Principles of Intravenous Fluids Therapy

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Abstract

Introduction: The hospital ED is one of the most important components of the health care system. There is an increase in numbers of hypovolemic patients visiting EDs leading to overcrowding, long waiting time, missed diagnostic cases and negative impact on patient satisfaction. Hypovolemia is one of the most common reasons people call for emergency medical help. Fortunately, Fluid is about half of healthy adult body weight. Total body fluid in adult male is about 60% of lean body weight, and about 50% of lean body weight in female. Blood is about 11 - 12% of total body fluid. But even if the hypovolemic patients experience has nothing to do, the problem may still be important and worth the time spent in an emergency room for evaluation and intravenous fluids administration So we aimed to update knowledge and review researches in the field of fluids therapy and reduction in waiting time and Overcome Crowdness Patients in emergency department.

Methods: Collection of all possible available data about the intravenous fluids therapy in the Emergency department. By many research questions to achieve these aims so a midline literature search was performed with the keywords "critical care", "emergency medicine", "principals of intravenous fluids therapy", "fluids and electrolytes". All studies introduced that the intravenous fluids therapy is a serious conditions that face patients of the emergency and critical care departments. Literature search included an overview of recent definition, causes and recent therapeutic strategies.

Results: Hypovolemic state can be diagnosed when there are signs and symptoms of hemodynamic compromise and there is apparent source of blood loss. It not easy to diagnose when there is occult blood loss, as internal hemorrhage, into the alimentary tract, or when plasma volume alone is lost. And in all cases should be given fluids therapy for resuscitations firstly.

Conclusion: "Prevention is better than cure" Decline in death rates could be achieved by proper lifesaving interventions by good fluids therapy administrations and then proper approach to determine the causes of hypovolemia in emergency department.

Keywords: Management; Hypovolemia; Fluids Therapy

Introduction

To maintain health, the balance of fluids and electrolytes in the intracellular and extracellular spaces needs to remain relatively constant. Whenever a person experiences an illness or a condition that prevents normal fluid intake or causes excessive fluid loss, I.V. fluid replacement may be necessary. I.V. therapy that provides the patient with life-sustaining fluids, electrolytes and medications offers the

advantages of immediate and predictable therapeutic effects. The I.V. route is, therefore, the preferred route, especially for administering fluids, blood products, electrolytes and drugs in an emergency.

This route also allows for fluid intake when a patient has GI malabsorption. I.V. therapy permits accurate dosage titration for analgesics and other medications. Potential disadvantages associated with I.V. therapy include drug and solution incompatibility, adverse reactions to various medications, localized infection, sepsis, and other complications [1].

Materials and Methods

Study design

This study was carried out as a systematic review. Collection of all possible available data about the principals of fluids therapy in the Emergency department.

Materials

1. Literatures from emergency medicine and intensive care textbooks.

2. Published articles from famous emergency medicine and intensive care journals.

3. Papers, abstracts and texts published on the internet concerned with the acute chest pain patients.

4. Thesis and papers in Egyptian Universities.

Search strategy

A Medline literature search was performed with the keywords "critical care", "emergency medicine", "the principals of fluids therapy", "electrolytes and fluids administrations". All studies introduced that face patients of the emergency and critical care departments. Literature search included an overview of recent definition, causes and recent therapeutic strategies.

Medline (PubMed), Up to date, Blackwell-synergy, Elsevier, Oxford medicine library and e-medicine was searched using standardized methodological filter for identifying trials, which represent the most famous scientific sites on the internet.

The most famous paid evidence based web sites journals and internet sites which represent honest references to most of the Emergency medicine physicians will be searched as:

- *BMJ Evidence Based,*

- *Cochrane.org,*

- *The Journal of Trauma,*

- *The New England Journal of Medicine,*

- *The Journal of Critical Care.*

Criteria for selecting those studies

a. Initial screen to exclude studies not relevant to the review questions.

b. Second screen determines which of the relevant studies are evidence based and of the highest quality to be included in the systematic review to be as free from bias as possible.

Inclusion criteria

- Different articles on the principals of fluids therapy in Emergency patients.

- Studies with appropriate research methodology according to the standards of critical appraisal was included.

- Any type of study design including:

  - Randomized controlled trials.

  - Open clinical trials.

  - Review articles.

  - Systematic review articles.

  - Meta-analysis.

Exclusion criteria

- All studies that are not relevant to the principals of fluids therapy in emergency patients.

- Rejected articles, articles with poorly designed studies were also excluded.

Study prepared by:

- Uses paid evidence based websites for searching about papers and texts.

- Used Microsoft Office Word documents 2010 in typing and preparation of the systematic review.

- Used Internet Explorer Browser version 7 for searching in the internet about papers, abstracts and texts.

Results and Discussion

Types of I.V. solutions

Solutions used for I.V. fluid replacement fall into the broad categories of crystalloids (which may be isotonic, hypotonic, or hypertonic) and colloids (which are always hypertonic).

Crystalloids

Isotonic

Isotonic fluids, such as normal saline solution, have a concentration of dissolved particles, or tonicity, equal to that of the intracellular fluid. Osmotic pressure is therefore the same inside and outside the cells, so they neither shrink nor swell with fluid movement. Isotonic solutions have an osmolality (concentration) between 240 and 340 mOsm/kg [1].
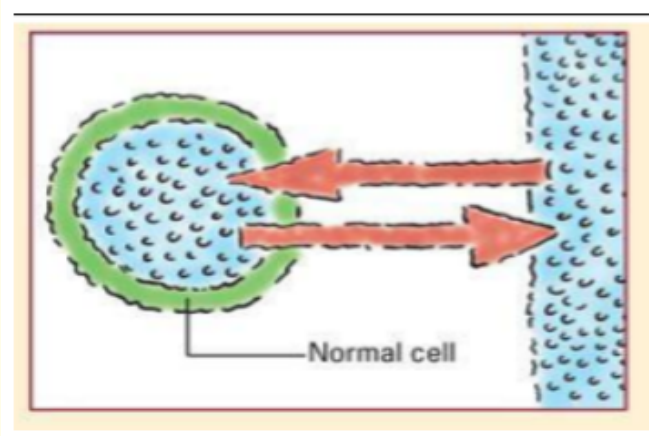

Figure A

Isotonic crystalloids distribute evenly through ECF; approximately only 25% will remain in the intravascular space and 75% will be in the interstitial space. This means that out of 1L of crystalloid only 250 mL will remain in blood. Due to their tonicity, larger volumes of isotonic crystalloids, compared to colloids or blood, are needed for intravascular expansion. Due to ECF distribution, excessive use of any IVF can result in peripheral oedema and an increase in intravascular pressure. Depending on the patient and their current physiology, especially cardiac function, this may put strain on their heart and result in pulmonary edema. In cases of sepsis, the capillary membranes become 'leaky' due to the action of proinflammatory cytokines. The key is, as always, to carefully monitor your patient and their response [2].

0.9% normal saline

Content: Na^+ 154 mmol/L, K^+ 0 mmol/L, Cl^- 154 mmol/L, Osmolarity 308 mOsm/L.

The chloride content is higher than in plasma (95 - 105) and therefore, excess use can result in a hyperchloremic acidosis. Over the past few years, more evidence has emerged indicating that hyperchloremic states can result in worse patient outcomes. Hyperchloremic appears to impair splanchnic and renal blood flow and interfere with T-cell function and the coagulation system. Hence, most guidelines [3,4] are now endorsing the use of balanced crystalloids, such as Hartmann's or Plasmalyte, for resuscitation. However, it is one of the most widely available and used crystalloids on medical and surgical wards. One advantage of normal saline is that we can supplement potassium.

Sodium and the resulting osmolarity are also slightly higher than in plasma and, with excess use, can result in more sodium in the ECF and hence water, resulting in increased volume (peripheral oedema). Note that there is no potassium and use of this crystalloid alone could result in dangerous hypokalaemia. This can be countered by adding potassium to the fluid, usually in quantities of 20 or 40 mmol in 1 L (administration of potassium has to be done at a slow rate.

Physiologically balanced solutions [5]

Crystalloids with an electrolyte composition similar to plasma are called physiologically balanced solutions and they are thought to be less physiologically disruptive than normal saline when used in large quantities, as they should not produce an acidosis.

Ringers

Content: Na^+ 147 mmol/L, K^+ 4 mmol/L, Cl^- 156 mmol/L, Ca^{2+} 2.2 mmol/L, Osmolarity 309 mOsm/L. Sodium and potassium are within plasma range.

Hartmann's (Lactated Ringer's solution)

Content: Na^+ 131 mmol/L, K^+ 5 mmol/L, Cl^- 111 mmol/L, Ca^{2+} 2 mmol/L, Lactate (HCO_3^-) 29 mmol/L, Osmolarity 279 mOsm/L.

Sodium, potassium and osmolarity are within plasma range, while chloride is marginally high. The human liver converts the sodium lactate component swiftly into bicarbonate and water. Hence, Hartmann's is an alkalising fluid which would be the ideal choice for patients with metabolic acidosis.

Metabolic acidotic states often coincide with hyperkalaemia, as the body attempts to move H^+ ions out of the plasma and into the cell, which happens in exchange for potassium. However, if an alkalinizing fluid such as Hartmann's is administered, this process is reversed and the potassium moves back into the cell. By correcting the metabolic acidosis, the hyperkalaemia is addressed and corrected at the same time. The bicarbonate content quoted comes from the lactate molecule which uses H^+ ions and leaves the HCO_3^- instead.

Plasmalyte 148

Content: Na^+ 140 mmol/L, K^+ 5 mmol/L, Cl^- 98 mmol/L, Gluconate 23 mmol/L, Acetate 27 mmol/L, Mg^{2+} 1.5 mmol/L, Osmolarity 295 mOsm/L. Isotonic fluid that also has an alkalising effect.

1.26% Bicarbonate

Content: Na^+ 150 mmol/L, K^+ 0 mmol/L, Cl^- 0 mmol/L, Ca^{2+} 0 mmol/L, Bicarbonate (HCO_3^-) 150 mmol/L, Glucose 0g, Osmolarity 300 mOsm/L (approximately, it is isotonic). Bicarbonate should be used under senior direction only. It can be used to replace bicarbonate in patients with low levels (< 20 mmol/L) in a high dependency unit (HDU), for example in the context of acute kidney injury, which is a bicarbonate-losing state.
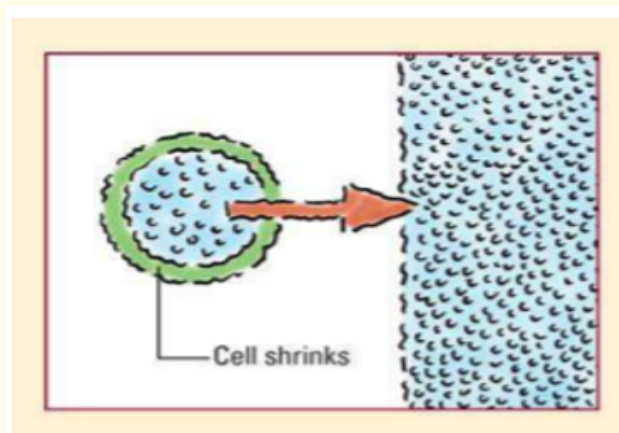

Figure B

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Hypertonic [5]

Hypertonic fluid has a tonicity greater than that of intracellular fluid, so osmotic pressure is unequal inside and outside the cells. Dehydration or rapid infusion of hypertonic fluids, such as 3% saline or 50% dextrose, draws water out of the cells into the more highly concentrated extracellular fluid. Hypertonic solutions are those that have an osmolality greater than 340 mOsm/kg. Examples include:

- Dextrose 5% in half-normal saline solution

- 3% sodium chloride solution

- Dextrose 10% in normal saline solution.

Patients with cardiac or renal disease may be unable to tolerate extra fluid. Watch for fluid overload and pulmonary edema.

Because hypertonic solutions draw fluids from cells, patients at risk for cellular dehydration (patients with diabetic ketoacidosis [DKA], for example) shouldn't receive them.

Since they can cause drastic changes in cell volume, they should be used under expert guidance only. An example would be 1.8%, 3%, 5% or 7.5% saline. These hypertonic fluids are occasionally used in patients who have a traumatic brain injury and evidence of cerebral oedema, or in severely hyponatraemic patients who have had a seizure, or in cardiac arrest They should not be used outside the intensive therapy unit (ITU) unless under the care of a specialist team such as endocrinologists or in a neurosurgery unit.

Hypotonic [5]

Hypotonic fluids, such as half-normal saline solution, have a tonicity less than that of intracellular fluid, so osmotic pressure draws water into the cells from the extracellular fluid. Severe electrolyte losses or inappropriate use of I.V. fluids can make body fluids hypotonic. Hypotonic solutions are fluids that have an osmolality less than 240 mOsm/kg. An example of a commonly used hypotonic solution is half-normal saline solution.

Essentially, they provide water to the cells by having a lower number of effective osmoles than the ICF and, therefore, water will go down its gradient into the cells and cause cell swelling. Hypotonic fluids will distribute evenly across all compartments, so 33% will remain in ECF (and of this only 25% in the intravascular compartment) and 66% will enter the cells. Their clinical use is fairly limited.

5% dextrose

Content: Glucose 50g (50 mg/mL), Na^+ 0 mmol/L, K^+ 0 mmol/L, Cl^- 0 mmol/L, Ca^{2+} 0 mmol/L, Osmolarity 278 mOsm/L. Glucose is the only molecule besides water in this crystalloid and it is not an effective osmole in health (see earlier text). Once administered, glucose is taken up intracellularly by insulin and only water is left behind. Therefore, 1L of 5% dextrose is equivalent to 1L of water being administered (without the risk of haemolysis). It is a fluid that will hydrate the cells, but inversely it can cause hyponatremia if used in excess. It is not suitable for resuscitation, as much larger volumes would be needed, and only a small amount would remain in the intravascular space. This fluid should never be given to a hyponatraemic patient.

0.45% saline

Content: Na^+ 75 mmol/L, K^+ 0 mmol/L, Cl^- 75 mmol/L, Ca^{2+} 0 mmol/L, Glucose 0 mmol/L, Osmolarity 150 mOsm/L. This is half-strength saline that is used with caution in HDU settings to treat hypernatremia. Sodium levels must be checked regularly to ensure they are corrected slowly, generally not exceeding 0.5 - 1 mmol/L/hr.

Dextrose/saline (0.18% saline + 4% dextrose)

Content: Na^+ 30 mmol/L, K^+ 0 mmol/L, Cl^- 30 mmol/L, Ca^{2+} 0 mmol/L, Glucose 40g, Osmolarity 284 mOsm/L. Hypotonic fluid providing glucose and lower sodium content than 0.9% saline. It should not be used as a maintenance fluid or in children under 16.

Both dextrose and half-strength saline are used to treat hypernatremic states, but close monitoring in an HDU setting is required to ensure that the sodium levels normalise slowly (maximum 0.5 - 1 mmol/hr).

Hypotonic solutions should be given cautiously because fluid then moves from the extracellular space into cells, causing them to swell. That fluid shift can cause cardiovascular collapse from vascular fluid depletion. It can also cause increased intracranial pressure (ICP) from fluid shifting into brain cells.

Hypotonic solutions shouldn't be given to patients at risk for increased ICP-for example, those who have had a stroke, head trauma, or neurosurgery [2]. Signs of increased ICP include a change in the patient's level of consciousness; motor or sensory deficits; and changes in the size, shape, or response to light in the pupils. Hypotonic solutions also shouldn't be used for patients who suffer from abnormal fluid shifts into the interstitial space or the body cavities-for example, as a result of liver disease, a burn, or trauma.
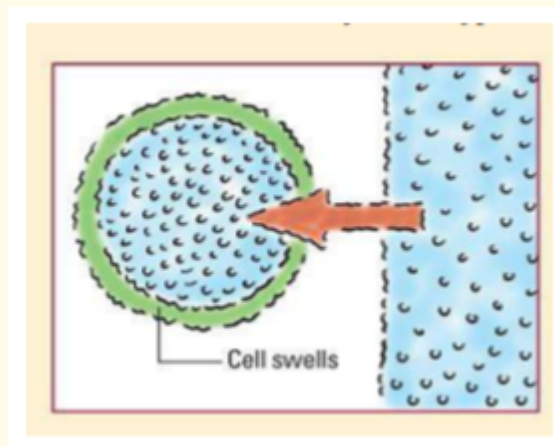

Figure C

Colloids [5]

The use of colloids over crystalloids is controversial. Still, the doctor may prescribe a colloid-or plasma expander-if your patient's blood volume doesn't improve with crystalloids. Examples of colloids that may be given include:

- Albumin (available in 5% solutions, which are osmotically equal to plasma, and 25% solutions, which draw about four times their volume in interstitial fluid into the circulation within 15 minutes of administration)

- Plasma protein fraction

- Dextran

- Hetastarch.

Colloids pull fluid into the bloodstream. The effects of colloids last several days if the lining of the capillaries is normal. The patient needs to be closely monitored during a colloid infusion for increased blood pressure, dyspnea, and bounding pulse, which are all signs of hypervolemia.

Colloids are IVFs used to expand intravascular volume, as they are meant to act using the same way as endogenous proteins and increase the intravascular oncotic pressure. This increased oncotic pressure is hypothesised to retain the fluid in the intravascular space for longer and attract water into the intravascular space. In theory, colloids provide much more fluid in the intravascular space (nearly all of the colloid given), in comparison with a much smaller percentage of crystalloid (depending on its tonicity) which is also distributed to other compartments. There has been a longstanding debate on the use of colloids versus crystalloids for resuscitation of unwell patients. Colloids are more expensive and occasionally can cause serious side effects such as exacerbation of acute kidney injury and coagulopathies. Some colloids have also been linked with anaphylaxis. There has been a meta-analysis of the use of colloids versus crystalloids in resuscitation, which showed no benefit of starches, a subgroup of high-molecular colloids. Some of the starches, for example hydroxyethyl starch (HES), have actually been withdrawn from clinical use because their serious side effects do not outweigh their benefits. This is not a forum for review of the latest research but there have been some significant studies regarding the use of colloids.

The term colloid describes a mixture of two or more substances that are evenly mixed; this can include gases, liquids or solids mixed in a solution. In clinical practice, these fluids include particles greater than 10,000 Da and it is these larger molecules that allow the solution to exert oncotic pressure and maintain water in the intravascular compartment.

The larger molecules are either from animal, plant or glucose base; we will review each type of colloid in turn.

Gelatins

Gelatins are semi-synthetic colloids made from animal connective tissue (hydrolysed collagens). The protein molecules are 30,000 Da and cannot cross the capillary membrane so will remain in the plasma, but side effects can include anaphylaxis. Patients should be asked (where practical) prior to their use, as some may object on a religious basis.

An example is Gelaspan which is composed of modified gelatin, a succinylated gelatin with molecular weight of 26,500 Da. Content of Gelaspan: Na^+ 151 mmol/L, K^+ 4 mmol/L, Cl^- 103 mmol/L, Ca^{2+} 1 mmol/L, Acetate 24 mmol/L, Mg^{2+} 1 mmol/L, and 40g of succinylated gelatin in 1000 mL.

Starches

Starches are made from plant extracts, amylopectins linked with a hydroxyethyl group. These colloids can persist in the circulation up to 24 hours after administration due to their large molecular size (they have a wide range of molecular size up to 200,000 Da). They are expensive to produce. An example is HES 10%.

Starches can lead to the following side effects: persistent itch, coagulopathy, exacerbation of acute kidney injury and risk of anaphylaxis (smaller than gelatins). Their serious side effects have resulted in their removal from use in the United Kingdom (Government Medical Safety Alert for HES 2013) [6].

Dextrans

Dextrans are made from glucose polymers. For example, Dextran 70 has molecules of 70,000 Da in weight. It increases oncotic pressure but also decreases plasma viscosity. It can cause hyperglycaemia and hyperosmolality, as it also contains sodium chloride and is a hyperosmolar IVF.

Albumin

Albumin is a naturally occurring protein and is developed from human albumin. It comes in varying strengths (5% and 20% albumin in 0.9% saline) and is isotonic in the lower concentrations of up to 5%. It is commonly used as the IVF of choice during ascitic drainage to avoid large fluid shifts. It can cause hypersensitivity reactions.

Several points for thought regarding colloid use:

- Colloids should be used for resuscitation only and not maintenance.

- Colloids are of value in hypovolemic resuscitation, but in haemorrhagic shock, replace blood with blood.

- Colloids are usually diluted in a 0.9% saline-type solution and their use can result in variable results.

- Use of certain colloids can result in renal injury and anaphylaxis.

- Gelatins are the most commonly used synthetic colloids.

If neither crystalloids nor colloids are effective in treating the imbalance, the patient may require a blood transfusion or other treatment.

Blood components [5]

Following rigorous screening, donor blood is processed into blood components such as red cell and platelet concentrates, fresh frozen plasma (FFP) and cryoprecipitate. Plasma from donor blood is processed and incorporated into blood plasma derivatives such as factors VIII and X, human albumin solution and immunoglobulins
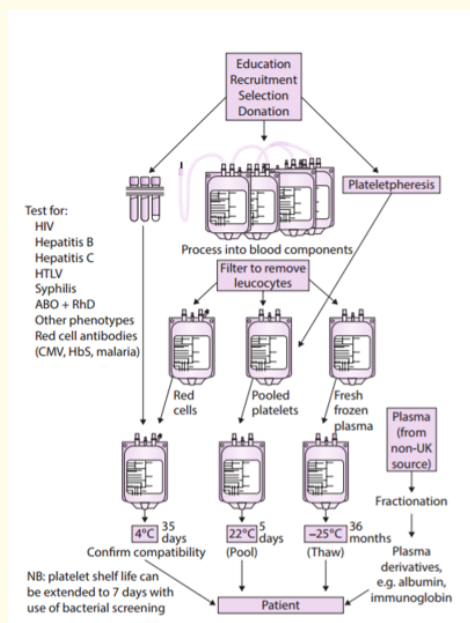

Figure D

Whole blood

A unit of whole blood consists of around 405 - 495 mL of leucocyte depleted blood with added citrate phosphate dextrose anticoagulant.

This is no longer commonly used in the United Kingdom, due to the unnecessary risk of reactions to components of blood transfused. This maximises the ways in which donor blood can be split into different components and used to help as many people as possible.

Red cells

Indication: To restore oxygen-carrying capacity in severe anaemia or ongoing bleeding, where alternative treatments are ineffective or not appropriate.

Fresh frozen plasma

Indication: Treatment of patients with bleeding in the presence of single or multiple clotting factor deficiency. No longer indicated for warfarin reversal; use prothrombin complex instead if required. Do not use as a plasma volume expander as there is the risk of a severe allergic reaction.

Major haemorrhage [6]

Major haemorrhage protocol exists in hospitals to co-ordinate the response to a significant loss of blood volume, as can be seen in trauma or surgical patients. Apart from clinicians, the haematology laboratory and porters are alerted so that blood components can be prepared and transported to the patient without delay. Major haemorrhage may be identified when bleeding leads to signs of haemorrhagic shock (systolic BP < 90 mmHg, HR > 100 bpm etc.); the patient is likely to have lost 30% - 40% of circulating blood volume by this stage. Major haemorrhage may also be defined as blood loss of more than 150 mL/min, or 50% of blood volume loss within 3 hours or more than one blood volume loss within 24 hours (> 70 mL/kg). Classes of hemorrhage.

Class	Blood loss	Response	Treatment
I	< 15% (0.75l)	Min. fast heart rate, normal blood pressure	Minimal
II	15 - 30% (0.75 - 1.5l)	Fast heart rate, min. low blood pressure	Intravenous fluids
III	30 - 40% (1.5 - 2l)	Very fast heart rate, low blood pressure, confusion	Fluids and packed RBCs
IV	> 40% (> 2l)	Critical blood pressure and heart rate	Aggressive interventions

Aim to site two large bore cannulas, taking samples for FBC, clotting profile, fibrinogen, U+Es, LFTs and G&S. Whilst waiting for blood to arrive, replace intravascular fluid volume with a warmed, balanced crystalloid (Hartmann's, Plasmalyte) or colloid (Volpex, Gelofusin) if profound hypotension occurs. Do not hesitate to administer O RhD negative blood if there is ongoing bleeding whilst waiting for group specific blood. Tranexamic acid as a bolus or infusion is also useful in limiting fibrinolysis in major haemorrhage.

Major haemorrhage protocol often consists of two or more packs of blood components in differing amounts. An example is set out below, check your local hospital guideline to determine what your protocol consists of.

- **Pack 1:** 4 units of RBCs

- **Pack 2:** 6 units of RBCs, 4 units of FFP, 1 pool of platelets. 2 pools of cryoprecipitate if fibrinogen level < 1.5 g/L Pack 1 is issued in the first wave and then pack 2 and subsequent repeats of pack 2 are issued following assessment of the patient's response, whether there is ongoing bleeding and upon advice from a senior haematologist.

In some cases of major haemorrhage, massive transfusion and coagulopathy, transfusion of RBC, FFP and platelet units is advocated in a near 1:1:1 approach. This is because transfusion of large volumes of IVF and RBCs leads to dilutional coagulopathy; platelet, fibrinogen and other clotting factor levels fall, especially when insufficient levels of platelets or FFP are transfused. Consumptive coagulopathy occurs when platelets and clotting factors are used up in the physiological response to trauma. Increased fibrinolysis, hypothermia, hypoxia, acidosis and hypocalcaemia also contribute to coagulopathy in major haemorrhage. Massive transfusion can lead to metabolic disturbances such as hypocalcaemia. The citrate anticoagulant in blood components can bind to ionised calcium, which can lead to clinical manifestations of hypocalcaemia (treat with calcium chloride or gluconate as necessary).

Remember [5]

Standard administration of 2 units of red blood cells over 2 - 3 hours each.

In elderly patients or those with existing circulatory compromise such as heart failure, administer Furosemide 20 - 40-mg orally or intravenously after the second unit of red cells and then with each alternate unit thereafter.

Re-assess the patient within 2 hours of the initial transfusion. Has there been an adequate haemodynamic response? Have BP and HR returned to normal range? Urine output maintained at ≥ 0.5 mL/kg/hr?

Is there a need for further units of red blood cells? Are FFP, platelets or cryoprecipitate now indicated if there is ongoing bleeding or abnormal coagulation?

Consider instigating the major haemorrhage protocol if there is rapid ongoing blood loss or haemorrhagic shock develops.

As a minimum, monitoring of the patient receiving a blood transfusion should include temperature, pulse, BP and RR, with a baseline 0 minutes before the transfusion starts and then 15 minutes after this. Check these observations again within 60 minutes of completing each individual unit. If any symptoms of a reaction occur, check these observations again; if there is a significant change, consider stopping the transfusion and taking further action to stabilise the patient.

You must monitor the patient closely for warning signs of fluid overload, dehydration, electrolyte abnormalities (hypocalcaemia, hyperkalaemia), altered consciousness or other adverse outcome. Complications of blood transfusions include immunological causes such as blood group incompatibility, haemolysis, graft-versus-host disease, transfusion-associated lung injury and urticaria. Nonimmunological causes include transmission of infection, iron overload, electrolyte changes in massive transfusion and air embolism.

Specifically, this text focuses on the identification and management of transfusion-associated circulatory overload.

Delivery methods [1]

The choice of I.V. delivery is based on the purpose of the therapy and its duration; the patient's diagnosis, age, and health history; and the condition of the patient's veins. I.V. solutions can be delivered through a peripheral or central vein. Catheters and tubing are chosen based on the therapy and site to be used. Here's a look at how to choose a site-peripheral or central-and which equipment you'll need for each.

Peripheral lines

Peripheral I.V. therapy is administered for short-term or intermittent therapy through a vein in the arm or hand. Potential I.V. sites include the metacarpal, cephalic, and basilic veins. In an adult, using veins in the leg or foot is unusual because of the risk of thrombo-

phlebitis and should be avoided if at all possible. For neonatal and pediatric patients, other sites include veins of the head, neck, and lower extremities.

Needle size matters

Choosing the right diameter (or gauge) needle or catheter is important for ensuring adequate flow and patient comfort. The higher the gauge, the smaller the diameter of the needle. If you want to give a lot of fluid over a short period of time, or if you will be giving more viscous fluids (such as blood), use a catheter with a lower gauge (such as 14G, 16G, or 18G) and a shorter length, which offers less resistance to fluid flow. For routine I.V. fluid administration, use higher gauge catheters, such as a 20G or a 22G. French catheters are the exception to the needle gauge rule: The higher the number, the greater the diameter.

Central lines

Central venous therapy involves administering solutions through a catheter placed in a central vein, typically the subclavian or internal jugular vein, less commonly the femoral vein. Central venous therapy is used for patients who have inadequate peripheral veins, need access for blood sampling, require a large volume of fluid, need a hypertonic solution to be diluted by rapid blood flow in a larger vein, or need a high-calorie nutritional supplement [7].

Getting pumped

Electronic infusion pumps deliver fluids at precisely controlled infusion rates. Because each machine requires its own type of tubing, check the manufacturer's directions before use. Most tubings contain anti-free-flow protection to prevent fluid overload and back-check valves to prevent drugs from mixing inside piggyback systems (one I.V. line plugged into another at a piggyback port). Filters on some tubing eliminate particulate matter, bacteria, and air bubbles.

Other types of tubing are available specifically for administering individual drugs or for piggybacking multiple drugs [8].

Complications of I.V. therapy [9]

Caring for a patient with an I.V. line requires careful monitoring as well as a clear understanding of what the possible complications are, what to do if they arise, and how to deal with flow issues.

Infiltration, infection, phlebitis, and thrombophlebitis are the most common complications of I.V. therapy. Other complications include extravasation, a severed catheter, an allergic reaction, an air embolism, speed shock, and fluid overload.

When you're trying to think of the four most common complications of I.V. therapy, remember that getting any complication is a PITI:

- Phlebitis

- Infiltration

- Thrombophlebitis

- Infection.

Air embolism [10]

An air embolism occurs when air enters the vein and can cause a decrease in blood pressure, an increase in the pulse rate, respiratory distress, an increase in ICP, and a loss of consciousness.

When air is apparent

If the patient develops an air embolism, notify the doctor and clamp off the I.V. Place the patient on his left side, and lower his head to allow the air to enter the right atrium, where it can disperse more safely by way of the pulmonary artery. Monitor him and administer oxygen. To avoid this serious complication, prime all tubing completely, tighten all connections securely, and use an air detection device on an I.V. pump.

Speed shock

Speed shock occurs when I.V. solutions or medications are given too rapidly. Almost immediately, the patient will have facial flushing, an irregular pulse, a severe headache, and decreased blood pressure. Loss of consciousness and cardiac arrest may also occur.

If speed shock occurs, clamp off the I.V., and notify the practitioner immediately. Provide oxygen, obtain vital signs frequently, and administer medications as ordered. Also, keep in mind that the use of infusion control devices can prevent this complication.

Fluid overload

Fluid overload can happen gradually or suddenly, depending on how well the patient's circulatory system can accommodate the fluid. Look for neck vein distention, puffy eyelids, edema, weight gain, increased blood pressure, increased respirations, shortness of breath, cough, and crackles in the lungs on auscultation.

Slow the flow

If the patient develops fluid overload, slow the I.V. rate, notify the practitioner and monitor vital signs. Keep the patient warm, keep the head of the bed elevated, and give oxygen and other medications (such as a diuretic) as ordered.

How you intervene

Nursing care for the patient with an I.V. includes the following actions:

- Check the I.V. order for completeness and accuracy. Most I.V. orders expire after 24 hours. A complete order should specify the amount and type of solution, all additives and their concentrations, and the rate and duration of the infusion. If the order is incomplete or confusing, clarify the order before proceeding.

- Monitor daily weights to document fluid retention or loss. A 2% increase or decrease in body weight is significant. A 2.2-lb (1-kg) change corresponds to 1 qt (1L) of fluid gained or lost.

- Measure intake and output carefully at scheduled intervals. The kidneys attempt to restore fluid balance during dehydration by reducing urine production. A urine output of less than 30 ml/hour signals retention of metabolic wastes. Notify the practitioner if your patient's urine output falls below 30 ml/hour.

- Always carefully monitor the infusion of solutions that contain medication because rapid infusion and circulation of the drug can be dangerous.

- Keep in mind the size, age, and history of your patient when giving I.V. fluids to prevent fluid overload. For pediatric patients, use a volume control I.V. delivery device to limit the amount of fluid the patient receives hourly and to prevent the accidental administration of excessive amounts of fluid.

- Note the pH of the I.V. solution. The pH can alter the effect and stability of drugs mixed in the I.V. bag. Consult medication literature or the practitioner if you have questions.

- Change the site, dressing, and tubing as often as facility policy requires. Solutions should be changed at least every 24 hours.

Documenting an I.V. infusion [11,12]

If your patient has an I.V. infusion, make sure you document the following information:

- The date, time, and type of catheter inserted

- The site of insertion and its appearance

- The type and amount of fluid infused

- The patient's tolerance of, and response to, therapy

- Patient and the patient's response)

- When changing I.V. tubing, don't move or dislodge the I.V. device. If you have trouble disconnecting the tubing, use a hemostat to hold the I.V. hub while twisting the tubing. Don't clamp the hemostat shut because doing so may crack the hub.

- Always report needlestick injuries. Exposure to a patient's blood increases the risk of infection with bloodborne viruses such as HIV, hepatitis B virus, hepatitis C virus, and cytomegalovirus.

About 1 out of 300 people with occupational needlestick injuries become HIV-seropositive.

Teaching about I.V. therapy [13]

When teaching a patient who is receiving I.V. therapy, be sure to cover the following topics and then evaluate your patient's learning:

- Expectations before, during, and after the I.V. procedure

- Signs and symptoms of complications and when to report them

- Activity or diet restrictions

- Care for an I.V. line at home.

IVF for resuscitation

Among ICU patients with hypovolemia, the use of colloids compared with crystalloids did not result in a significant difference in 28-day mortality. Although 90-day mortality was lower among patients receiving colloids, this finding should be considered exploratory and requires further study before reaching conclusions about efficacy [14,15].

Individual clinical practice will vary regarding the use of colloids over crystalloids in certain situations such as resuscitation in a cardiac arrest. It is, however, worth noting that the use of balanced crystalloids, such as Hartmann's or Plasmalyte, is recommended by national and international guidelines for administration in the unwell adult patient [16,17].

Thousands of patients in intensive care units (ICUs) throughout the world are treated with fluid therapy to restore effective blood volume and ensure optimal organ perfusion [18,19]. Fluid therapy includes abroad variety of products that are typically categorized as crystalloids and colloids. Although the goal is to use intravenous fluids to expand the intravascular space, fluid also moves into the extravascular space. Crystalloids are thought to counteract that movement via the osmotic pressure exerted by their solutes, whereas colloids are designed to exploit oncotic pressure gradients for the same effect [20]. Thus, theoretically, expansion of blood volume may be proportional to solute tonicity or oncotic power. The crystalloid family includes isotonic and hypertonic solutions that are also categorized into nonbuffered (e.g. isotonic saline) and buffered solutions (e.g. Ringer lactate, acetate, maleate). The colloid family includes hypooncotic (e.g. gelatins,4% or 5% of albumin) and hyperoncotic (e.g. dextrans, hydroxyethyl starches, and 20% or 25% of albumin) solutions. Generally, colloid solutions are thought to be more efficient than crystalloids in terms of the amount of fluid that remains in the intravascular space and so less fluid is required when using colloids vs crystalloids to achieve similar hemodynamic goals [21,22].

However, there are other effects of these fluids, including alterations to the immune response to critical illness. Additionally, there is concern that hydroxyethyl starches may increase the risk of death or acute kidney injury [23,24]. Most colloid solutions are also more expensive than crystalloids. In recent studies of general ICU patient populations, fluid replacement with 5%of albumin [25] or with 6% of hydroxyethyl starch [26] showed similar effects on mortality compared with isotonic saline. Although there was a suggestion that the subset of patients with severe sepsis might benefit from resuscitation with albumin [26] the current Surviving Sepsis Campaign guidelines recommended crystalloids as the preferred fluid therapy and against the use of hydroxyethyl starches [4].

Colloid vs crystalloid

Figure E

In general, several review and consensus bodies are currently advocating the use of balanced crystalloids (e.g. Hartmann's, Plasmalyte) in resuscitation of acutely unwell patients. This advice is based on several large studies comparing outcomes when different types of fluids are used for initial resuscitation. Balanced crystalloids have a similar ion composition to plasma, as they are isotonic. This means that ions distribute within the intravascular space and through the semi-permeable capillary membrane into the interstitial space [4].

There is no forward movement into cells as they do not penetrate the cell's lipid bilayer membrane. Balanced crystalloids distribute between the intravascular space and the interstitial space at a ratio of approximately 25% - 75%, respectively.

Intravascular volume is restored by increasing the oncotic pressure in the intravascular space, i.e. water moves into the intravascular space, increasing circulatory volume. However, this effect is short-lived with balanced crystalloids, as the majority of fluid administered migrates into the interstitial space. This means that a larger volume of balanced crystalloid is required to initially replace the deficit in the intravascular volume and then to maintain it over time [27,28].

So far, we have established that current expert advice is to administer a balanced crystalloid in bolus form as part of initial resuscitation of an acutely unwell patient. The aims of administering IVF (balanced crystalloid, colloid, both or blood components) in this situation are to restore intravascular fluid volume, stabilise haemodynamics and maintain tissue perfusion [29].

On the whole, colloids are good plasma volume expanders; they contain large molecules that do not easily cross the semi-permeable capillary membrane and the volume required to replace the deficit of fluid is 1:1. The ratio of required volume of balanced crystalloid to volume of fluid lost is 3:1 in comparison. Infused colloids also stay within the intravascular space for a longer period of time than crystalloids do. When used for resuscitation, colloids can cause anaphylactic reactions or peripheral/pulmonary/cerebral oedema or heart failure, especially when used in excessive volumes. Oedema occurs later than in crystalloid use but is more sustained.

In sepsis, anaphylaxis, severe trauma and other forms of inflammation, the capillary vessel walls become leakier, allowing the colloid molecules to cross into the interstitial layer - oedema. Some studies have also shown an increased risk of mortality with the use of colloids in these situations - avoid using them [30].

In addition, large volumes of some colloids (starches, dextran) can contribute to coagulopathy by interfering with platelet function, and clotting factor complexes, especially if clotting factors are depleted and not replaced - avoid using them. Although more robust clinical trials have been conducted and meta-analysed recently, a common outcome measured is mortality; starch based colloids used as resuscitation fluids have been associated with a higher risk of mortality and therefore their use is advised against. Starch-based colloids and gelatins are also advised against in severe sepsis and those at risk of acute kidney injury.

In summary, balanced crystalloids (Hartmann's, Plasmalyte) are now the recommended fluid of choice for initial resuscitation of an acutely unwell patient, where there is no ongoing bleeding. Gelatin-based colloids (Volplex, Gelofusin) are useful when there is ongoing bleeding, whilst waiting for replacement blood to arrive. Treat the patient individually; they may need more than one type of fluid to restore adequate circulation and tissue perfusion, and in varying amounts. Monitor electrolyte levels to avoid life-threatening imbalances. As always, review your implemented treatment quickly, consider additional measures and seek senior and multidisciplinary help [31].

Medical considerations in fluid assessment and management

To cover both urine output and insensible losses, healthy adults require around 30 - 40 mL/kg of water over 24 hours. This equates to 2 - 2.5L of fluids/day in a 70-kg adult. These requirements will be different in some groups of patients, for example those in renal failure or the frail elderly. This is discussed in detail in the sections that follow [32].

No fluid balance available:

- Estimated maintenance from weight.

- Estimate insensible losses (0.5 - 1.5 L/24 hours).

- Estimate deficit: From your fluid assessment.

Fluid balance available

- Recorded intake and losses from chart

- Estimate insensible losses (0.5 - 1.5 L/24 hours)

- Estimate deficit: From your fluid assessment.

Once the fluid requirements are known they can be written up as 500- and 1000-mL bags at the appropriate rate. Do not forget to factor in oral intake. Where it is safe to do so, prescribe fluids so that they will run out during the next working day so that the team looking after the patient can reassess.

Fluid deficit	Mild	Moderate	Severe
Heart rate (HR)	Normal (N)	>100	>120
Blood pressure (BP)	N	N SBP < 20 mmHg decrease DBP < 10 mmHg decrease	SBP > 20 mmHg decrease DBP > 10mmHg decrease
Urine output	>0.5 mg/kg/hr	<0.5 mg/kg/hr	<0.3 mg/kg/hr
% Body weight loss	3–5	5–10	10–15
Estimated deficit	<750 mL	750 mL–1.5 L	>1.5 L

System	Fluid depletion
Cardiovascular	• Tachycardia? • Hypotension? • Capillary refill time (CRT) >2 seconds? • Decreased skin turgor? • Dry mucous membranes? • Postural drop in blood pressure?
Respiratory	• Respiratory rate (RR) >20 breaths/min?
Renal	• Decreased urine output <0.5 mL/kg/hr? • Concentrated urine?
Neurological	• Low Glasgow Coma Scale (GCS) <8? • Comatose? Meningism? Retinal signs? (may be associated with CNS bleed)

Figure F

A fluid-challenge technique should be used to determine a patient's actual response to fluids, while limiting the risks of adverse effects. A fluid challenge incorporates four elements that should be defined in advance [33,34]:

- First, the type of fluid must be selected. Crystalloid solutions are the first choice, because they are well tolerated and cheap. The use of albumin to correct severe hypoalbuminemia may be reasonable in some patients.

- Second, the rate of fluid administration must be defined. Fluids should be infused rapidly to induce a quick response but not so fast that an artificial stress response develops; typically, an infusion of 300 to 500 ml of fluid is administered during a period of 20 to 30 minutes.

- Third, the objective of the fluid challenge must be defined. In shock, the objective is usually an increase in systemic arterial pressure, although it could also be a decrease in heart rate or an increase in urine output.

- Finally, the safety limits must be defined. Pulmonary edema is the most serious complication of fluid infusion. Although it is not a perfect guideline, a limit in central venous pressure of a few millimeters of mercury above the baseline value is usually set to prevent fluid overload.

Stimulation of the patient and any other change in therapy should be avoided during the test. Fluid challenges can be repeated as required but must be stopped rapidly in case of non-response in order to avoid fluid overload.

Stages of fluid therapy

The framework recently proposed by Vincent and De Backer [34] recognizes four distinct phases or stages of resuscitation: Rescue, Optimization, Stabilization, and De-escalation (ROS-D) (Table 1 and figure 1).

	Rescue	Optimization	Stabilization	De-escalation
Principles	Lifesaving	Organ rescue	Organ support	Organ recovery
Goals	Correct shock	Optimize and maintain tissue perfusion	Aim for zero or negative fluid balance	Mobilize fluid accumulated
Time (usual)	Minutes	Hours	Days	Days to weeks
Phenotype	Severe shock	Unstable	Stable	Recovering
Fluid therapy	Rapid boluses	Tibiae fluid infusion conservative use of fluid challenges	Minimal maintenance infusion only if oral intake inadequate	Oral intake if possible avoid unnecessary i.v. fluids
Typical clinical scenario	Septic shock Major trauma	I ntraoperative GDT Burns DKA	NPO postoperative patient Drip and suck' management of pancreatitis	Patient on full enteral feed in recovery phase of critical illness Recovering ATN
Amount		Guidelines, for example, SSC, pre-hospital resuscitation. trauma, burns, etc.		

Table 1: Characteristics of different stages of resuscitation: Fit for purpose fluid therapy. GDT: goal directed therapy; DKA: Diabetic Keto Acidosis; NPO: Nil Per Os; ATN: Acute Tubular Necrosis; SSC: Surviving Sepsis Campaign.

Logically, these describe the four different clinical phases of fluid therapy, occurring over a time course in which patients experience a decreasing severity of illness.

The Rescue phase anticipates an immediate escalation of fluid therapy, for resuscitation of the patient with life threatening shock (characterized by low arterial pressure, signs of impaired perfusion, or both) and characterized by the use of fluid bolus therapy (See box).

Box 2 Terminology

- Fluid bolus: a rapid infusion to correct hypotensive shock. It typically includes the infusion of at least 500 ml over a maximum of 15 min
- Fluid challenge: 100-200 ml over 5-10 min with re-assessment to optimize tissue perfusion[17]
- Fluid infusion: continuous delivery of i.v. fluids to maintain homeostasis, replace losses, or prevent organ injury (e.g. prehydration before operation or for contrast nephropathy)
- Maintenance: fluid administration for the provision of fluids for patients who cannot meet their needs by oral route. This should be titrated to patient need and context and should include replacement of ongoing losses. In a patient without ongoing losses, this should probably be no more than $1-2 \text{ ml kg}^{-1} \text{ h}^{-1}$
- Daily fluid balance: daily sum of all intakes and outputs
- Cumulative fluid balance: sum total of fluid accumulation over a set period of time[18]
- Fluid overload: cumulative fluid balance expressed as a proportion of baseline body weight. A value of 10% is associated with adverse outcomes[19]

Box: Terminology.

In Optimization, the patient is no longer in immediate life-threatening danger but is in a stage of compensated shock (but at high risk of decompensation) and any additional fluid therapy is given more cautiously, and titrated with the aim of optimizing cardiac function to improve tissue perfusion with ultimate goal of mitigating organ dysfunction. The workgroup felt strongly that a clear distinction had to be made between a 'fluid bolus', that is, large volume given rapidly to rescue, without close monitoring, and a 'fluid challenge' (See box for definition) which was considered as a test where the effects of a more modest volume given more slowly are assessed, in order to prevent inadvertent fluid overload (also defined in box). Stabilization reflects the point at which a patient is in a steady state so that fluid therapy is now only used for ongoing maintenance either in setting of normal fluid losses (i.e. renal, gastrointestinal, insensible), but this could also be fluid infusion (including rehydration) if the patient was experiencing ongoing losses because of unresolved pathology. However, this stage is distinguished from the prior two by the absence of shock (compensated or uncompensated) or the imminent threat of shock. Finally, while in the first three stages ('SOS'), fluids are usually administered, in the last stage (D), fluids will also be removed from the patient and usually, the goal will be to promote a negative fluid balance (Figure 2). Typically, most patients requiring fluid resuscitation will enter this conceptual framework in the Rescue phase (Figure 1). However, some may enter at the Optimization phase, as they do not have hypotension and they are either in a compensated state or are at imminent risk for shock, where fluid challenges rather than fluid boluses are the initial management. All patients will then proceed to Stabilization and De-escalation as their clinical condition improves, and the prioritization for fluid management now switches to prevention of its adverse effects. The group recognized that this is a dynamic process where patients may experience temporary deterioration, for example, as a consequence of a severe infection, necessitating switching from a Stabilization strategy back to Optimization. Less often, the clinical condition is again life threatening, for example, as a consequence of septic or haemorrhagic shock, moving the patient back into the Rescue phase.
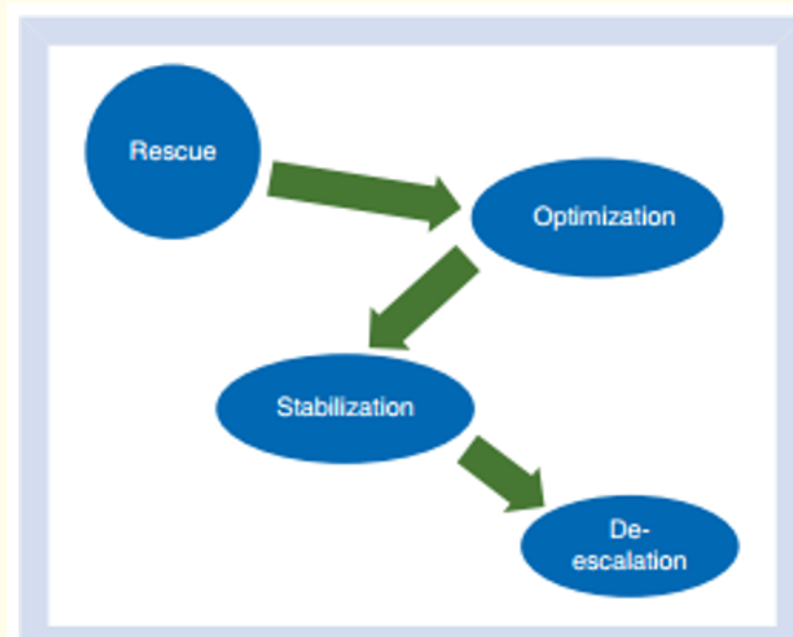

Figure 1: Relationship between the different stages of fluid resuscitation. Reproduced with permission from ADQI (www.ADQI.org).
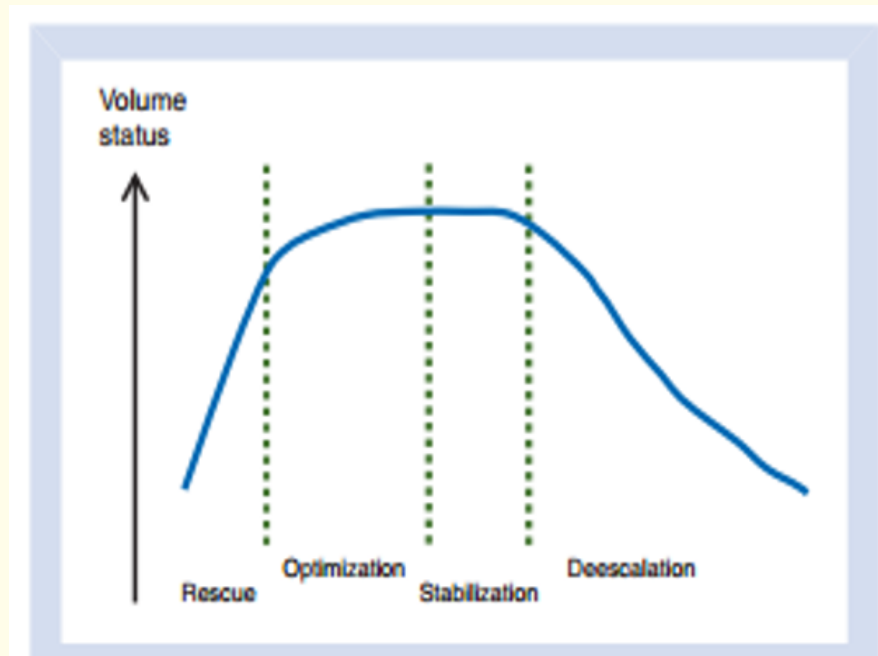
Figure 2: Patients volume status at different stages of resuscitation. Reproduced with permission from ADQI (www.ADQI.org).

Monitoring and reassessment [35]

A most important aspect of this new conceptual framework for fluid therapy is the individual assessment of the patient's fluid requirements, the timely administration of that fluid, and then the frequent re-assessment of response and ongoing needs. All too often, the 'recipe' fluid therapy that is 'one size (dose) fits all' is chosen for reasons of convenience or possibly because clinicians do not actually think about why they are giving fluids in the first place. While daily fluid and electrolyte requirements can be reasonably well estimated for the average person, it is becoming more apparent that patients, and certainly seriously ill patients, are not 'average' and have widely varying and individual requirements. To enable the clinician to assess fluid requirements, we propose a minimum and desirable monitoring set at each stage of fluid therapy (Figure 3A and 3B). In the Rescue phase, initial management should be initiated using a combination of clinical and haemodynamic parameters together with near-patient diagnostics and without need for sophisticated initial assessment such as echocardiography (Figure 3A). In this phase, reassessment and re-challenge should be performed without the clinician leaving the bedside; it requires constant observation of the patient's haemodynamic situation in order to prevent life-threatening over- or undertreatment. Once fluid boluses have been given and the clinician has determined that the patient has been 'rescued', additional patient-centered data obtained by monitoring responses by Echo/Doppler, CVP, and/or $SCVO_2$ catheters to provide additional goal-directed endpoints for further management (Figure 3B) can beused. These additional parameters will help determine the appropriate time to transition from Rescue to Optimization. In the Optimization phase, the emphasis of fluid therapy moves away from saving the life of the patient to ensuring adequate blood and therefore oxygen delivery to at-risk organs. The aim in this phase is to prevent subsequent organ dysfunction and failure because of both hypoperfusion and tissue oedema. In the Stabilization and De-escalation phase, in contrast to the Rescue and Optimization phase, the patient may only need to be seen once every few hours with the clinician either prescribing i.v. fluids

(or potentially diuretics if there is evidence of symptomatic volume overload) on the basis of physical examination, blood chemistry, and the likely clinical course (Figure 3B).
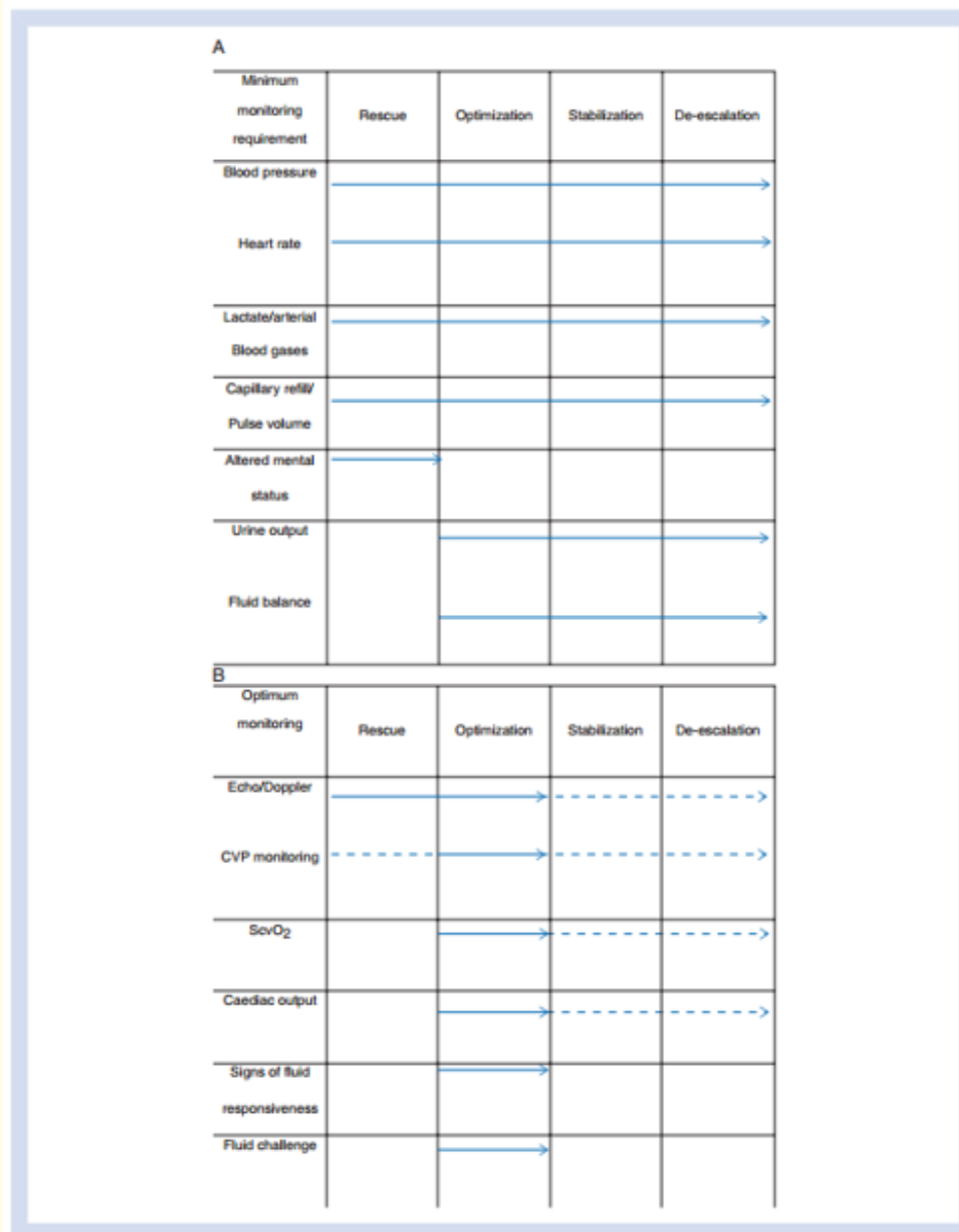

Figure 3: *Assessment of fluid requirements. Reproduced with permission from ADQI (www.ADQI.org). (A) Minimum monitoring set at each stage of fluid therapy. (b) Desirable monitoring set at each stage of fluid therapy.*

Conclusion

I.V. fluid therapy can be lifesaving but like all medical interventions carries with it a degree of risk. The aims of the workgroup were to define 'Fit for purpose fluid therapy' tailored to the specific indications, time-, phase-dependent variables, or both and the context of the patient. We created a conceptual framework on which future guidelines or research could be modeled and expanded. The group aimed to move away from a 'one size fits all' approach for the early phases of fluid therapy (introducing a distinction between a fluid bolus and that of a fluid challenge), towards a bespoke, carefully managed approach in order to optimize patient outcome.

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