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Fluid therapy in the peripartum

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Summary

Perioperative fluid therapy remains controversial in terms of the type and quantity of fluid to be administered, and its indications. In this review, we revise the key points in order to establish physiological changes during pregnancy and their importance, to assess the haemodynamic effects of anaesthetic techniques in pregnant woman, to distinguish the possible causes of hypotension in pregnant woman, to perform a critical and individualised assessment of pre-hydration with a risk-benefit balance and selection of the most appropriate intravenous solution. We also report on hydroelectrolytic restoration in special cases: delivery, hypertensive disorders of pregnancy and Caesarean sections, and review the literature and most recent meta-analyses on the issues studied. *Anestezjologia i Ratownictwo 2010; 4: 450-458.*

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Introduction

The principles of perioperative fluid therapy were established in the late 1950s and early 1960s, but controversy remains about the type and quantity of fluid to be administered, and its indications.

A relatively constant volume of fluids and a stable composition of body fluids are necessary to maintain homeostasis. During delivery, the total volume of intravenous liquids is determined by the amount of compensatory volume expansion (intravascular compartment volume – ICV). The aim is to avoid secondary hypotension to vasodilation caused by anaesthesia and to correct hypovolaemia, thereby ensuring adequate cardiac output for supply of the oxygen needed and a normal concentration of electrolytes and glucose. This is achieved by administering physiological solutions that contain components with colloid osmotic and oncotic effects (isotonic and iso-oncotic solutions), meet minimum hydric requirements and restore cutaneous, intestinal or renal (extracellular compartment volume [ECV]) deficits, among others [1].

The most widely used intravenous solutions include fluids with glucose/dextrose crystalloids, normal and balanced saline solutions and Hartmann solution (complex sodium lactate). However, intravenous injection during delivery is not free of adverse effects. The administration of large volumes of intravenous glucose (> 25 g glucose) can lead to hyperglycaemia in the mother and iatrogenic hyperinsulinism in the foetus, as well as subsequent postnatal hypoglycaemia and jaundice. Another potential risk of the excessive administration of large amounts of salt-free intravenous solutions is acute dilutional hyponatraemia in the mother and newborn. Other reported adverse effects include headache, sickness, maternal overhydration, delay in delivery efforts and difficulty in establishing breast-feeding. Intravenous treatments may also cause pain and local discomfort and restrict the freedom of movement of the mother during delivery [2].

The Spanish Association of Gynaecology and Obstetrics (SEGO) considers that the final aim of care guidelines for dilation and delivery is to assure proper health conditions for the mother and the newborn, as listed in their 2008 recommendations (www.prosego.es). They emphasise that excessive administration of fluid should be avoided, since a large amount of fluid is mobilised [1] in the postpartum.

The anaesthetist needs to be able to accurately assess the intravascular volume and restore it with isotonic and iso-oncotic colloid solutions, as well as restore extracellular liquids, as appropriate, using isotonic crystalloid solutions. Errors in fluid reposition or transfusion can produce major morbidity or even death.

Compensatory volume expansion

Regional analgesia offers the best risk/benefit profile for the mother and foetus in the control of delivery pain. In Caesarean sections, subarachnoid anaesthesia has been the approach of choice since confidential surveys in England and Wales demonstrated, 20 years ago, that airway management problems were the first cause of death in obstetrics anaesthesia [2].

The adverse effect most frequently associated with subarachnoid block during Caesarean section is hypotension (fall in systolic pressure to <100 mm Hg or decrease of 20% in baseline arterial pressure). The incidence is very high, with some authors reporting hypotension in 70-80% [3] of patients and others in 100% [4]. A level of block of around T6-T4 is considered appropriate for a Caesarean section (T6 is thought to be sufficient). A sympathetic block appears to be caused by regional anaesthetics acting on α-preganglionar fibres, producing vasodilation and a reduced venous feedback, which can be aggravated by aortocaval compression from the gravid uterus; these changes result in hypotension and a decrease in cardiac output [5].

There is an increase in blood volume from the start of pregnancy, reaching 40% by the time of delivery, and there is a greater increase in plasma (45%) than red blood cell (15-20%) volume, leading to dilutional anaemia or "physiological anaemia of pregnancy". The increase in hypervolemia is due to the effect of the renin-angiotensin-aldosterone system on sodium and water retention and to the action of oestrogen and progesterone hormones. The decrease in peripheral vascular resistances favours this increase in volemia, which is necessary to meet the increasing demands of the uterus and placental-foetus unit. Blood losses are around 400-500 mL in vaginal delivery and 800-1000 mL in Caesarean section, which are completely restored by the increased blood volume [6-8].

During pregnancy, there is a 30-40% increase in cardiac output to satisfy maternal and foetal metabolic requirements [6-8]. This can be achieved by a 30% increase in systolic volume (SV) and by a 15% increase in the heart rate (HR). During delivery, uterine contraction and a lesser compression on the inferior cava vein can produce an increase in cardiac output of up to 50%. During the early postpartum period, an increase in cardiac output of up to 80% is produced by the uterus involution, with a return to normal values at around 2 weeks post-delivery. Despite the increases in blood volume and cardiac output, a fall in diastolic and mean arterial pressures is produced by a decrease in peripheral vascular resistances in the gestant [7]. Blood pressure (BP) increase during pregnancy is considered pathological, except at the delivery, due to the major increases in cardiac output at that time.

From week 24 of gestation, the inferior vena cava is compressed in the supine decubitus position by the gravid uterus, leading to a decrease in cardiac output (35-50%) and a variable decrease in the downstream blood flow. During the last months of gestation, around 15% of pregnant women suffer from supine hypotension syndrome, whose symptoms include hypotension, pallor, perspiration, nausea and vomiting. At this stage, the abdominal aorta is compressed by the uterus when the gestant is in the supine position [6,7].

Maternal hypotension is associated with higher aspiration risk (due to sickness, vomiting), hypoxia, acidosis, or even loss of consciousness (from cerebral hypoperfusion) in the mother, and with neurological injury in the foetus since the uterine flow is perfusion-pressure dependent at the end of gestation [9-11]. Hypotension has also been related to weak neonatal breastfeeding reflexes [12] and breast-feeding difficulties [13]. The effects on the foetus vary according to the intensity and duration of the hypotension. Placental hypoperfusion results in foetal bradycardia. Transient hypotension causes foetal or umbilical cord pH changes, while a four-minute hypotension results in foetal hypoxia and neonatal alterations [14,15]. All of these effects depend on the time period between administration of the anaesthetic blockade and the foetal extraction, with the uterine cut-foetal extraction interval being especially important.

Hanss *et al*. [16] recently reported a high variability in the impact of hypotension and the response to treatment in terms of an imbalance between the sympathetic and parasympathetic system, based on an HR variability analysis (low rate/high rate ratio). In addition, there is a reduction in the sensitivity of α and β adrenergic receptors, leading to a decreased response to catecholamines [7].

Several studies have demonstrated the effects of fluid therapy on the prevention of hypotension during vaginal delivery or Caesarean section with regional or subarachnoid anaesthesia, respectively. Since Wolmann [17] introduced the prehydration concept, the most widespread prophylactic measure against hypotension has been vascular restoration via intravenous crystalloids or colloids. Initial studies [17,18] found that the administration of crystalloids in doses of 10-20 ml/kg^{-1} before subarachnoid anaesthesia, reduced the incidence and severity of hypotension due to neuroaxial blockade. However, these results have been questioned by several studies on prehydration guidelines [19-23], based on the ineffectiveness of crystalloid solutions, perhaps due to their short intravascular life [23]. Some investigators recently reported that crystalloid preload had no effect on the impact or severity of hypotension [24]. The introduction of crystalloid solutions to restore volume produces an increase in ECV, leading to a weight increase. Crystalloid solutions also decrease the albumin concentration and hence the colloid osmotic pressure, resulting in water movement from the ICV to the ECV, and oedemas. They have also been associated with dilutional anaemia, leading to a reduced oxygen transport capacity or pulmonary oedema [23,25].

As an alternative, prehydration with colloids has demonstrated to be more appropriate than with crystalloids, decreasing the incidence of hypotension, increasing output and maintaining the colloid oncotic pressure [26].

Several commercial **colloids** are available, with different pharmacokinetic and pharmacodynamic characteristics. They can be classified as natural or synthetic. Natural colloids include albumin, while there are three groups of synthetic colloids: dextran, gelatin and hydroxyethylstarch (HES).

Albumin is not commonly used in volume restoration therapy and is restricted to cases of hypoalbuminemia (<20 g/L) or allergy to synthetic colloids, or when the maximum colloid dose must be exceeded. With the use of colloids, there may be a risk of transmitting infections such as hepatitis C.

Dextrans are polysaccharides obtained from sucrose and transformed into glucose polymers. They are the least used synthetic colloids due to their adverse effects. Dextrans cause alterations in dose-dependent haemostasis and affect the renal function, and are associated with a higher incidence of allergic reactions in comparison to HES [27-29].

Gelatins are polypeptides from animal collagen degradation. The polydispersity of gelatin molecules ranges between 15,000 and 90,000 daltons. Because of this low molecular size, they are rapidly eliminated by the kidney and their expansion is therefore only maintained for 2-4 hours. Allergic reactions are the most frequent adverse effect of gelatin administration. There is also a risk of the transmission of bovine spongiform encephalopathy (prion) [30].

Hydroxyethylstarches (HES) are modified natural polymers extracted from corn and potatoes. They are rich in amylopectin and possess volume expansion properties. Their physical and chemical characteristics can be defined by the degree of hydroxyethylation and the C2/C6 hydroxyethylation ratio, which are the two major determinants of their circulating half-life, and by their molecular weight (MW), which determines their colloid activity. Thus, for the same serum concentration, the number of molecules depends on the MW. MW is the key parameter in assessment *in vivo* of the colloid osmotic effect, pharmacokinetics, plasma and tissue accumulation, and adverse effects on coagulation and renal function. Colloid osmotic pressure depends on the number of molecules present, which is determined by dividing the product concentration by the MW. A low MW *in vivo* implies that the solution is more readily eliminated, with a lower accumulation in plasma and tissue. Alterations in coagulation and renal functions also depend on the MW and concentration of HES.

The adverse effects of HES include coagulation disorders, associated with alterations in the binding and concentration of Factor VIII/Von Willebrand Factor, and with platelet adhesion changes. These effects have been more frequently reported in HES with a higher MW and are virtually absent in the new generation of HES (e.g., 6% HES 130 / 0.4 / 9; Voluven®), even at high doses (up to 50ml/kg weight) [31-34].

Comparative studies concluded that colloidal solutions, such as 6% HES solutions (Elohe®, Voluven®), are more effective to restore intravascular volume than

gelatins, present lesser allergenic potential and cause less coagulation compared with other colloidal solutions [9,22,35,36]. On the other hand, Butwick and Carvalho [37] reported that infusion of 500 ml 6% HES (Hespan®), a previous-generation HES with a MW of 200 kD, causes a mild impairment in haemostasis that is not caused by 1500 ml of Ringer-lactate. Nevertheless, these changes are within the range of standard values and their clinical relevance has yet to be determined.

It is difficult to draw conclusions from meta-analyses due to the distinct colloids sold in different countries and used in the studies [38]. Moreover, it was recently reported that patients with a certain genetic predisposition (β2 adrenergic receptor genotypes) need lower volumes to treat hypotension after subarachnoid anaesthesia in Caesarean sections [39].

Several studies have demonstrated a longer intravascular persistence of colloids than of crystalloids [22]. Thus, only 28% of the total volume of Ringer-lactate remains present after 30 min, compared with 100% of HES. The output was higher and the incidence of hypotension was lower in patients receiving HES than in those receiving Ringer-Lactate [26]. In order to maintain proper osmotic pressure, colloid prehydration requires a small amount of volume infusion [35,40]. The longer intravascular permanence of colloids also means that they must be properly titred to avoid overhydration and the above-mentioned adverse effects, including acute hyperoncotic renal failure [4]. However, it should be borne in mind that not all HES products are the same, and Voluven® has proven to be safe at the renal level).

With regard to the controversy between colloids and crystalloids, a recent meta-analysis [24] concluded that crystalloids were more effective than no fluid administration (relative risk [RR] 0.78, confidence interval [CI] 95% 0.60 to 1.00, one trial, 140 women, sequential analysis), and that colloids were more effective than crystalloids (RR 0.68, 95% CI 0.52 to 0.89, 11 trials, 698 women) in preventing hypotension after subarachnoid anaesthesia in Caesarean sections. No differences were found as a function of dosage, infusion rate or colloid or crystalloid administration method.

Intravenous fluid administration before subarachnoid anaesthesia for Caesarean section is accepted as a standard anaesthetic practice [25]. However, prehydration cannot be considered a completely harmless technique. The risk/benefit relationship should be taken into account in all patients. One possible effect of fluid infusion overload is a decrease in colloid osmotic pressure, which is already diminished in pregnancy. Alongside elevated central venous pressure, this reduction increases the risk of acute pulmonary oedema, especially in the postpartum period, due to autotransfusion caused by uterine involution [23,35]. In addition, the diastolic volume increase can induce a further release of atrial natriuretic peptide with a vasodilator effect, thereby increasing the vasodilation of the spinal blockade and aggravating the hypotension [20,41]. For this is currently considered that fluid loading should begin at the time that the local anaesthetic is starting to take effect (after induction of spinal anaesthesia or coload) [42]. It was reported that the increased in preload produced by the administration of intravenous, reduces but does not eliminate, intraoperative hypotension [35].

Hypotension is decreased by the intravenous administration of fluids before epidural analgesia with high-dose local anaesthetics, but not with low doses of the newer local anaesthetics, probably due to a lower risk of hypotension with these drugs. There is inadequate evidence to determine whether preloading is beneficial for women being administered low-dose regional analgesia during labour, or for women with pregnancy complications [43].

Basic hydric requirements

In the absence of liquid intake, fluid and electrolyte deficits can rapidly develop as a result of continuous urine formation, digestive secretions, sweating and losses from skin and respiratory tract. Normal maintenance requirements are shown in Table 1.

Table 1. Estimate of maintenance fluid requirements

Weight	Speed
For the first 10 kg	4 ml/ kg /h
From 10 to 20 kg	2 ml/ kg /h
From 20 kg onwards	1 ml/ kg /h

As these losses are usually hypotonic (more water than sodium loss). The most frequently used solutions are of the Ringer Lactate type because, besides adding NaCl from the physiological serum, the typical acidity of tissue injury is prevented by the lactate buffer (Table 2).

Table 2. Characteristics of the most widely used colloids in Spain

	Succinyl Gelatin (Gelafundina)	HES 200/0.5% (Hemohes 6%)	HES 130/0.4% (Voluven)
Expansion effectiveness	90-100%	100%	100%
Duration of expansion effectiveness (approximate hours)	4-6	4-6	4-6
Dose limit	no	33mL $Kg^{-1}d^{-1}$	50mL $Kg^{-1}d^{-1}$
Nephrotoxicity	No	Lower	Lower
Elimination route	Glomerular Filtration + Metabolized by proteasas to a lesser degree	Glomerular Filtration+ serum α-amylase fragmentation	Glomerular Filtration+ serum α-amylase fragmentation
Permits + 37ºC	No	Yes	Yes
Raw material	Bovine	Corn Starch	Corn Starch
Alteration of haemostasis	No	Slight decrease in F VIII and vW Factor	Slight decrease in F VIII and vW Factor
Tissue accumulation	No	Lower	Lower
Molecular weight (KDaltons)	30	200	130
Molecular weight (number). Mn	23-200	~ 80,000	~ 70,000
Presence of Ca	No	No	No

Taken from Basora M *et al* [38]

A balanced electrolyte solution represents a plasma electrolytic pattern with regard to sodium, potassium, calcium, magnesium, chloride, anions, phosphate and mainly bicarbonate or metabolised ions. The intake of balanced solutions automatically corrects any electrolyte disorder in the ECV and would therefore, except for a potential volume overload, be free of iatrogenic effects.

New findings on the physiology of the digestive system have raised questions about the desirability of an extended preoperative fasting period [44], and a shortening of the fasting period can yield favourable results in certain circumstances. Fasting during labour is a widespread practice in obstetrics but is supported by few scientific studies. This measure was widespread in the 1940s, after the report by Curtis Mendelson on the devastating effects of acid aspiration syndrome (AAS) on pregnant women [45].

The risk of AAS during pregnancy is often attributed to an increased gastroesophageal reflux (from a uterine growth-induced rise in intra-abdominal pressure [46] and progesterone-induced decrease in the tone of the lower oesophageal sphincter tone) and to an increased volume and acidity of gastric content due to gastrin-like activity synthesised in the placenta [47,48]. The result is an increase volume and acidity of gastric contents with a delay in emptying (especially since the second trimester of pregnancy [49].

During delivery, the risk of broncho-aspiration is increased by the gynaecological position and Valsalva manoeuvre. There are also evident anatomical changes that increase the incidence of failed intubation during Caesarean section [2], including weight gain, enlarged breasts, tissue oedema and change in Mallampati grade [50]. Contradictory results have been published by different gastric-emptying studies in the postpartum period [51-55].

The intake of small amounts of clear fluids or isotonic drinks is currently accepted because they do not appear to increase the risk of AAS [56-58]. There is no evidence to justify oral fluid restrictions after an uncomplicated Caesarean section [59,60].

Replacement of previous deficits

Deficit in patients is usually proportional to the length of the fasting period and can be estimated by multiplying the normal maintenance index by the hours of fasting.

Abnormal fluid losses often contribute to previous deficiencies. Haemorrhage, vomiting, diuresis or diarrhoea often contribute to a larger deficit. Hidden losses (redistribution) due to oedema fluid retention are important. Increased fluid losses caused by hyperventilation, fever and sweating are also often overlooked. Ideally, any deficits should be replaced by balanced solutions before surgery in all patients, and the fluids should be similar in composition to the fluids lost.

Hypertensive states of pregnancy comprise a heterogeneous group of pathological processes linked to pregnancy whose common factor is blood pressure increase [61]. Vasospasm appears to be the main pathophysiological element underlying all multisystemic repercussions characteristic of pre-eclampsia. There is a 10-15% decrease in plasma volume in pre-eclampsia versus normal pregnancy. A reduction in plasma volume is characteristic of pre-eclampsia and is a risk factor for hypovolemic shock. Pre-eclampsia is also associated with widespread vasospasm, increased systemic vascular resistance (SVR), decreased or normal PVC-PCP values and varying cardiac output. The vascular bed loses its resistance to the pressor effects of angiotensin II, to which it shows extreme sensitivity. In conclusion, pre-eclampsia appears to be primarily characterised by an increase in aggregability and platelet consumption associated with an exaggerated activation of clotting fibrin deposits in different organ systems, with subsequent reactive fibrinolysis [6,62].

There is no unanimity [26, 63-65] on the need for prophylactic volemia expansion in patients with pre-eclampsia/eclampsia because of differences in their haemodynamic patterns. Since the scientific evidence is inconclusive, there is a tendency to apply only a prudent volemia expansion [6, 66], above all because such patients are at high risk of acute pulmonary oedema, of which excessive fluid administration is a major cause. When using hypotensive agents or techniques that produce hypotension (subarachnoid or epidural anaesthesia or both), volemic expansion is required to avoid abrupt falls in BP, which may compromise uteroplacental irrigation and cause acute foetal distress [6,8]. Although there is no agreement on the quality or amount of intravenous fluids to be administered, colloidal solutions are used because intravascular protein loss secondary to endothelial damage is the main cause of decreased oncotic pressure in pre-eclampsia [8].

Relatively little data have been published on clinical practice in this respect, but there appears to be an increase in the use of plasma expanders at the expense of albumin in this type of patient. There is no consensus on the type or amount of product or on the duration of treatment. Appropriate monitoring is required during and after prehydration with plasma expanders [67].

Two systematic reviews have been published on the effectiveness and safety of plasma volume expansion in non-pregnant, critically ill patients. The first addressed the use of human albumin for expansion and concluded that it does not decrease the risk of death [68]. The second study compared colloid with crystalloid solutions during resuscitation, also concluding that colloid administration does not decrease the mortality risk [69]. These reviews led to a recommendation by the English Committee on Safety of Medicine (CSM) that hypoalbuminemia alone is not an appropriate indication for the use of human albumin [66].

One of the most important tasks of the anaesthetist is to continuously monitor blood loss. An accurate estimate is important to guide fluid and transfusion therapies but is difficult to achieve, given the possible presence of concealed haemorrhages (within injuries or under the clothes). The most widely used method for estimating blood loss is measurement of the blood by visual assessment of the blood in surgical dressings and laparotomy compresses. Thus, a soaked dressing (4x4) contains 10mL of blood, whereas a soaked compress contains 100-150 mL. A more precise estimation can be obtained by weighing dressings or compresses before and after use.

Blood loss of 500 mL is considered normal in a vaginal delivery (900 ml in the case of twins), and a loss of 1000 ml in a Caesarean section. Haematocrit and haemoglobin levels reflect the relationship of blood cells with plasma but do not always indicate blood loss, and measurements can also be affected by rapid fluid movements and intravenous restoration. Haematocrit measurements are useful in prolonged procedures or when losses cannot be easily estimated (Table 3).

In addition, there are inevitable losses of other fluids, mainly due to the evaporation and internal redistribution of body fluids. Evaporation losses are greater in large wounds and are directly proportional to the exposed surface area and duration of the surgical procedure.

Ideally, blood losses are restored with crystalloid or colloid solutions to maintain intravascular volume (normovolemic) until the risk of anaemia is greater than the risks of transfusion. Nevertheless, according to the Consensus on Alternatives to Allogeneic Blood Transfusion [70], *"…allogeneic blood should only be given to increase oxygen transport in patients with tissue oxygen deficit"*. No transfusion threshold is defined, because this is closely related to the patient's ability to tolerate normovolemic anaemia and hence to their cardiopulmonary reserve.

In practice, most doctors administer a 3–4-fold higher volume of crystalloid solutions than the amount of blood loss (≤ 15% BV loss) or apply a 1:1

Table 3. Blood loss classification

	Type I	Type II	Type III	Type IV
Blood loss (ml)	> 750	750-1000	1500-2000	> 2000
Blood volume (%)	< 15%	15-30%	30-40%	> 40%
Heart rate	< 100	100-120	120-140	> 140
Blood pressure	Normal	Normal	Hypotension	Hypotension
Pulse pressure	Normal	Decreased	Decreased	Decreased
Capillary refill	Normal	Decreased	Decreased	Decreased
Respiratory frequency	14-20	20-30	30-35	> 35
Diuresis (ml/h)	> 30	20-30	5-20	0-5
Mental state	Anxious	Anxious	Confused	Lethargy

ratio when using colloids (from 15% to 40% BV loss), until the transfusion point is reached (>40% BV loss). Subsequently, blood is restored unit-by-unit, preferably with red blood cells.

Losses due to distribution and evaporation are primarily related to the size of the wound and the extent of dissection and surgical handling. In this context, a Caesarean section may be considered a mild trauma that requires an additional 4-6 mL/Kg/hr of fluids.

Conclusions

A balanced electrolyte solution contains the same pattern of sodium, potassium, calcium, magnesium, and osmolarity as plasma. It also has the same physiological acid-base balance as plasma through the use of metabolised anions instead of bicarbonate. These solutions present the following advantages:

1. The same balanced solution can be used either as a crystalloid or colloidal solution for fluid restoration or volume administration, respectively.
2. These solutions do not cause iatrogenic electrolytic disorders or increase extracellular chloride.

Hypotension is the most common complication of subarachnoid anaesthesia for Caesarean section and must be treated in order to avoid any impact on the neonate. There are different options for preventing the appearance of hypotension, although none are totally effective or free of adverse effects, and their use is often combined to achieve better outcomes. Colloids are more effective than crystalloids in the prophylaxis of hypotension, although no prophylactic treatment can completely prevent it. HES is a more effective prehydration fluid than gels for maintaining haemodynamic stability and decrease vasopressor requirements for patients undergoing subarachnoid anaesthesia for Caesarean section.

Blood losses of up to 15% of blood volume can be restored with balanced crystalloid solutions, whereas blood losses over 15% of blood volume should be restored with balanced colloid solutions.

Synthetic colloids, such as modified fluid gelatins and HES, are preferable to human albumin.

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