UNIVERSIDADE
BEIRA INTERIOR

Intravenous Fluid Therapy: Essential Components and Key Considerations

Catarina Rocha Dias Tavares Silva

Dissertação para obtenção do Grau de Mestre em
Medicina
(mestrado integrado)

Orientador: Dr. Pedro Miguel Ribeiro Marcos

janeiro de 2025

Folha em branco

Declaração de Integridade

Eu, Catarina Rocha Dias Tavares Silva, que abaixo assino, estudante com o número de inscrição 43702 do Mestrado Integrado em Medicina da Faculdade de Ciências da Saúde, declaro ter desenvolvido o presente trabalho e elaborado o presente texto em total consonância com o **Código de Integridades da Universidade da Beira Interior**.

Mais concretamente afirmo não ter incorrido em qualquer das variedades de Fraude Académica, e que aqui declaro conhecer, que em particular atendi à exigida referenciação de frases, extratos, imagens e outras formas de trabalho intelectual, e assumindo assim na íntegra as responsabilidades da autoria.

Universidade da Beira Interior, Covilhã 16 / 01 / 2025

Catarina Rocha Dias Tavares Silva

Catarina Rocha Dias Tavares Silva

(a43702)

Agradecimentos

Em primeiro lugar, quero agradecer ao Dr. Pedro Marcos, pela orientação e acompanhamento estrito neste caminho bonito, e, por vezes, tortuoso.

Aos meus pais, que sempre me acalmaram nos momentos de maior tempestade, a quem devo tudo o que tenho e consegui até hoje.

Ao Luís, o meu pilar para o bem e para o mal, que nunca me deixa deitar a toalha ao chão e que tem sempre uma palavra calma para mim.

Aos meus amigos da Covilhã, que bem sabem que o tema da tese é praticamente tabu, mas que, mal apareça feita, é mais um motivo de celebração. Vocês já são família.

Folha em branco

Abstract

Introduction. Intravenous (IV) fluid therapy plays a vital role in modern medical practice, particularly in critical care management. This review aims to summarize the composition, indications, and contraindications of IV fluids, serving as a useful resource for healthcare professionals.

Methods. Review of the literature published in MEDLINE via PubMed, and Web of Science, between 2009 and 2024. Systematic reviews, meta-analyses, expert reviews, and guidelines were preferred for analysis. The labels of IV fluids used at Pêro da Covilhã Hospital were reviewed.

Results. IV fluids can be administered for various reasons, including resuscitation, correction of electrolyte imbalances, or more critical cases. They can be divided into two categories: crystalloids and colloids. Crystalloids, in turn, can be subdivided into unbalanced solutions, such as saline (0.45%, 0.9%, 3%), or balanced solutions, such as Ringer's lactate and polyelectrolytic solutions. Colloids can be derived from plasma, such as 5% albumin, or semi-synthetic, such as 4% modified fluid gelatin. Crystalloids are generally more cost-effective, have a lower risk of allergic reactions, and are more readily available than colloids. However, the use of each solution should be individualized based on the patient's specific needs and corresponding conditions.

Conclusions. It is essential to have a thorough understanding of available IV fluid solutions to select the best option for each patient's condition at any given time. This review summarizes the most relevant information to guide these decisions. Future research should develop IV fluids that combine the benefits of colloids and crystalloids for safer, more personalized, and cost-effective treatments.

Keywords

Fluid therapy; intravenous; crystalloids; colloids; components

Folha em branco

Resumo

Introdução. A fluidoterapia intravenosa (IV) desempenha um papel importante na prática clínica, especialmente na gestão de doentes críticos. Esta revisão narrativa pretende analisar de sumariamente a composição, indicações e contraindicações dos fluidos IV, servindo como um recurso útil para profissionais de saúde.

Métodos. Revisão da literatura publicada na MEDLINE via *PubMed* e *Web of Science*, entre 2009 e 2024. Foram preferidas revisões sistemáticas, meta-análises, revisões de especialistas e *guidelines*. Foram analisados os rótulos dos fluidos IV usados no Hospital Pêro da Covilhã.

Resultados. Os fluidos IV são administrados por diversas razões, incluindo ressuscitação, correção de desequilíbrios eletrolíticos ou casos mais críticos. Dividem-se em duas categorias: cristaloides e coloides. Os cristaloides podem ser subdivididos em soluções não balanceadas, como soluções salinas (0.45%, 0.9%, 3%), ou soluções balanceadas, como o lactato de Ringer e soluções polieletrolíticas. Os coloides podem ser derivados plasmáticos, como albumina 5%, ou semissintéticos, como gelatina fluida modificada a 4%. Os cristaloides são, geralmente, mais custo-efetivos, apresentam menor risco de reações alérgicas e estão mais amplamente disponíveis do que os coloides. Contudo, a utilização de cada solução deve ser individualizada, considerando as necessidades específicas e as condições correspondentes de cada paciente.

Conclusões. A compreensão dos fluidos IV é crucial para que se escolha a melhor opção para cada paciente a qualquer momento. Esta revisão resume as informações mais relevantes. As pesquisas futuras devem ter como objetivo o desenvolvimento de fluidos IV que combinem os benefícios dos coloides e cristaloides, visando tratamentos mais seguros, personalizados e economicamente eficientes.

Palavras-chave

Fluid therapy; intravenous; crystalloids; colloids; components

Folha em branco

Index

Folha em branco

Tables List

Folha em branco

Abbreviations List

ECF	Extracellular Fluid
EGL	Endothelial Glycocalyx Layer
ICF	Intracellular Fluid
ICP	Intracranial Pressure
IV	Intravenous
NICE	National Institute for Health and Care Excellence
pH	Potencial of hydrogen
RL	Ringer's Lactate
SIADH	Syndrome of Inappropriate Antidiuretic Hormone Secretion
TBI	Traumatic Brain Injury

Folha em branco

1. Introduction

Intravenous (IV) fluid therapy has always been a cornerstone of medical practice. For this reason, it is increasingly important to share and spread knowledge about the composition of various types of available fluids to ensure their proper use (1). Each year, over 30 million patients receive IV fluids, making fluid therapy fundamental in the management of conditions such as sepsis, hemorrhagic shock, and other life-threatening illnesses (2). The management of IV fluid therapy should be done with awareness, acknowledging its potential effects on multiple organ systems. It is imperative to administer these fluids cautiously and not “blindly”(3).

The historical significance of fluid therapy became especially apparent during the cholera epidemic of 1830, which was one of the most devastating pandemics in modern history (4, 5). The urgent need for effective treatments prompted British physician Thomas Latta to develop the first IV therapy for cholera in 1832. This therapy consisted of a mixture of water and sodium, and it laid the groundwork for future advancements by researchers in various fields (6). For instance, in the late 19th century, Alexis Carrel conducted experiments with transplanted organs and designed a sodium chloride solution that resembled plasma, building on the earlier work of Latta (7). Following Carrel's efforts, numerous scientists, doctors, biochemists, and physiologists refined existing formulas through experiments on amphibians and mammals, all with the goal of improving upon the contributions of their predecessors. Key figures in this field include Alexis Hartmann, Sidney Ringer, and Hartog Jakob Hamburger.

The administration of IV fluids involves more than just following a specific prescription algorithm. It is often shaped by the beliefs and habits of the prescribing healthcare professional, but it must be tailored to each patient and their specific condition. Surveys show that many prescribers are unaware of the specific fluid and electrolyte needs of individual patients, as well as the composition of various IV fluid options available (3).

We propose to conduct a brief review of IV fluid therapy to create a valuable resource for healthcare professionals, particularly young doctors and medical students. This resource will outline the essential composition, indications, and contraindications of the most commonly used IV fluids. This review was conducted using studies published in MEDLINE via PubMed and Web of Science between 2009 and 2024. The search query employed was as follows: ("Fluid therapy" OR "Fluid" OR "Resuscitation fluid" OR "Serum") AND "Intravenous" AND ("Colloid" OR "Crystalloid") AND "Composition" AND "Review". Systematic reviews, meta-analyses, expert reviews and guidelines were preferred for analysis. Only articles written in English and with free full text available were considered. The labels of IV fluids used at Pêro da Covilhã Hospital were also reviewed.

2.Physiology of Fluids

The main goal of IV fluid administration is to guarantee adequate tissue perfusion by increasing intravascular volume (8). IV fluids can be administered for various reasons, including resuscitation and the correction of electrolyte imbalances. However, before administering IV solutions, it is crucial to understand the compartments of body fluids in the human body. These compartments can be divided into two major categories: intracellular fluid (ICF), which accounts for nearly 60% of the body's total fluids, and extracellular fluid (ECF), constituting about 40%. Notably, the water content and ionic concentrations differ between the ICF and ECF: the ECF has a higher concentration of sodium, while the ICF is richer in potassium (9). The movement of fluid between these compartments generates hydrostatic pressure, driven by water, and osmotic pressure, driven by plasma proteins (10).

More than a century ago, Ernest H. Starling observed that, under normal conditions, there is a balance in almost every capillary. The Starling principle is essential for understanding fluid dynamics within the human body. It identifies four key variables that influence fluid exchange across the capillary wall: capillary oncotic pressure, interstitial oncotic pressure, capillary hydrostatic pressure, and interstitial hydrostatic pressure (11). These Starling forces explain the balance between two processes: filtration, which is the movement of fluid out of capillaries; and reabsorption, the movement of fluid back into the capillaries. Both processes are crucial for maintaining homeostasis. This principle has been adapted to describe the hydrostatic and oncotic pressure gradients across the semipermeable membrane, which are the primary determinants of transvascular exchange (12). The average pressure at the arterial ends of capillaries is 15 to 25 mmHg higher than at the venous ends. This difference indicates that filtration predominates on the arterial side, while reabsorption is more common on the venous side (13).

Starling's model has increasingly been replaced by the endothelial glycocalyx layer (EGL) model. This layer is located on the luminal surface of endothelial cells lining of blood vessels. It consists of a glycocalyx of membrane-bound macromolecules, including sulfated proteoglycans, hyaluronan, glycoproteins, and plasma proteins that adhere to this surface matrix (14). The main function of the EGL is to regulate permeability during the transcapillary exchange of water. Additionally, it plays a crucial role in linking the permeability of the endothelial basement membrane to colloid oncotic pressure. This relationship is vital because it affects the membrane's permeability and subsequently influences transcapillary flow (12, 15).

3.Types of IV Fluids

IV fluids can be divided into two classes: crystalloids and colloids. In general, crystalloids distribute more readily to other tissues, while colloids remain in the intravascular space. When prescribing these fluids, it is crucial to consider the patient's medical history, fluid balance, vital signs, jugular venous pressure, and laboratory results, including blood counts, urea, creatinine, and electrolytes (3). Although IV fluid administration is generally considered safe, it does carry some risks. It is essential to monitor patients during and after the administration of IV fluids. Careful observation is needed for local reactions at the infusion site, such as thrombosis and phlebitis, and systemic reactions, including hypotension, fever, dyspnea, and itching (16). Additionally, an overdose of fluids can lead to complications such as edema, compartment syndrome, acute respiratory distress syndrome, and dilutional coagulopathy (17, 18).

The most relevant IV solutions available in clinical practice for fluid therapy are described in the next sections, emphasizing their composition, main indications, contraindications, and adverse events. A summary of their compositions can be found in Table 1.

3.1. Crystalloids

Crystalloids are predominantly based on a solution of sterile water with added electrolytes to approximate the mineral content of human plasma, allowing them to easily cross from the vascular space into the interstitium (19). Crystalloids come in a variety of formulations, from those that are hypotonic to plasma to those that are isotonic or hypertonic (20).

These fluids are the most administered IV fluid because they are cheaper and are widely available, easily transportable and storable, and produce equivalent outcomes to colloid preparations (21). There are two types of crystalloids: saline solutions (or unbalanced solutions) and balanced solutions (such as Ringer’s lactate, polyelectrolytic solutions, and dextrose 5%) (6, 22). While unbalanced solutions contain only sodium chloride, balanced solutions replace chloride anions with buffers such as lactate, acetate, or gluconate, which can be metabolized into bicarbonate or excreted (15). Regarding the latter, we have Ringer's lactate, which is buffered with lactate, and polyelectrolyte solutions, such as Plasma-Lyte 148®, which are buffered with acetate and gluconate (19).

3.1.1. Saline solutions

Saline-based fluids have traditionally been the standard treatment for IV volume replacement when blood or blood products are either unnecessary or unavailable (3). This discussion will focus on three types of saline solutions: 0.45% saline, which is hypotonic; 0.9% saline, which is isotonic; and 3% saline, which is hypertonic.

The 0.45% saline solution, known as half normal saline or 0.45% sodium chloride, contains 77 mmol/L of sodium and chloride. The pH varies between 4.5 and 7.0, being more frequently 5.6, and its osmolarity is 154 mOsm/L, making it hypotonic to human plasma. It can be used in

the treatment of hypovolemia and extracellular hypertonic dehydration, i.e., for hydration purposes and in cases of hypernatremia. It is contraindicated in patients at risk of cerebral edema and fluid overload. It could lead to the syndrome of inappropriate antidiuretic hormone secretion (SIADH), hypotonicity, and electrolyte imbalances (namely hyponatremia), especially if administered improperly, such as being too quick (23).

The 0.9% saline solution, known as normal saline or 0.9% sodium chloride, contains 154 mmol/L of both sodium and chloride, pH of 6.0, and osmolarity of 308 mOsm/L. Although many refer to it as "physiologic saline", this solution is far from it. Its chloride concentration is significantly higher than that found in human extracellular fluid, which makes it supra-physiological. Additionally, its osmolarity is not the same as that of human plasma, which is typically 288 mOsm/L (10, 15, 24). A 0.9% saline solution can be used to treat conditions such as hypovolemia, sodium depletion, and extracellular isotonic dehydration. It is also effective for volume resuscitation during cases of shock. Additionally, this solution can serve as a vehicle or solvent for administering other medications (23). It is contraindicated in patients with hypernatremia, fluid overload, and certain renal conditions. It can lead to hyperchloremic metabolic acidosis when given in large volumes and is also associated with hypotension and a pro-inflammatory state (19, 25-27). In the renal system, normal saline may cause vasoconstriction, decreased glomerular filtration rate, and higher risks of kidney injury (2, 19, 26). In the lungs, it can contribute to interstitial pulmonary edema and endothelial injury (28). Cardiovascularly, it may increase the need for vasopressors and is linked to higher mortality rates in patients with septic shock or those undergoing major abdominal surgeries. Despite these risks, 0.9% saline is the most commonly used crystalloid solution worldwide, effective for rapidly expanding blood volume in conditions like dehydration, hemorrhage, vomiting, and diarrhea (1, 11, 27).

The 3% saline solution, a hypertonic solution, contains 513 mmol/L of sodium and chloride. The pH varies between 4.5 and 7.0, being more frequently 5.0, and its osmolarity is 1027 mOsm/L, making it hypertonic to human plasma. It is mainly used to treat severe, refractory hypovolemic shock and traumatic brain injuries (TBI). This solution establishes an osmotic gradient that reduces cerebral edema, thereby decreasing intracranial pressure (ICP) in patients with TBI, without impacting survival or cognitive outcomes (29). However, when administered too quickly, it can lead to osmotic demyelination syndrome, rebound increases in ICP, and acute renal failure (15, 29, 30). It is recommended that a 3% saline solution be injected through a central venous catheter to minimize the risk of peripheral vessel injury, endothelial damage, or thrombosis (31).

3.1.2. Ringer's lactate

Ringer's lactate (RL) is a calcium-containing balanced solution first described by Sydney Ringer and later modified by Alexis Hartmann, who introduced lactate to the original formulation (11, 32). This solution contains 131 mmol/L of sodium, 5 mmol/L of potassium, 3.7

mmol/L of calcium, 112 mmol/L of chloride (substantially lower than in saline solutions), and 28 mmol/L of lactate (33). Including rapidly metabolized organic anions, such as lactate, has been shown to avoid increasing plasma acidity and results in fewer adverse effects, such as acid-base disturbances, compared to saline solutions (10). A significant advantage of lactate is that its concentration can be measured at the bedside, enabling better patient monitoring (33). Additionally, Sydney Ringer observed that adding calcium improved cardiac contractility (32).

RL has been associated with fewer renal side effects, faster clotting times, and improved clot strength (34, 35). This solution can be used for fluid resuscitation, especially in surgical and trauma patients, and helps restore electrolyte balance. RL is often the first-line choice for patients with sepsis and acute pancreatitis, and in perioperative settings, it may reduce postoperative complications (36-38).

However, RL may lead to a transient decrease in plasma osmolarity, which could be detrimental for patients with elevated ICP (39). Rapid infusion of this solution may also result in metabolic alkalosis and has been associated with increased apoptosis in tissues such as the bowel, liver, and lungs. This cellular damage can result in the destruction of macrophages, endothelial cells, epithelial cells, and smooth muscle cells (18). In addition, RL should not be administered to patients who have hyperkalemia.

3.1.3. Polyelectrolytic

Polyelectrolytic solutions closely resemble human plasma due to their more isotonic nature than other crystalloids (31). These solutions typically contain 140 mmol/L of sodium, 5 mmol/L of potassium, 1.5 mmol/L of magnesium, 98 mmol/L of chloride, 27 mmol/L of acetate, and 23 mmol/L of gluconate (6). Including magnesium, acetate, and gluconate represents an innovation in fluid therapy, necessitating closer patient monitoring.

Polyelectrolytic solutions have various indications and applications in clinical settings. They can be used to dilute medications commonly administered in intensive care, such as opioids, ketamine, and salbutamol (6). These solutions are particularly effective in correcting severe metabolic acidemia because their metabolism does not rely solely on the liver, resulting in a quicker response and a more pronounced alkalinizing effect. One significant advantage of polyelectrolytic solutions is their lack of calcium, which makes them compatible with blood and blood components (21). This characteristic proves to be extremely useful in situations of hemorrhagic shock that require rapid blood transfusions (23). Furthermore, the use of these solutions has been associated with a notable reduction in postoperative infections and the incidence of renal failure requiring dialysis (40).

Although polyelectrolytic solutions offer various advantages, they can, in rare instances, trigger anaphylactic and hypersensitivity reactions. Moreover, these solutions may cause hyperkalemia in patients taking specific medications, including angiotensin-converting enzyme inhibitors, angiotensin II antagonists, tacrolimus, or cyclosporine (21). There is also a potential risk that these solutions could worsen severe metabolic alkalosis (41). Furthermore, the

presence of acetate in these solutions may have adverse effects on patients undergoing hemodialysis or those with heart conditions, as it can decrease cardiac contractility and potentially lead to metabolic alkalosis due to its conversion into bicarbonate. Therefore, careful consideration and monitoring are crucial, particularly in at risk populations.

3.1.4. Dextrose 5%

Dextrose, the D-isomer of glucose, is a simple sugar that can be dissolved in water, 0.9% saline, or 0.45% saline. This review specifically focuses on dextrose 5% dissolved in water, which is classified as a hypotonic solution containing 252 mmol/L of glucose (42). Dextrose 5% is not commonly used for resuscitation due to its short half-life and inability to maintain oncotic pressure, making it more appropriate for maintenance regimens (43).

This fluid is particularly important during the perioperative period for neonates, a high-risk group that frequently experiences hypoglycemia. If left untreated, hypoglycemia can result in permanent neurodevelopmental impairments, white matter abnormalities, and increased mortality (29, 44). Additionally, this fluid is indicated for use in cases of diabetic coma resulting from diabetic ketoacidosis, hyperosmolar hyperglycemic state, severe hypoglycemia, or to correct hypernatremia. It can provide caloric support when enteral nutrition is impossible and alternative nutritional support methods have not yet been established (43). Furthermore, dextrose 5% can be used as a diluent for medications and as an irrigation medium during surgeries, such as transurethral resection of the prostate (45).

Common adverse effects include hyperglycemia and hyponatremia, which may cause osmotic diuresis and increase the risk of cerebral edema (31, 41).

3.2. Colloids

Colloids are an alternative to crystalloids, and their use will depend on the patient's clinical status. They are suspensions of large macromolecules derived from plasma or semisynthetic sources that remain in the intravascular compartment, generate oncotic pressure, and cannot pass through a semipermeable membrane (11, 37, 46). Colloids are considered to be more effective than crystalloids as plasma volume expanders (47). The two main types are albumin and semi-synthetic colloids, such as 4% succinylated modified fluid gelatin (24).

3.2.1. Albumin 5%

Albumin is the most abundant protein in human plasma, accounting for 50% to 60% of total plasma proteins. It is critical in maintaining oncotic pressure and fluid balance within the vascular system. Furthermore, albumin is a carrier protein for electrolytes, hormones, and drugs, acts as a buffer for hydrogen ions, and exhibits antioxidant and scavenging properties (43, 48).

Human albumin solution is manufactured from cryo-depleted human plasma, and it is considered the safest colloid (49, 50). Formulations include iso-oncotic solutions, such as 5% albumin, which have oncotic pressures similar to plasma, and hyper-oncotic solutions, which contain less sodium and are used less frequently in clinical practice.

The albumin 5% is indicated for patients experiencing marked hypoalbuminemia, peripheral edema, or those requiring fluid removal. Albumin is the only colloid shown to benefit patients with sepsis and is associated with lower mortality rates in individuals undergoing coronary bypass procedures. In cases of cirrhosis, albumin infusion reduces the risk of circulatory dysfunction caused by paracentesis and lowers the risk of spontaneous bacterial peritonitis, which in turn decreases the incidence of hepatorenal syndrome (15, 48, 51-53).

Although albumin has benefits, its high cost, the requirement for glass containers for distribution, concerns about viral transmission from blood-derived products, and the risk of allergic reactions (especially in patients with a tendency toward hypersensitivity) contribute to its declining popularity (37, 43). Moreover, it is not recommended for patients with TBI, as it has been associated with increased mortality in this group (37, 48, 54).

3.2.2. 4% modified fluid gelatin

The high cost and limited availability of human albumin solutions have driven the development of semisynthetic colloid solutions, such as gelatins (15). Gelatins are produced by hydrolyzing bovine or porcine collagen. This discussion will focus on 4% succinylated modified fluid gelatin, commonly known as 4% modified fluid gelatin or Gelofusine®, which contains 154 mmol/L of sodium, 120 mmol/L of chloride, and 0.4 mmol/L each of calcium and potassium.

The 4% modified fluid gelatin has a low chloride content, making it a suitable option for patients with hyperchloremic acidosis. Additionally, its reduced calcium concentration enhances compatibility with blood transfusions. The lower calcium content is particularly significant because calcium serves as a vital cofactor in the coagulation cascade; thus, a decreased concentration can lead to a more pronounced state of hypocoagulation during the transfusion process 12. However, it is important to note that gelatins have a shorter duration of action compared to albumin, which may influence fluid management strategies in critical care settings (55).

Although this semisynthetic colloid has its benefits, it also poses significant risks. It can lead to life-threatening anaphylaxis, which may present as cardiac arrest with ST elevation. Additionally, 4% modified fluid gelatin can cause hypocoagulation, by reducing clotting factors I and VIII, as well as von Willebrand factor, impairing platelet activation and decreasing the formation of thrombin and fibrin mesh (47, 56). Furthermore, there is an increased risk of acute kidney injury due to its accumulation in the reticuloendothelial system, leading to osmotic nephrosis-like renal lesions. These lesions may include injury to the basement membrane of epithelial cells, tubular vacuolation, and increased cell death (37, 57).

4.Conclusions

When administering IV fluids, it is essential to consider the patient's history, ongoing monitoring parameters, and any potential complications. Both crystalloids and colloids have their specific uses, benefits, and risks. Careful selection and monitoring are key to optimizing fluid therapy and ensuring patient safety. This review provides a relevant and quick-reference summary of IV fluid therapy.

Regarding crystalloids, saline, and balanced solutions are well-known options. While 0.9% saline solution is generally the first choice in most clinical settings, in particular for volume resuscitation, a thorough analysis of the indications, advantages, and disadvantages of each fluid, alongside a direct comparison with balanced solutions, suggests that balanced fluids offer greater safety in numerous clinical contexts. Additionally, the buffering of balanced solutions with anions other than chloride provides significant advantages, such as improved ionic interactions and reduced adverse effects. Within the range of crystalloids, dextrose 5% is a fluid with more limited clinical indications compared to other options.

When comparing colloids to crystalloids, the advantages of colloids are limited. For instance, albumin, a natural colloid, is valuable in specific cases, such as in cirrhosis, post-bypass surgery, and severe septic shock. However, as a blood-derived product, it poses certain risks and is expensive. This has led to the development of semi-synthetic colloids, such as 4% modified fluid gelatin, which also requires careful consideration before use.

The ongoing debate regarding the use of crystalloids versus colloids for volume expansion continues. Colloids theoretically have the advantage of remaining in the intravascular space longer, which allows for better management of fluid therapy volume and more effective volume expansion (58). On the other hand, crystalloids are more cost-effective, carry a lower risk of allergic reactions, and are more readily available, making them the most reliable and commonly administered fluid type. However, it is mandatory to thoroughly understand available IV fluid solutions to select the best option for each patient's condition at any given time.

In conclusion, IV fluid therapy is an essential tool in managing patients. Customizing IV fluid therapy according to each patient's needs is crucial to enhance its effectiveness and reduce potential complications. This review compiles the most relevant information on IV fluid therapy for young doctors and medical students, providing the context necessary to make well-informed decisions and improve patient safety. From a research perspective, prioritizing the development of new IV fluid formulations that combine the volume-expanding benefits of colloids with the safety and cost-effectiveness of crystalloids could be essential. The advancements in IV fluid therapy should aim toward safer, more effective, more personalized, and economically sustainable practices.

Table 1: Types and Composition of IV Fluids

Variables	Solutions							
	Crystalloids						Colloids	
	0.9% Saline	0.45% Saline	3% Saline	Ringer's Lactate	Polyelectrolyte	Dextrose 5%	Albumin 5%	4% Modified Gelatin
pH	6.0	4.5 – 7.0	5.8	6.5	7.4	3.5 – 6.5	6.4 – 7.4	7.4
Osmolarity (mOsm/L)	308	154	1030	280	295	278	309	274
Sodium (mmol/L)	154	77	513	131	140		148	154
Chloride (mmol/L)	154	77	513	112	98		128	126
Potassium (mmol/L)				5	5			0.4
Calcium (mmol/L)				3.7				0.4
Magnesium (mmol/L)					1.5			
Lactate (mmol/L)				28				
Acetate mmol/L					27			
Gluconate mmol/L					23			
Glucose mmol/L						252		

5. References

1. Rudloff E, Hopper K. Crystalloid and Colloid Compositions and Their Impact. Front Vet Sci. 2021;8:639848.
2. Martin C, Cortegiani A, Gregoretti C, Martin-Loeches I, Ichai C, Leone M, et al. Choice of fluids in critically ill patients. BMC Anesthesiol. 2018;18(1):200.
3. NICE Clinical Guidelines n. Intravenous fluid therapy in adults 2013.
4. Nalin DR. The History of Intravenous and Oral Rehydration and Maintenance Therapy of Cholera and Non-Cholera Dehydrating Diarrheas: A Deconstruction of Translational Medicine: From Bench to Bedside? Trop Med Infect Dis. 2022;7(3).
5. Cosnett JE. The origins of intravenous fluid therapy. Lancet. 1989;1(8641):768-71.
6. Fernández-Sarmiento J, Casas-Certain C, Ferro-Jackaman S, Solano-Vargas FH, Domínguez-Rojas J, Pilar-Orive FJ. A brief history of crystalloids: the origin of the controversy. Front Pediatr. 2023;11:1202805.
7. Carrel A. The preservation of tissues and its applications in surgery. 1912. Clin Orthop Relat Res. 1992(278):2-8.
8. Mayerhöfer T, Shaw AD, Wiedermann CJ, Joannidis M. Fluids in the ICU: which is the right one? Nephrol Dial Transplant. 2023;38(7):1603-12.
9. Pierce JD, Shen QH, Thimmesch A. The Ongoing Controversy: Crystalloids Versus Colloids. J InfusNurs. 2016;39(1):40-4.
10. Severs D, Hoorn EJ, Rookmaaker MB. A critical appraisal of intravenous fluids: from the physiological basis to clinical evidence. Nephrol Dial Transplant. 2015;30(2):178-87.
11. Gordon D, Spiegel R. Fluid Resuscitation: History, Physiology, and Modern Fluid Resuscitation Strategies. Emerg Med Clin North Am. 2020;38(4):783-93.
12. Myburgh JA, Mythen MG. Resuscitation fluids. N Engl J Med. 2013;369(13):1243-51.
13. Hall JG, Arthur. Textbook of Medical Physiology. 12th ed: Elsevier; 2011.
14. Weinbaum S, Tarbell JM, Damiano ER. The structure and function of the endothelial glycocalyx layer. Annu Rev Biomed Eng. 2007;9:121-67.
15. Casey JD, Brown RM, Semler MW. Resuscitation fluids. Curr Opin Crit Care. 2018;24(6):512-8.
16. 3% Sodium Chloride Injection Nih.gov. 2019 [Available from: https://dailymed.nlm.nih.gov/dailymed/fda/fdaDrugXsl.cfm?setid=a8058593-48af-457a-b0f0-166935c7d10c.
17. Medby C. Is there a place for crystalloids and colloids in remote damage control resuscitation? Shock. 2014;41 Suppl 1:47-50.
18. Santry HP, Alam HB. Fluid resuscitation: past, present, and the future. Shock. 2010;33(3):229-41.
19. Semler MW, Kellum JA. Balanced Crystalloid Solutions. Am J Respir Crit Care Med. 2019;199(8):952-60.

20. GS M. An update on intravenous fluid. Medscape Infect Dis http://wwwmedscapeorg/viewarticle/503138. 2005.
21. Weinberg L, Collins N, Van Mourik K, Tan C, Bellomo R. Plasma-Lyte 148: A clinical review. World J Crit Care Med. 2016;5(4):235-50.
22. Frazee EN, Leedahl DD, Kashani KB. Key Controversies in Colloid and Crystalloid Fluid Utilization. Hosp Pharm. 2015;50(6):446-53.
23. Infomed. [Available from: https://extranet.infarmed.pt/INFOMED-fo/.
24. Long E, Duke T. Fluid resuscitation therapy for paediatric sepsis. J Paediatr Child Health. 2016;52(2):141-6.
25. Pfortmueller CA, Funk GC, Reiterer C, Schrott A, Zotti O, Kabon B, et al. Normal saline versus a balanced crystalloid for goal-directed perioperative fluid therapy in major abdominal surgery: a double-blind randomised controlled study. Br J Anaesth. 2018;120(2):274-83.
26. Allen SJ. Fluid therapy and outcome: balance is best. J Extra Corpor Technol. 2014;46(1):28-32.
27. Kellum JA, Song M, Venkataraman R. Effects of hyperchloremic acidosis on arterial pressure and circulating inflammatory molecules in experimental sepsis. Chest. 2004;125(1):243-8.
28. Bihari S, Wiersema UF, Perry R, Schembri D, Bouchier T, Dixon D, et al. Efficacy and safety of 20% albumin fluid loading in healthy subjects: a comparison of four resuscitation fluids. J Appl Physiol (1985). 2019;126(6):1646-60.
29. Bailey AG, McNaull PP, Jooste E, Tuchman JB. Perioperative crystalloid and colloid fluid management in children: where are we and how did we get here? Anesth Analg. 2010;110(2):375-90.
30. Katharina Floss MBCC. Intravenous fluid therapy — background and principles. Clinical Pharmacist. 01 september 2008.
31. Saraghi M. Intraoperative Fluids and Fluid Management for Ambulatory Dental Sedation and General Anesthesia. Anesth Prog. 2015;62(4):168-76; quiz 77.
32. Baskett TF. The resuscitation greats: Sydney Ringer and lactated Ringer's solution. Resuscitation. 2003;58(1):5-7.
33. Langer T, Ferrari M, Zazzeron L, Gattinoni L, Caironi P. Effects of intravenous solutions on acid-base equilibrium: from crystalloids to colloids and blood components. Anaesthesiol Intensive Ther. 2014;46(5):350-60.
34. Malbrain M, Langer T, Annane D, Gattinoni L, Elbers P, Hahn RG, et al. Intravenous fluid therapy in the perioperative and critical care setting: Executive summary of the International Fluid Academy (IFA). Ann Intensive Care. 2020;10(1):19.
35. Martini WZ, Cortez DS, Dubick MA. Comparisons of normal saline and lactated Ringer's resuscitation on hemodynamics, metabolic responses, and coagulation in pigs after severe hemorrhagic shock. Scand J Trauma Resusc Emerg Med. 2013;21:86.
36. Seitz KP, Qian ET, Semler MW. Intravenous fluid therapy in sepsis. Nutr Clin Pract. 2022;37(5):990-1003.

37. Finfer S, Myburgh J, Bellomo R. Intravenous fluid therapy in critically ill adults. Nat Rev Nephrol. 2018;14(9):541-57.

38. Tenner S, Vege SS, Sheth SG, Sauer B, Yang A, Conwell DL, et al. American College of Gastroenterology Guidelines: Management of Acute Pancreatitis. Am J Gastroenterol. 2024;119(3):419-37.

39. Williams EL, Hildebrand KL, McCormick SA, Bedel MJ. The effect of intravenous lactated Ringer's solution versus 0.9% sodium chloride solution on serum osmolality in human volunteers. Anesth Analg. 1999;88(5):999-1003.

40. Garrioch SS, Gillies MA. Which intravenous fluid for the surgical patient? Curr Opin Crit Care. 2015;21(4):358-63.

41. Hundley D, Brooks A, Thomovsky E, Johnson P. Crystalloids: A Quick Reference for Challenges in Daily Practice. Top Companion Anim Med. 2016;31(2):46-53.

42. Naisbitt C, Buckley H, Kishen R. Crystalloids, colloids, blood products, and blood substitutes. Anaesth Intensiv Care Med. 2016;17(6):308-14.

43. Varrier M, Ostermann M. Fluid Composition and Clinical Effects. Crit Care Clin. 2015;31(4):823-37.

44. Datta PK, Pawar DK, Baidya DK, Maitra S, Aravindan A, Srinivas M, et al. Dextrose-containing intraoperative fluid in neonates: a randomized controlled trial. Paediatr Anaesth. 2016;26(6):599-607.

45. Amu OC, Affusim EA, Nnadozie UU, Nwachukwu CD. Outcome of transurethral resection of the prostate (TURP) using 5% dextrose water as irrigant. Niger J Clin Pract. 2023;26(10):1568-74.

46. Mitra S, Khandelwal P. Are all colloids same? How to select the right colloid? Indian J Anaesth. 2009;53(5):592-607.

47. Pisano A, Landoni G, Bellomo R. The risk of infusing gelatin? Die-hard misconceptions and forgotten (or ignored) truths. Minerva Anestesiol. 2016;82(10):1107-14.

48. Caironi P, Gattinoni L. The clinical use of albumin: the point of view of a specialist in intensive care. Blood Transfus. 2009;7(4):259-67.

49. Aguirre Puig P, Orallo Morán MA, Pereira Matalobos D, Prieto Requeijo P. [Current role of albumin in critical care]. Rev Esp Anestesiol Reanim. 2014;61(9):497-504.

50. Groeneveld AB, Navickis RJ, Wilkes MM. Update on the comparative safety of colloids: a systematic review of clinical studies. Ann Surg. 2011;253(3):470-83.

51. Sort P, Navasa M, Arroyo V, Aldeguer X, Planas R, Ruiz-Del-Arbol L, et al. Effect of Intravenous Albumin on Renal Impairment and Mortality in Patients with Cirrhosis and Spontaneous Bacterial Peritonitis. New England Journal of Medicine. 1999;341(6):403-9.

52. Guevara M, Terra C, Nazar A, Solà E, Fernández J, Pavesi M, et al. Albumin for bacterial infections other than spontaneous bacterial peritonitis in cirrhosis. A randomized, controlled study. J Hepatol. 2012;57(4):759-65.

53. Brown RM, Semler MW. Fluid Management in Sepsis. J Intensive Care Med. 2019;34(5):364-73.

54. Iguchi N, Kosaka J, Bertolini J, May CN, Lankadeva YR, Bellomo R. Differential effects of isotonic and hypotonic 4% albumin solution on intracranial pressure and renal perfusion and function. Crit Care Resusc. 2018;20(1):48-53.

55. Srivastava A. Fluid Resuscitation: Principles of Therapy and "Kidney Safe" Considerations. Adv Chronic Kidney Dis. 2017;24(4):205-12.

56. Moeller C, Fleischmann C, Thomas-Rueddel D, Vlasakov V, Rochwerg B, Theurer P, et al. How safe is gelatin? A systematic review and meta-analysis of gelatin-containing plasma expanders vs crystalloids and albumin. J Crit Care. 2016;35:75-83.

57. Bayer O, Reinhart K, Kohl M, Kabisch B, Marshall J, Sakr Y, et al. Effects of fluid resuscitation with synthetic colloids or crystalloids alone on shock reversal, fluid balance, and patient outcomes in patients with severe sepsis: a prospective sequential analysis. Crit Care Med. 2012;40(9):2543-51.

58. Kemp M. Crystalloids and colloids. South Afr J Anaesth Analg. 2020;26(6):S80-S5.