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Review

The passive leg raising test (PLR)☆

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ABSTRACT

Introduction: The passive leg raising test (PLR) allows physicians to determine which patients require treatment with intravenous fluids.
Objectives: It is important to be aware of tools that help us to determine the response to the passive leg raising test, as well as understanding in which clinical situations it can be performed.
Materials and methods: Non-systematic review. Medline and PubMed databases were consulted in search of relevant articles.
Results: Through echocardiography, pulse pressure and capnography can be determined as a response to leg raising.
Conclusions: This article explores the tools that are useful in determining the response to this maneuver, and the clinical conditions in which it is indicated.

Prueba de elevación de piernas pasiva

Palabras clave:
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Ultrasonografía
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RESUMEN

Introducción: la prueba de elevación de piernas pasivas permite determinar en qué paciente se requiere manejo con líquidos endovenosos.
Objetivos: es importante conocer las herramientas que ayudan a determinar la respuesta a la prueba de elevación de piernas pasiva, además conocer en qué situaciones clínicas se puede realizar.
Materiales y métodos: revisión no sistemática. Se consultaron las siguientes bases de datos Medline y Pubmed, en búsqueda de artículos relevantes.
Resultados: mediante ecocardiografía, presión de pulso y capnografía se puede determinar la respuesta a la elevación de piernas.

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Conclusiones: el presente artículo explora las herramientas que son útiles para determinar la respuesta a esta maniobra y las condiciones clínicas donde se indica.

Introduction

When we approach a patient with circulatory shock, we always ask ourselves if this patient requires resuscitation with intravenous fluids. More or less 50% of patients in the Intensive Care Unit (ICU) respond to the administration of intravenous fluids. This response is defined as an increase in Cardiac Output (CO) between 10% and 15% after the administration of intravenous fluids[1,2].

Energetic resuscitation with intravenous fluids can contribute to the development of pulmonary edema, respiratory failure, prolonged periods of mechanical ventilation, and abdominal hypertension[3,4]. Furthermore, the positive balance of fluids is related to an increase in mortality[5]. Directed therapy reduces the incidence of thirst, drowsiness, postoperative nausea, morbidity, and serum acid levels, as well as the length of hospital stay, the number of postoperative complications, the duration of mechanical ventilation, and days in the ICU[6–13]. As such, it is crucial to appropriately direct fluid therapy.

Materials and methods

This is a non-systematic review. The Medline and PubMed databases were consulted. The following keywords were chosen for the searches: fluid responsiveness, stroke volume, blood flow, shock, Doppler, echocardiography. These were related with: intra-abdominal hypertension, pulse contour analysis, pulse pressure variation, systolic pressure variation, systolic volume variability, respiratory distress syndrome, and pediatrics.

Results

There are several tests that allow us to assess the probability that a patient will respond to therapy with intravenous fluids. The static measures of cardiac preload, filling pressure, and volume are poor predictors of fluid responsiveness[1,14,15]. Dynamic measures, based on heart–lung interaction, like Systolic Blood Pressure Variation (SBPV), Pulse Pressure Variation (PPV), and Stroke Volume Variability (SVV) have been shown to be good indicators of the need for fluid therapy[2,16–20]. In clinical situations where there is no heart–lung interaction, these variables are not appropriate[21]. An example would be a patient with spontaneous respiration and arrhythmias.

The response to passive leg raising (PLR) has turned out to be a good indicator of response to fluid. The PLR test is a reversible maneuver and simulates a rapid infusion of fluids since the blood moves out of the lower limbs[22] and the abdominal compartment[23] through the intra-thoracic compartment[24]. This leads to an increase of left and right cardiac preload (autotransfusion), with later temporary increase in stroke volume (SV) and cardiac output.

Physiological response to leg raising

PLR mobilizes an average of 300 ml of blood from the lower limbs[13] and could move a bit more blood if it is initiated in the semi-sitting position, since it also mobilizes blood in the abdominal compartment[14]. The increase in volume in patients dependent on preload leads to an increase in SV. These changes are reversible and rapid. It requires quick methods for measuring CO or SV. For this reason, the thermodilution method is not applicable, even in automatic and semi-continuous modes, because these methods require at least 10 min to detect changes in CO. There are different ways of determining the response to this test, such as the increase in aortic blood flow through esophageal Doppler, changes in pulse pressure, VTI (velocity time integral), cardiac output (CO) (through transesophageal echocardiogram or transthoracic echocardiogram) and stroke volume (SV) (TEE, TTE or Vigileo).

In theory, the best indicator of response to PLR is the increase in SV or CO. Aortic pulse pressure is directly proportional to the SV of the left ventricle, and if arterial distensibility is not altered, the pulse pressure should show an increase in SV. Boulain et al[25]. found a relationship between changes in radial pulse pressure (PP) and SV ($r = 0.77$, $p < 0.001$) during PLR. PP increase is maintained for up to 4 min. The correlation indexes are adequate but not excellent. This is due, certainly, to the fact that radial pulse pressure does not reflect changes in pressure of the aortic pulse due to phenomena of propagation and reflection of the pressure wave during changes in blood flow induced by the raising of the legs. This study was conducted on a patient undergoing controlled mechanical ventilation and calculating CO with a pulmonary artery catheter[25].

The esophageal Doppler provides an adequate measure of blood flow in the descending aorta. This is a good indicator of overall CO[26] and has a good correlation with the pulmonary artery catheter[27]. Lafanechere et al[28]. wanted to improve the predictive value of this test through a more direct method for estimating SV. Through respiratory changes of the pulse pressure and changes in blood flow in the descending aorta, they found that an increase in blood flow in the descending aorta by more than 8% with the raising of the legs predicts fluid response with a sensitivity of 90% and a specificity of 83%. The positive predictive value is 82% and the negative predictive value is 91%. Pulse pressure variation greater than 12% has a sensitivity of 70% and a specificity of 92%[28].

Changes in pulse pressure due to changes in SV also depend on arterial compliance and vasomotor tone[29]. For this

reason, Monnet et al[30]. in their study compared changes in aortic blood flow, PPV, and PP during leg raising in two types of patients: those under controlled mechanical ventilation and without arrhythmias and those with invasive spontaneous ventilation and arrhythmias. They found that an increase in blood flow greater than or equal to 10% with PLR predicted fluid response with a sensitivity of 97% and a specificity of 94% (ROC 0.96). This increase in flow occurred after 30 s. An increase in PP greater than or equal to 12% with PLR predicted fluid response with a sensitivity of 60% and a specificity of 85% (ROC 0.75). In patients under controlled ventilation and without arrhythmias, a PPV greater than 12% predicted fluid response with a sensitivity of 88% and a specificity of 93%. In patients that presented spontaneous breathing on the ventilator and arrhythmias, the specificity of the PPV falls[30].

Nevertheless, measuring aortic blood flow with an esophageal Doppler can be more uncomfortable since it requires profound sedation and cannot be performed on patients without invasive ventilation. Negative intrathoracic pressure during mechanical ventilation can change the amount of increase in blood volume and the response of baroreceptors. Added to this, arterial tone may be modified during sedation, which changes the response to the increase or decrease in volume[31]. The data from the above studies was found from intubated and sedated patients. Thus we recommend that these studies be validated in non-intubated patients.

Lamia et al[32]. studied the effects of PLR measured with a transthoracic echocardiogram (TTE) and compared them to echocardiographic preload indicators, such as the Left Ventricular Diastolic Area index (LVEDAi), and the relation to diastolic peak wave velocity/lateral mitral annular early wave velocity (E/Ea). They calculated the SV as the product of velocity time integral (VTI) and the area of the aortic valve. They found that the peak of the VTI occurred within the first 90 s of PLR. If this maneuver induces increases in VTI, and thus the stroke volume index (SVI), by 12.5% or more, it predicts an increase of 15% or more in the SVI after the infusion of fluids with a sensitivity of 77% and a specificity of 100% in intubated and non-intubated patients. Preload indicators (LVEDAi and E/Ea), however, do not predict fluid responsiveness[32]. In the study by Maizel et al[31]., they also used TTE on non-intubated patients and showed similar results[31]. In a study by Préau et al[33]., good sensitivity and specificity of PLR was also found for measuring changes in SV with TTE in non-intubated patients with sepsis and pancreatitis. These studies allow us to measure the response to PLR with TTE in patients that are not under invasive mechanical ventilation to determine the need for intravenous fluids.

The aforementioned studies have several limitations. To calculate SV with TTE or TEE, the aortic diameter is required to calculate the aortic area. The aortic diameter can change due to an increase in SV[34]. These studies[31–33], and the use of esophageal devices that consider aortic diameter to be constant, can increase the false negative rate and thus under estimate the response to intravenous fluids. Inter-observer variability in these studies is less than 5%, which means that less experienced researchers may not obtain the same results[35].

Another, more simple, way of determining PLR response, and that is available in Colombian operating rooms and ICUs, is capnography. The quantity of exhaled CO_2 is proportional to CO in stable patients from the respiratory and metabolic point of view. Monnet et al[36]. determined their role in patients under controlled mechanical ventilation with or without arrhythmia. They found that an increase in exhaled CO_2 ($ETCO_2$) greater than 5% with PLR predicts an increase in cardiac index (CI) greater than 15% with a sensitivity of 71% and a specificity of 100%, with a significant area under the curve (AUC) (0.93) and acceptable correlation indexes ($r^2 = 0.45$)[36].

PLR requires the quick determination of CO. Biais et al[37]. tried to determine changes in CO through Vigileo and TTE in patients under spontaneous ventilation. They found an increase in SV with TTE after PLR in the first 90 s, just as in Lamia's study. They also found an increase in SV with Vigileo after PLR within the first 2 min with acceptable correlation indexes ($r^2 = 0.56$)[37]. This result is expected for several reasons. First, the measures for calculating CO with Vigileo are based on heart–lung interaction, which is lost in spontaneous ventilation[21]. Second, Vigileo in patients with pathologies involving low systemic vascular resistance is not appropriate[38–40]. The same is true for critically ill patients[41].

Importance of the position

Leg raising mobilizes an average of 300 ml of blood[22], and if it is initiated in the semi-sitting position, it could mobilize an additional 150 ml of blood in the abdominal compartment[42]. Jabot et al[23]. studied the hemodynamic effect of initiating the PLR maneuver in the semi-sitting position versus the supine position. They found that, if PLR is initiated in the semi-sitting position, the cardiac index increases more than if it is initiated in the supine position. This effect is due to blood gathering from the splanchnic compartment[23].

We must take into account that the studies were conducted in a 45° semi-sitting position[30,32], 30° semi-sitting position[31], or in supine position[25,28]. The meta-analysis from Cavallaro et al[43]. found no differences between initiating PLR in dorsal decubitus[43].

Passive leg raising test in pediatrics

Like aortic peak flow velocity, PLR predicts an increase in CO in the pediatric population, unlike certain dynamic variables (PPV, SVV, SBPV)[44].

Clinical situations in which the passive leg raising test may not be performed

The increase in intra-abdominal pressure leads to important hemodynamic changes in patients in the ICU and surgical units. It leads to an increase in mean arterial pressure (MAP) and SVR, and a decrease in cardiac output secondary to a decrease of blood flow in the vena cava due to collapse[45]. Furthermore, the increase in intra-abdominal pressure leads to a reduction in pulmonary compliance, which may alter heart–lung interaction. PPV and SVV increase when intra-abdominal pressure increases and continue to be adequate indicators of hypovolemia in this clinical situation[46,47]. The

incidence of elevated intra-abdominal pressure (IAP) in critical patients (defined as IAP greater than or equal to 12 mmHg) is 50%. The incidence of abdominal compartment syndrome (IAP greater than or equal to 20 mmHg) is 8%[48,49]. PLR could have false negatives in this kind of patient. Mahjoub et al[50]. found that intra-abdominal pressure greater than or equal to 16 mmHg has a false negative rate of 48% for PLR with a sensitivity of 100% and a specificity of 87.5%[50].

In patients with Adult Respiratory Distress Syndrome (ARDS), there are alterations to pulmonary compliance. This is a condition that requires an adequate heart–lung interaction in the patient under invasive controlled mechanical ventilation and sinus rhythm. The dynamic variables, like pulse pressure variation, require pulmonary compliance to be adequate to properly predict fluid responsiveness[2]. Monnet et al[51]. found that in patients with pulmonary compliance under 30 ml/cm H_2O under controlled mechanical ventilation and sinus rhythm, PPV is less acute for determining the need for fluids compared to PLR and the end-expiratory occlusion test (ROC PPV 0.69, PLR 0.94, end-expiratory occlusion test 0.93)[51].

Conclusions

PLR is a maneuver that allows physicians to determine which patients require fluid therapy. The response can be determined through an increase in CO or SV with a transesophageal Doppler, a transthoracic echocardiogram, and increase in VTI, PP, and so on. This type of maneuver presents false negatives in patients with increased intra-abdominal pressure. It is superior to PPV in patients with ARDS and pulmonary compliance under 30 ml H_2O.

Conflicts of interest

The authors have no conflicts of interest to declare.

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