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Research Article

Non-invasive Methods to Predict Hypotension after Spinal Anesthesia

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Abstract

Hypotension is a frequent event after spinal anaesthesia. Empiric fluid administration is usually performed to prevent this complication but with the risk of volume overload. Aim of this narrative review is to describe the non-invasive methods currently present in the literature to have a helpful guide in adjusting the volume state to prevent hypotension after spinal anaesthesia.

Keywords: Hypotension; Spinal Anesthesia; Non-Invasive Fluid Challenge

Background

Spinal anesthesia is a technique widely employed in clinical practice. One of the common side effects consists in a reduction of systemic vascular resistances, with systemic hypotension [1-3]. Subarachnoidal administration of local anesthetics is associated with the block of the autonomic nervous system, which controls peripheral vascular tone. Different factors might be related to the risk for hypotensive episodes after spinal block such as anesthetic technique, history of hypertension, basal heart rate and obesity [4,5].

Hypotension is one of the most frequent adverse event of spinal anesthesia with an incidence of 15-33% up to 95% for cesarean section [6,7]. The clinical importance of this adverse effect had been shown in several studies which proved that hypotension correlated with morbidity and mortality [8]. Severe bradycardia and cardiac arrest were reported in healthy patients following neuraxial anaesthesia, with a reported incidence of cardiac arrest of 6.4 per 10 000 associated with spinal anaesthesia and the thirty-day mortality after spinal anesthesia was 6.67% [6]. To prevent this event, blind administration of fluids is usually used but both hypervolemia and hypovolemia can be harmful during the perioperative period [9]. Non-invasive haemodynamic monitoring has permitted to evaluate modifications of heart rate and of blood pressure [10,11]; to prevent morbidity from severe hypotension following spinal anesthesia, it is important to recognize the early signs of hypotension and prompt management of it. The purpose of this narrative review is to describe different methods recently used to predict this hypotension immediately following the subarachnoid anesthesia, before other factors other than the spinal block such as the surgery may interfere with the hemodynamic of patients.

Materials and Methods

We used a variety of sources to collect current data, searching the key words: "Spinal Hypotension", "Spinal Anesthesia", "Hypotension", "Haemodynamic", "Non-invasive", "Artificial Neural Network". Our research included scientific works and ongoing trials from 1992 to 2015 that evaluated non-invasive methods to predict hypotension after spinal anesthesia and we excluded articles that used invasive or semi-invasive methods.

Discussion

The non-invasive methods most used in the prediction of post-spinal hypotension are the transthoracic echocardiography, the bioimpedance and the so-called Passive-Leg-Raising Test.

Transthoracic echocardiography

Donati et al. evaluated the modifications of heart rate, arterial pressure, cardiac output, stroke volume and ejection fraction in 12 patients undergoing to unilateral subarachnoid anesthesia. The monitoring of these parameters was made with Doppler echocardiography technique and the analysis of the Left Ventricular Outflow Tract (LVOT) and of the Velocity Integral Time (VTI) through the parasternal and the apical view. They concluded that the transthoracic echocardiography is very useful as non-invasive haemodynamic monitoring in patients undergoing to unilateral spinal anesthesia [10].

Cabrera et al. enrolled 55 patients who received spinal anesthesia; they used transthoracic echocardiography through the subcostal, apical and parasternal view to measure left ventricular systolic and diastolic volumes, ejection fraction, the Doppler transmitral and tissue inflow velocity and the left ventricular outflow tract velocity before and after the spinal anesthesia. The conclusion was that the reduction in arterial blood pressure after a spinal block might be due to some degree of direct ventricular depression and that the transthoracic echocardiography offered the opportunity to study the haemodynamic status of the patient without invasive methods [11].

In our randomized trial, we studied the role of transthoracic echocardiography to predict hypotension after spinal anesthesia. We randomized 160 patients in two groups: one control group and one in which we evaluated the changes with the breath of the diameter of the inferior vena cava through the echocardiographic subcostal view, to adjust the fluids infusion before the spinal puncture and to prevent hypotension episodes. The results showed a significative decreasing of the rate of post-spinal hypotension related to the fluid assessment through the transthoracic echocardiography [12].

Bioimpedance and bioreactance

Bioimpedance technique is based on the measurements of

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impedance to transmission of a small electrical current throughout the body or chest area. The analysis of the transthoracic voltage amplitude changes is based on the response to high-frequency current [13].

Ouzounian et al. studied if the thoracic electrical bioimpedance could predict the risk for maternal hypotension in 42 patients during regional anesthesia for cesarean delivery (27 had spinal anesthesia and 15 had epidural anesthesia). The authors reported that pregnant women with increased baseline systemic vascular resistance index or systolic blood pressure were predisposed to develop hypotension post-spinal/epidural anesthesia [14].

Due to the limitations associated with bioimpedance in different situations (changes in tissue fluid volume, the distance between electrodes, respiration-induced changes, arrhythmias, acute changes in tissue water, body motion, patient body size, variations with the temperature and the humidity of the skin), it was suggested another method of processing the impedance signal: the Bioreactance.

The Bioreactance measures phase shift of an oscillating current in voltage when current traverses the thoracic cavity instead the bioimpedance measures only the changes in signal amplitude. The Bioreactance can be used as a clinical tool to evaluate volume responsiveness in different clinical settings [13].

Doherty et al. analyzed the haemodynamic changes with a non-invasive cardiac output monitor based on bioreactance in 20 women presented for elective cesarean delivery under spinal anesthesia. They registered different parameters (cardiac output, heart rate, systolic blood pressure, stroke volume, total peripheral resistance, thoracic fluid content at baseline, post-spinal and post-delivery time) to identify rapid haemodynamic fluctuations associated with the anesthetic technique. The conclusion was that the bioreactance may contribute to the improvement of the anesthetic management in obstetrics [15].

In an another study Ledowski et al. have experimented, using an alternating current and a system of electrodes attached to the palmar surface of the hand, the "skin conductance" variables to predict in 40 women scheduled for elective cesarean delivery under combined spinal-epidural anesthesia. The variables measured were the Number of Fluctuations of Skin Conductance per second (NFSC) and the Area Under the Curve (AUC) of the skin conductance fluctuations but none of these variables correlated significantly with the degree of hypotension or showed values predictive of severe hypotension after spinal anesthesia [16].

Passive leg raise test (PLRT)

The Passive Leg Raise Test can predict fluid responsiveness and it is an alternative to predict the haemodynamic response to the fluid administration. It is based on the assumption that the lifting of the legs passively from the supine position into a 45º position of both legs induces a gravitational transfer of blood from the lower limbs towards the thorax. This test is used recently to assess fluid responsiveness considering that the estimated venous pool moved from the legs is about 200-300 ml [17,18].

In an ongoing trial (ProCRHYSA trial) we are evaluating the usefulness of the PLRT to predict post-spinal hypotension in elective surgery. We are using the changes of $etCO_2$ before and after the PLRT to assess the fluid management before the spinal anesthesia to prevent hypotension episodes [12].

Meirowitz et al. recruited 40 women undergoing subarachnoid anesthesia for cesarean delivery. They used the PLRT before the spinal puncture to predict the hypotension and they also used non-invasive haemodynamic monitoring system based on the Bioreactance to evaluate the fluid responsiveness during the PLRT. The results showed that PLRT was not predictive of hypotension during cesarean delivery under spinal anesthesia [19].

Kinsella et al. Norris used to predict hypotension at cesarean delivery after spinal anesthesia the "tilt test", in which 27 recruited patients from the supine position were sitting up straight with the legs hanging down unsupported over the side of the bed. If there was an increase in heart rate or a decrease in systolic pressure the patients would have develop hypotension after the spinal puncture. The authors concluded that this test was not useful to predict hypotension after spinal anesthesia [20].

Other Methods

Artificial neural networks

Artificial neural networks (ANN) are formed from different single units to constitute a neural structure to simulate the human brain processes information; they are able to recognise patterns even from complex data to estimate non-linear relationships [21].

Lin et al. developed an ANN-based predictive model based on fourteen parameters: age, gender, height, weight, hematocrit, ASA, history of diabetes, history of hypertension, emergency or elective surgery, and surgical category, dose of local anesthetics, basal systolic blood pressure, basal diastolic blood pressure and basal heart rate. 1501 patients were recruited for this study; the results showed that the ANN model presented the power in predicting the occurrence of hypotension much better than just clinical judgment.

Continuous non-invasive arterial pressure device

A monitor for Continuous Non-invasive Arterial Pressure monitoring (CNAP) was recently introduced. The principle is to keep the blood volume of the finger arteries constant by applying an exterior pressure to the vessel wall with a cuff around the finger.

Ilies et al. enrolled 65 women to receive a spinal anesthesia for a cesarean section and they compared the CNAP method with the conventional intermittent oscillometric Non-Invasive Arterial Pressure measurement (NIAP). The authors showed that the CNAP demonstrated detection of a higher proportion of patients with hypotension than that found with NIAP [6].

Perfusion index

The perfusion index derived from a pulse oximeter is based on the ratio of the pulsatile blood flow to the non-pulsatile blood in peripheral tissue. Toyama et al. concluded that baseline perfusion index correlated with the degree of hypotension during spinal anaesthesia for caesarean delivery. Hyuga et al. also evaluated that perfusion index changed quickly in response to vasodilation after spinal anesthesia [22,23]. The perfusion index is easy to interpret, however the relatively low accuracy compared to other techniques

Table 1: Brief summary of non invasive methods to determine hypotension after spinal anesthesia.

	ADVANTAGES	DISADVANTAGES
TRANSTHORACIC ECHOCARDIOGRAPHY	Titrated fluid therapy Real time results	Not always praticable Procedural time Availability Operator dependent
BIOIMPEDANCE/ BIOREACTANCE	Reproducibility Ease of application	Difficulties in accuracy
PLRT	Reproducibility Titrated fluid therapy	Discordant results Procedural time
ANN	Detecting relationships between several variables	Interpretation of results
CNAP	Reproducibility Ease of application	Difficulties in accuracy Not comfortable Can't prevent spinal hypotension
PERFUSION INDEX	Reproducibility Ease of application Convenience	Difficulties in accuracy Can't prevent spinal hypotension

appear to be the great limit of this method in clinical practice; compared to echocardiography and to PLRT, the perfusion index cannot preview the risk to developing post-spinal hypotension, rather it can quickly detect spinal hypotension after its development.

Conclusion

The non-invasive methods to predict post-spinal hypotension can be very helpful to avoid severe complications, particularly in patients with high cardiovascular risk (Table 1). The perfusion index is a useful, simple and convenient which exploits the already widespread use of the pulse oximeter in the operating room completing its evaluation immediately after the development of hypotension, but it can't prevent the hypotension before the spinal anesthesia. Transthoracic echocardiography is reproducible, easily and quickly performed in the majority of patients and useful to perform a titrated fluid therapy; the bioreactance method was useful in predicting and correcting hemodynamic changes related to anesthesia; the results for the Passive Leg Raise Test are controversial about its utility and, as well as for the other methods, no study has performed a comparison of diagnostic accuracy between different non-invasive methods. Further studies are therefore needed to evaluate the real usefulness in predicting hypotension after spinal anaesthesia. The use and development of these methodologies can be a first step toward developing a vision of a fluid-challenge therapy fit to the patient's volume status and no longer an empirical therapy.

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