiving aspirin, non-steroidal anti-inflammatory medications or any anticoagulant medications; patients with peripheral vascular diseases.

Equipment

Radical-7®; Masimo Corp., Irvine, CA, an instrument containing Masimo Rainbow SET technology use a multi-wavelength sensor to distinguish between oxygenated, deoxygenated blood, blood with carbon monoxide, blood with oxidized hemoglobin and blood plasma was used in this study (Figure 1 & 2). It works on the principal of pulse oximetry which is a continuous and non-invasive method of measuring the level of arterial oxygen saturation in blood. The measurement is taken by placing a sensor on a patient, usually on the fingertip. The instrument displays the calculated data in two ways: A) As a percent value for arterial oxygen saturation (SpO_2), B) As a pulse rate (PR). 14 Sensory blockade was assessed using ether swab method. The dermatome level was assessed every 1 minute until the level stabilized, taken as 4 consecutive tests giving the same result. This was noted as the highest level of spinal blockade. After confirming adequate level of block, the surgery was allowed to proceed. Perfusion index (PI) in upper limb and lower limb, heart rate(HR), systolic blood pressure(SBP), diastolic blood pressure (DBP), mean blood pressure (MBP) was noted at 1, 2, 3 and 5 minutes after SAB then every 5 minutes till 20 minutes after spinal block irrespective of whether the procedure completed or not. Body movements cause changes in the pulse oximetry AC/DC ratio so care was taken to avoid changes in body posture of patient. Applying pressure to the sensor may cause changes in blood flow in the skin microcirculation and so was avoided.

Statistical analysis

For qualitative data, Chi-square test and for quantitative data Student's t-test was applied. For multi group comparisons, Analysis of Variance (ANOVA) was used. Data were entered and coded in MS Excel (Version, 2007) and all statistical analyses were performed by using SPSS software (Version 22, SPSS Inc, Chicago, IL, USA). A p value of <0.05 was considered as significant.

RESULTS

100 patients of either sex of lower abdomen surgery with age range from 18-70 years of ASA grading I-III. The average age of these patients was 55.66±11.44 years. A total of 67 % patients were female and 33% were male. Maximum number of patients (68) were graded ASA II i.e. 60%; followed by ASA I 28% and ASA III 12%. According to block onset, Maximum number of patients had 3 minutes block onset followed by 4 minutes in 32 patients. Mean heart rate at baseline was 87.44±16.52 which showed a significant increase at 1 minute, 2 minutes and 3 minutes to 100±16.68 95.01±16.63 and 91.14±16.91 respectively (P<0.001), decreased to 87.72±17.77 (p>0.05) at 5 minutes and 86.84±52.20 (p>0.05) at 10 minutes.

Fig. 1. Radical-7®; Masimo Corp

Fig. 2. Radical-7®; Masimo Corp., reusable sensor placed over finger covered with opaque cover came with device

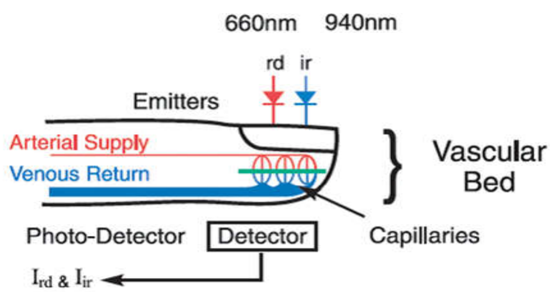

Fig. 3. Principle of Pulse Oximetry

The 15 and 20 min values were 77.17±15.04 and 75.91±15.87 respectively (P, 0.001). We noted that at baseline SBP(mm Hg) was 154.05±21.57 which decreased to 149.65±18.67;

143.36±18.73; 138.7±19.76, 130.46±24.95; 125.18±21.14; 123.71±20.60 and 123.14±20.20 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes respectively. It was observed that at baseline DBP (mm Hg) was 87.99±12.18 which increased to 89.34±11.31 at 1 minute but decreased significantly thereafter to 84.78±12.12, 80.19±12.48, 76.51±14.27; 72.19±11.58; 72.23±11.03 and 72.27±12.53 at 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes respectively. We observed that at baseline MBP (mm Hg) was 114.81±13.55 which decreased significantly to 109.41±11.80; 104.31±12.79; 99.9±13.40, 97.94±16.34; 93.26±15.43; 92.25±14.12 and 92.22±15.20 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes interval respectively (P<0.001) (Table : I).

Table I. Comparison of Mean of mean blood pressure (MBP) (in mm Hg)

Mean Blood Pressure	Mean±SD	Statistical significance
Baseline MBP	114.81±13.55	
1 minute MBP	109.41±11.80	<0.001 Significant
2 minutes MBP	104.31±12.79	<0.001 Significant
3 minutes MBP	99.9±13.40	<0.001 Significant
5 minutes MBP	97.94±16.34	<0.001 Significant
10 minutes MBP	93.26±15.43	<0.001 Significant
15 minutes MBP	92.25±14.12	<0.001 Significant
20 minutes MBP	92.22±15.20	<0.001 Significant

At baseline perfusion index of upper limb was 1.19±1.02 which decreased to 1.11±0.88, 1.06±0.81, 1.01±0.75, 1.01±0.78; 0.93±0.65; 0.85±0.57 and 0.79±0.52 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes respectively. P <0.01 for all readings till 5 minutes and P < 0.001 for 10 -20 minute readings (Table : II). % change was observed from baseline and it is evident from the table II that it decreased continuously from 1 minute onwards till final follow up of 20 minutes.

Table II. Mean comparison of perfusion index of upper limb

Perfusion index	Mean±SD	Statistical significance
Baseline PI	1.19±1.02	
1 minute PI	1.11±0.88	<0.01 Significant
2 minutes PI	1.06±0.81	<0.01 Significant
3 minutes PI	1.01±0.75	<0.01 Significant
5 minutes PI	1.01±0.78	<0.01 Significant
10 minutes PI	0.93±0.65	<0.001 Significant
15 minutes PI	0.85±0.57	<0.001 Significant
20 minutes PI	0.79±0.52	<0.001 Significant

Table III. Correlation of mean sensory block time with perfusion index at various time intervals

Perfusion index	Mean±SD	Sensory block time Mean±SD	Correlation coefficient (r value)
Baseline PI	0.67±0.51	3.78±0.90	-0.123
1 minute PI	1.12±0.58		-0.085
2 minutes PI	1.58±0.93		-0.099
3 minutes PI	2.14±1.36		-0.115
5 minutes PI	2.72±1.78		-0.122
10 minutes PI	3.79±2.40		-0.044
15 minutes PI	4.36±2.74		0.027
20 minutes PI	4.71±2.90		0.042

At baseline perfusion index was 0.67±0.51 which increased to 1.12±0.58; 1.58±0.93, 2.14±1.36, 2.72±1.78; 3.79±2.40; 4.36±2.74 and 4.71±2.90 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes respectively (Table III, CHART : 1). (P<0.001) We noted the % change of mean BP from baseline to final follow up at 20 minutes and found that it decreased continuously. Correlation of mean sensory block time with perfusion index at various time intervals. When we correlated mean sensory block time with perfusion index from baseline to 20 minutes, no significant correlation found (p>0.05). When perfusion index increases continuously from baseline at various time intervals in our study, simultaneous mean blood pressure decreases from baseline. When we correlated the percent increase of perfusion index (LL) with percent decrease of mean blood pressure; statistically it found to be highly significant (p <0.01).

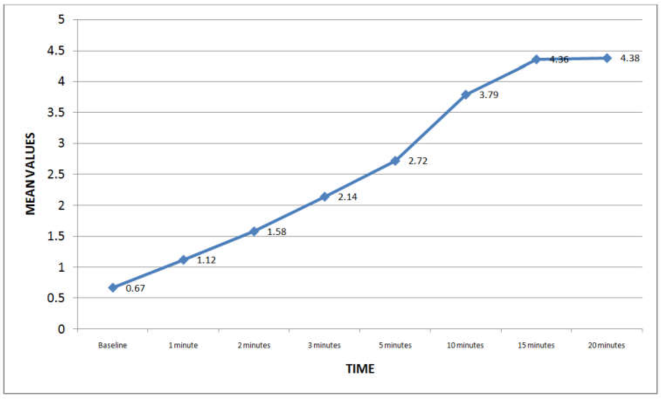

Chart 1. Mean comparison of perfusion index of lower limb

DISCUSSION

The baseline hemodynamic variables viz. heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP) and PI in all the patients at the start of procedure were comparable and did not differ significantly. Mean heart rate increased significantly at 1 minute, 2 minutes and 3 minutes (p value <0.001) and then decreased at 5 minutes and 10 minutes (p value >0.05). The change in the value at 15 and 20 minutes were statistically significant (p value <0.001). It was showing a decreasing trend. The initial tachycardia could be attributed to the anxiety regarding the procedure with the heart rate settling gradually. No patient developed bradycardia requiring treatment. According to Carpenter *et al*. (1992) usually a decrease in heart rate occurs during spinal anaesthesia which is similar to our study except the initial 3 minutes. IclalOzdemirKol *et al*. (Holmes, 1959) also noted a decrease in heart rate after spinal anaesthesia in control group. Conversely, Langesaeter *et al*. (2011) stated that most frequent response to spinal anaesthesia for elective caesarean section is a marked decrease in systemic vascular resistance and partial compensation from increased stroke volume and heart rate. The baseline SBP was154.05±21.57 which decreased progressively at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes to reach a value of123.14±20.20. The decrease observed in SBP values showed statistical significance (p value <0.001). IclalOzdemirKol *et al*. (2009) observed a significant decrease of mean SBP in the control group as compared with baseline. Carpenter *et al.* (1980) conducted study on 952 patients and identified that hypotension developed in 314 patients (33%), bradycardia in 125 (13%), nausea in 175 (18%), vomiting in 65 (7%), and dysrhythmia in 20 (2%). Hypotension was first recognized 50 years back following spinal anaesthesia when it was attributed to caval compression by Holmes (1959). Klohr *et al.* (1999) conducted a retrospective study in which they found that hypotension is most common complication during spinal anaesthesia for caesarean section.

The baseline DBP increased at 1 minute but decreased significantly thereafter at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes interval. DBP (p value <0.001) showed a trend similar to that of SBP. The baseline MBP was 114.81±13.55 which decreased significantly at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes interval respectively. Perfusion index values in upper limb showed a progressive decrease from baseline. We found that at baseline, perfusion index was 1.19±1.02 which decreased to 1.11±0.88, 1.06±0.81, 1.01±0.75, 1.01±0.78; 0.93±0.65; 0.85±0.57 and 0.79±0.52 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 minutes and 20 minutes respectively (P value<0.01). Our study is in concurrence with that of Hiroyuki Sumikura *et al*. (2008) who observed that Perfusion Index- Finger showed a precipitous drop at 5 minutes to value of 3.2 from the baseline value of 4.9 after the spinal anaesthesia. As against these findings, Hyuga *et al* (2012) did not find any change in PI at finger. In fact, PI at the finger and groin remained constant in their study. The mean PI in lower limb at baseline was 0.67±0.51 which increased significantly to 1.12±0.58; 1.58±0.93, 2.14±1.36, 2.72±1.78; 3.79±2.40; 4.36±2.74 and 4.71±2.90 at 1 minute, 2 minutes, 3 minutes, 5 minutes, 10 minutes, 15 and 20 minutes respectively (p value <0.001). Similar trend of increase in PI toe after spinal anaesthesia was observed in the studies of Hiroyuki Sumikura *et al*. (2008) (PI toe increased significantly from a baseline value of 1.7 to 4.5 within 5 minutes) and Hyuga *et al*. (2012) (PI increased up to 600% at 15 minutes). PI values in both these studies showed a plateau at 15 minutes similar to the trend seen in our study. Toyama *et al*. (2013) observed that parturient with higher baseline PI (>3.5) had greater fall in SBP (from the baseline of 130 mm hg to 80 mm hg) at 5 minutes as compared to parturient with low baseline PI(<3.5) in which SBP showed a modest reduction to 110 mm hg from baseline of 120 mm hg. They concluded that higher baseline Perfusion Index was associated with profound hypotension and that baseline PI could predict the incidence of the spinal anaesthesia induced hypotension during Caesarean delivery. Higher PI before spinal anaesthesia indicates decreased peripheral vascular tone which results in blood volume being trapped in the extremities and the sympathetic blockade with spinal anaesthesia would further increase the blood pooling. Thus PI can be used as an indicator of vascular tone.

Zifeng *et al*. (Xu *et al*., 2013) found significant increase in PI following caudal administration of lignocaine in children. PI increased by 2.01 ± 1.19 (representing a 363 ± 318% increase from baseline) and 4.38 ± 1.86 (representing a 778 ± 578% increase from baseline) at five and twenty minutes, respectively, after caudal block. There were no significant differences in MBP and HR following caudal lignocaine administration compared to their baseline values. Ginosar *et al*. (2009) observed that after 20 minutes of epidural anaesthesia, PI increased by 326%, compared with 10% decrease and a 3% increase in MBP and toe temperature, respectively so they concluded that perfusion index was an earlier and more sensitive indicator of the development of epidural induced sympathectomy than either skin temperature or mean arterial pressure. Hajime Yamazaki *et al*. (Sumikura *et al*., 2008) observed that there was 60.5% increase in PI after 5 minutes of stellate ganglion block in the limb and after 15 minutes PI reached a peak with increase of 87.3% from baseline. A higher PI value indicates a stronger pulsatile signal and better peripheral circulation at the sensor site. Because PI is an indicator of peripheral blood flow and peripheral blood flow in the limb is a clinical sign of effective block, increased PI on the site of block may be reliable means to determine the efficacy of a regional block.

As per our results the baseline PI in the upper limbs (1.19) is almost double that of the lower limbs (0.67). The former consistently falls over the first 20 minutes after a successful subarachnoid block while the latter rises from the baseline value during the same time period reflecting a blood shift to the lower part of body. Sumikura *et al*. (Lima and Bakker, 2005) found that PI ratio i.e. PI toe to PI finger increased significantly within 5 minutes. In our study we found that Perfusion index in the lower limbs has a strong negative correlation with the mean blood pressure (p <0.01). Hence an increasing perfusion index is closely followed by a proportionate fall in mean arterial pressure. A rapidly increasing PI should alert the anesthesiologist of possibility of impending hypotension and the need to take corrective action at the earliest. Ginosar *et al*. (2009) reported a 326% increase in PI as compared to a 10% decrease in mean arterial pressure at 20 minutes after epidural anaesthesia. The onset of block was 3 minutes in majority of the patients (44) followed by 4 minutes in 32 patients. Mean (SD) time of onset of sensory block was 3.78(0.9) minutes post spinal anaesthesia. No significant correlation could be found between mean sensory block time and perfusion index (p>0.05). Galvin *et al*. (2006) observed an increase in PI values compared with baseline, beginning as early as 3 minutes after local anaesthetic injection and reaching statistical significance at a time of 12 minutes and 10 minutes for sciatic and axillary block respectively. They also noted that patients with failed blocks demonstrated minimal or no change in PI value suggesting that the increase in PI value is directly related to blockade than serum levels of local anaesthetic.

In 9 patients in our study, PI toe did not increase even after 20 minutes of subarachnoid block. The sensory block in all these patients was adequate as checked clinically and no supplemental anaesthesia was required in these 9 patients. All these patients demonstrated a change in MBP and HR similar to the patients in whom PI had increased significantly. In these patients the failure of PI to increase can be attributed to cold extremities. Other reason could be stress and anxiety that can induce sympathetic activation, which in turn induces peripheral vasoconstriction. Spinal anaesthesia induced sympathectomy results in selective vasodilatation of lower limbs with venous pooling of blood and hypotension. The results of our study support this fact where we found a significant fall in systolic, diastolic as well as mean blood pressure from baseline values (p<0.01) with a simultaneous significant increase in PI values in lower limb (P< 0.001). A more reliable parameter of baseline sympathetic tone and vasodilatation, which gives faster and more easily quantifiable results was studied as a potential tool for reliably and consistently marking onset of sympathetic block even before sensory block has set in. This is the perfusion index which combines simplicity, cost effectiveness, reliability and easy availability. With regard to early and reliable prediction of block outcome, the important factor is not the actual PI value itself, but the relative change in PI value over time, after local anaesthetic injection.

There are some limitations of the present study. Photoplethysmographic analysis is quite sensitive to patient movement, and PI is also easily decreased by several factors such as stress and anxiety that can induce sympathetic activation, which in turn induces peripheral vasoconstriction (Galvin *et al*., 2006). The accuracy of pulse oximeter photoplethysmographic wave analysis has been demonstrated to be greater in patients with higher perfusion status (Broch *et al*., 2011). Although the pulse oximeter used in our study (Masimo Radical 7; Masimo Corp., Irvine, CA, USA) is demonstrated to be useful to monitor peripheral perfusion even in neonates and critically ill neonates (Broch *et al*., 2011; Zaramella *et al*., 2005), these factors may have had a negative effect on the sensitivity and specificity of preoperative PI for predicting hypotension. The drawback in our study was that we imposed an arbitrary criteria on the end point being studied, although these endpoints were based on previous published data. The perfusion index is easy to interpret, however it has a relatively low accuracy compared to advanced techniques like echocardiography.

Conclusion

Perfusion index in the lower limbs has a strong negative correlation with the mean arterial pressure. Perfusion index can be used as a simpler tool to asses the efficacy of spinal anaesthesia and for predicting the hemodynamic responses to anesthetic drugs, techniques of neuroaxial anaesthesia and to intraoperative stimuli. There are some limitations of the Perfusion index. Photoplethysmographic analysis is quite sensitive to patient movement, and PI is also easily decreased by several factors such as stress and anxiety that can induce sympathetic activation, which in turn induces peripheral vasoconstriction

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