

CRYSTALLOID FLUID THERAPY



Fredericksburg, Va. View the from east bank of the Rappahannock River March 1863

“It is well that war is so terrible, we should grow too fond of it”.

Robert E. Lee, following the horrific battle of Fredericksburg Christmas day, 1863.

“Kill them. Kill them all!” (Stonewall Jackson).

Martha,

I can inform you that I have seen the monkey show at last, and I don't want to see it no more. I never want to go on another fight anymore sister. I want to come home worse than I ever did before".

(Thomas Warwick, 34th Alabama)....

A line of hills overlooked Fredericksburg, Virginia, a key Confederate transportation link midway between Richmond and Washington. Union general Ambrose E. Burnside's plan had been to cross the Rappahannock by pontoon, occupy the town, then take the thinly defended heights. Bold action did not come naturally to Ambrose Burnside, though he had led his men to Fredericksburg determined to display the fighting spirit his predecessor George McClellan had so conspicuously lacked.

But now the war department failed him, and 17 days passed waiting for pontoon bridges to arrive. By the time the bridge was in place, Lee had 75,000 men waiting in the hills. Stonewall Jackson was on the right, James Longstreet on the left along a bluff called Marye's Heights. From the top of the heights Lee could just see Chatham mansion across the river on the Union side, where 30 years before he had courted his wife Mary Custis. It was now Burnside's headquarters. On December 11th Union guns began shelling Fredericksburg, setting much of the town on fire. Then the troops started across the river. Some wondered why the Confederates did not make it harder for them to cross.

"They want to get us in", one private said. "Getting out won't be quite so smart and easy".

While waiting to attack the heights, Union men looted what was left of the town. The great assault came two days later on December 13th. Federal forces advanced towards Marye's Heights. Lee could not believe the enemy would be so foolish. His artillery covered all the approaches. Four lines of riflemen waited behind a stonewall that ran along the base of the hill.

"General" an officer assured James Longstreet, "A chicken could not live in that field when we open on it"

"How beautifully they came on. Their bright bayonets glistening in the sun made the line look like a huge serpent of blue and steel. We could see our shells bursting in their ranks, making great gaps, but on they came, as though they would go straight through us and over us. Now we gave them canister, and that staggered them. A few more paces onward and the Georgians in the road below us rose up and let loose a storm of lead into the faces of the advancing brigade".

(Confederate Soldier).

"The brilliant assault of their Irish brigade was beyond description. We forgot they were fighting us, and cheer after cheer at their fearlessness went up along our lines".

(General George Pickett)

It was suicide.

“They came forward” one man said, “as though they were breasting a storm of rain and sleet. Faces and bodies half turned to the storm, shoulders shrugged”. The Irish brigade got within 25 paces of the wall. The men of the 24th Georgia who shot them down were Irish too. A Union officer watching from a church steeple saw brigade after brigade charge the stone wall. “They seemed to melt”, he said, “like snow coming down on warm ground”

They still believed that to take a position, you massed your men and moved up and gave them the bayonet. There were practically no bayonet wounds in the Civil War, much more than there were in the First World War or the Second. They never came in that kind of contact, or at least very seldom came in that kind of contact, but they still thought that to mass their fire they had to mass their men. So they lined up and marched up toward an entrenched line and got blown away.

(Shelby Foote, Civil War Historian).

Fourteen assaults were beaten back from Marye’s Heights before Burnside decided it could not be taken. 9,000 men fell before the Confederate guns.

More credit for valor is given to Confederate soldiers. They’re supposed to have had more élan and dash. Actually, I know of no braver men in either army than the Union troops at Fredericksburg which is a serious defeat. But to keep charging that wall at the foot of Marye’s heights, after all the failures there had been, and they were all failures, is a singular instance of valor.

(Shelby Foote, Civil War Historian).

Watching from above, even Robert E. Lee was moved. “It is well”, he said, “that war is so terrible, we should grow too fond of it”.

Colonel Joshua Lawrence Chamberlain and his 20th Maine were among the thousands of Union men pinned down at the foot of the heights. That night the temperature fell below freezing and a stiff wind blew. Men now froze as well as bled to death. Night brought quiet.

“But out of that silence rose new sounds, more appalling still - strange ventriloquism, of which you could not locate the source. A smothered moan as if a thousand discords were flowing together into a keynote, weird, unearthly, terrible to hear and bear, yet startling with its nearness. The writhing concord broken by cries for help. Some begging for a drop of water. Some calling on God for pity and some on friendly hands to finish what the enemy had so horribly begun. Some with delirious dreamy voices murmuring loved names as if the dearest were bending over them. And underneath, all the time, the deep bass note from closed lips too hopeless or too heroic to articulate their agony”

(Union Soldier)

“At last, out wearied and depressed, I moved two dead men a little and lay down between them, making a pillow of the breast of a third, drew the flap of his overcoat over my face and tried to sleep”.

(Joshua Lawrence Chamberlain).

They were stuck there all night and all the next day, crouching behind a wall of their own dead, trying not to hear the Confederate bullets thudding into the corpses of their friends. Burnside, openly weeping, declared that he himself would lead the new attack. Subordinates talked him out of it. That night, Chamberlain and his men scraped out shallow graves for the dead. As they worked, the Northern Lights began to dance in the winter sky.

“Who would not pass on as they did? Dead for their country’s life and lighted to burial by the meteor splendors of their native sky”.

(Joshua Lawrence Chamberlain).

It was very unusual to see the Northern lights that far south, but the whole heavens were lit up with streamers of fire, and whatever the Northern Lights are. And the Confederates took it as a sign that God almighty Himself was celebrating a Confederate victory. (Shelby Foote, Civil War Historian).

“The slaughter is terrible. The result disastrous. Until we have good generals, it is useless to fight battles”. (Union soldier)

The Union had lost 12,600 men. The South had lost 5,300 men, but many of them were only missing - gone home for Christmas. The battered Union army limped back across the river. Icy rain began to fall. From the ruins of Fredericksburg, Confederate soldiers openly taunted the Union troops huddled miserably on the far side of the Rappahannock.

After the battle of Fredericksburg, the Confederates went back into the town and they saw all the damage that had been done during the Union occupation of the town - it was a great deal of damage, real vandalism - and they were shocked and someone on Jackson’s staff said, “How are we going to put an end to all this kind of thing?” And Jackson said, “Kill them. Kill them all”

(Shelby Foote, Civil War Historian).

David McCullough and Shelby Foote in Ken Burns’, “The Civil War”, 1990.

Following the stalemate of the Confederate invasion of the North at the Battle of Antietam, Robert E. Lee braced his lines for a final Union assault. When McClellan failed to attack the following morning Lee saw his chance. Recognizing that he could not continue to sustain huge losses in the way that the Union Army could, he withdrew his Army of North Virginia back across the Potomac, he would regroup and fight another day. McClellan was ecstatic, he could at last claim a “great victory”. Lincoln too was overjoyed. Antietam was victory enough to give him the political kudos to finally announce his emancipation proclamation that would irrevocably alter the way in which the great European powers viewed the American Civil War. There would be no further serious talk of breaking the Union blockade and recognizing the Confederacy. But Lincoln’s elation was short lived. Reports came in that McClellan had not moved in pursuit of Lee. Lincoln went to Sharpsburg in person and frantically urged McClellan to go after the rebels and finish them. But McClellan, badly shaken by the ferocity and the scale of the battle, had lost his nerve. Despite giving Lincoln assurances he would cross

the Potomac, two weeks later he still had not moved. Lee, by this time, was well gone. Lincoln was furious. Though McClellan had saved the North from invasion, he could have won the war. Lincoln knew he had the men, the industry and the material to gain victory over the South, but what he lacked was the commander. He dismissed McClellan for a second time - this time permanently, and put his trust in Ambrose Burnside, a general who had a reputation for initiative and aggression. He would be the man to finally match it with Robert E. Lee.

Burnside would lead a massive renewed Army of the Potomac, 114,000 strong, into Virginia, the fourth attempted invasion of the South. But Lee had a genius for knowing the mind of his adversary. He knew that Burnside would attack, indeed he was in command because of his predecessor's unwillingness to do so. Lee chose his ground well. Over 70,000 Rebels would be waiting for the new Union commander at the city of Fredericksburg on the Rappahannock River, where he had established a virtually impregnable line of defence. On the morning of December 11, Burnside opened the battle with a massive Union artillery barrage on Fredericksburg, under the cover of which his army moved across the Rappahannock. Lee had established extremely strong defensive lines outside of the city however at Marye's Heights while Stonewall Jackson had taken up a similarly impressive position on Prospect Hill. General George Meade attacked Jackson's position first, but after achieving an early breakthrough was bloodily repulsed by Jackson's artillery. Jackson, as was his idiosyncrasy in battle and victory, raised his arm high into the air as if in prayer, a signal that his men well recognized. The Rebel Yell rent the air in victory.

With Meade reeling back from Prospect Hill, Burnside gambled on an all out assault on, Lee's left, at James Longstreet's lines at Marye's Heights. Here would play out one of the most sickening scenes of the entire Civil War. Burnside sent wave after wave after wave of Union soldiers against the Heights, indeed no fewer than fourteen charges, each and everyone a shocking and bloody repulse under ferocious and unrelenting Confederate fire. Burnside, openly weeping by now, offered to lead one final attack himself, but this was refused by his staff. The repeated and pointless Union charges on Marye's Heights gave the first horrific hint of how warfare would look on the industrial scale in the First World War over two generations later. Unlike in Jackson's sector the Rebel Yell was not heard on Marye's Heights. Even the most hardened Confederate veterans could scarce believe the bravery they had witnessed. In one of the most famous and extraordinary gestures of soldierly brotherhood in the history of warfare, Confederate troops gave emotional cheers in tribute to a gallant enemy. Even Robert E. Lee looking at the fighting through field glasses from Prospect Hill was overcome with admiration and emotion. He turned to James Longstreet and famously muttered, "It is well that war is so terrible, we should grow too fond of it".

The magisterial Civil War Historian, Shelby Foote related that, "More credit for valor is given to Confederate soldiers. They're supposed to have had more élan and dash. Actually, I know of no braver men in either army than the Union troops at Fredericksburg". Just as the Battle of Fredericksburg finally dispelled a long held myth, that Confederate soldiers were superior to their Northern counterparts in valor, so the landmark studies known as SALT - ED and SMART have also dispelled a long held myth - that Normal Saline is the preferred crystalloid in fluid resuscitation!

CRYSTALLOID FLUID THERAPY

Introduction

For many decades **Crystalloid Fluid Therapy** has remained the standard treatment in IV fluid resuscitation.

Crystalloid Fluid Therapy preparations include:

1. Normal saline (0.9 %)
2. Balanced salt solutions

These aim to provide a more **physiological pH** and **isotonic salt concentration** with respect to human plasma.

Examples include:

- Hartman's solution (i.e Lactated Ringer's solution)
- Plasma-lyte (148)

Note that none of the currently used resuscitation fluids are *truly* “physiological”

Traditionally, 0.9% sodium chloride (“normal saline”) has been the most commonly administered intravenous fluid.

More recently however, there have been concerns over that fact that larger volumes of intravenous saline are associated with hyperchloremic metabolic acidosis and acute kidney injury, and worse outcomes compared with resuscitation using more physiologically balanced salt solutions.

Two recent major studies **SALT - ED** (Saline against Lactated Ringer's or Plasma-Lyte in the Emergency Department) and **SMART** (Isotonic Solutions and Major Adverse Renal Events Trial) have now lent at least evidence to the debate.

SALT - ED STUDY

Among **non-critically** ill adults treated with intravenous fluids in the emergency department, there was no difference in the primary trial outcome, namely hospital-free days (at 28 days) between treatment with balanced crystalloids and treatment with saline.

However with respect to secondary outcomes balanced crystalloids resulted in a lower incidence of major adverse kidney events within 30 days than saline

SMART STUDY

Among **critically** ill adults, the use of balanced crystalloids for intravenous fluid administration resulted in a lower **rate of death from any cause, new renal replacement therapy, or persistent renal dysfunction** than the use of saline.

History

The first successful IV fluid resuscitation is attributed to the British physician **Dr Thomas Latta** (1796 - 1833). In 1832 London was in the grip of a devastating cholera epidemic. Dr Latta administered rectal fluids to a moribund woman dying of cholera but to no avail. Then desperation, and without medical precedent, he administered IV fluids

“She had apparently reached the last moments of her earthly existence” he recorded, “and now nothing could injure her – indeed, so entirely was she reduced, that I feared I should be unable to get my apparatus ready ere she expired. Having inserted a tube into the basilic vein, cautiously – anxiously, I watched the effects; ounce after ounce was injected, but no visible change was produced.

Still persevering, I thought she began to breathe less laboriously, soon the sharpened features, and sunken eye, and fallen jaw, pale and cold, bearing the manifest impress of death’s signet, began to glow with returning animation; the pulse, which had long ceased, returned to the wrist; at first small and quick, by degrees it became more and more distinct ... and in the short space of half an hour, when six pints had been injected, she expressed in a firm voice that she was free from all uneasiness, actually became jocular, and fancied all she needed was a little sleep.”

It was a truly miraculous recovery - this woman was probably the first in history to survive cholera from such a moribund state. Then inexplicably the medical “establishment” showed no interest in the case whatever ! In the words of the eminent Dr Neil Long, Latta then “...published his results in the Lancet but as with most of medicine it took another 70 years before it was widely adopted !”

Physiology

Normal electrolyte values for human plasma are as follows:

Electrolyte	Normal Range
Sodium	135 - 145 mmol/L
Chloride	95 - 100 mmol/L
Potassium	3.5 - 5.5 mmol/L
Bicarbonate	24 - 28 mmol/L
Calcium	2.1 - 2.6 mmol/L
Magnesium	0.8 - 1.0 mmol/L
pH	7.35 - 7.45
Osmolality	275 - 295 mOsm/kg

Crystalloid Solutions

Electrolyte compositions of crystalloid solutions are as follows:

ELECTROLYTE	NORMAL SALINE ("Isotonic" saline)	BALANCED CRYSTALLOID	
		A balanced salt solution is a a solution made to a physiological pH and isotonic salt concentration .	
		HARTMAN'S Soln. (LACTATED RINGERS)	PLASMA-LYTE (148) (Baxter Australia & UK)
Na+	154 mmol/L	131 mmol/L	140 mmol/L
Cl -	154 mmol/L	112 mmol/L	98 mmol/L
K+	NIL	5 mmol/L	5 mmol/L
Ca++	NIL	2 mmol/L	NIL
Lactate	NIL	29 mmol/L	NIL
Mg+	NIL	NIL	1.5 mmol/L
pH	5.5	5 - 6	7.4
TONICITY ⁴	Isotonic (measured) ⁴	Hypotonic	Isotonic
Osmolarity (<i>calc</i>)	308 mOsmol/L	278 mOsmol/L	295 mOsmol/L
Osmolality (<i>meas</i>)	286 mOsmol/kg	256 mOsmol/kg	271 mOsmol/kg
Glucose	NIL	NIL	NIL
Acetate	NIL	NIL	27 mmol/L
Gluconate	NIL	NIL	23 mmol/L

Management

Normal saline:

Normal saline has historically been the most widely used crystalloid fluid, however it does have some adverse effects when used in large amounts, and the “balanced” salt solutions (**Hartmanns** and **Plasma-lyte**) have some advantages over normal saline.

Normal saline is mildly hypertonic

Normal saline has higher concentrations of sodium and chloride compared to human plasma

The main *adverse* effects of normal saline include:

1. Normal anion gap **hyperchloremic acidosis**.

- Not desirable in patients who are already acidemic to begin with.

Note that acidosis (induced by the hyperchloraemia) will tend to worsen hyperkalemia (potassium is increased by acidosis) - even though normal saline contains no potassium.

2. **Hyperchloremia** causes renal vasoconstriction, so excess normal saline can impair renal function.

Patients with metabolic alkalosis will benefit from normal saline - this will replace **lost chloride** (the cause of the metabolic alkalosis) in cases of protracted vomiting

Balanced Salt Solutions:

Lactate:

The lactate of **Hartmanns solution** is metabolized into **bicarbonate** by the liver, which can help correct metabolic acidosis. The lactate therefore acts as a buffer for acid.

Note that Ringer's Lactate does not cause lactic acidosis, because it contains sodium **lactate** (not lactic **acid**).

Potassium:

Hartmanns and Plasma-lyte have a potassium concentration similar to the concentration in plasma, however it is insufficient to produce a useful effect in case of *severe* potassium deficiency; therefore, it should not be used for correction of severe potassium deficiency.

There is a theoretical concern that Hartmanns may exacerbate hyperkalemia, however this concern is unfounded (*assuming the Hartmanns is not delivered at an excessive rate*) because:

1. If a patient has hyperkalemia, then Hartman's has a potassium concentration which is lower than the patient's potassium concentration.

Administering Hartman's to a patient with hyperkalemia will tend to pull the patient's potassium towards 5 mEq/L, and thereby decrease the potassium level

2. Potassium has a Vd that is greater than simply the extravascular space
3. Hartman's has a mild alkalinizing effect (via its lactate being metabolized to bicarbonate) and so this will actually help to reduce potassium levels.

The maximum recommended rate of delivery of potassium is generally quoted as up to **20 mmols** per hour delivered via **100 ml** Baxter bags.

In terms of potassium delivered this would be the equivalent of 4 liters of Hartman's per hour or **1 liter of Hartman's over 15 minutes**. In any case the potassium is being delivered in a much greater volume of fluid, i.e 1000 mls of fluid (as opposed to 100 mls of fluid in the Baxter bags, or for that matter in just 10 mls with the old dangerous 10 mmols in 10 ml ampoule or 2 grams in 10 mls formulations), and so is much less concentrated.

Magnesium:

There is a theoretical concern that Plasma-lyte could aggravate a pre-existing hypermagnesemia.

Hartmanns Solution versus Plasma-lyte:

Currently there isn't any firm evidence regarding the comparison of Hartman's versus Plasma-lyte.

Hartman's however uses **lactate** as an anion, whereas Plasma-lyte which uses **acetate** and **gluconate** as anions.

Lactate is possibly a more physiologic choice, which may improve cardiac function (via its beneficial effect of buffering acidosis via the production of bicarbonate ions).

Acetate and gluconate ions are metabolized ultimately to carbon dioxide and water, which requires the consumption of hydrogen cations and so produces some metabolic alkalinizing effect as well.



The Aurora Borealis (Northern Lights)

“Who would not pass on as they did? Dead for their country’s life and lighted to burial by the meteor splendors of their native sky”.

Joshua Lawrence Chamberlain.

Soldiers throughout history have reported miraculous “signs” that they believed showed them God’s favour in battle. At the Battle of Milvian Bridge in 312 A.D, the Emperor Constantine I claimed to have seen a blazing vision of a cross in the sky. He believed it to be a vision sent by the Christian God, and that by this sign he would conquer his rival the joint Emperor Maxentius.

At the Battle of Mons during the First World War, in August 1914, British troops claimed to have seen an Angel that had miraculously led them to victory, the famous “Angel of Mons”.

At the Battle of Fredericksburg, December 1863, a rare and spectacular Aurora Borealis appeared over the battlefield at night. Confederate troops believed that it was a miraculous sign sent by God, acknowledging the righteousness of their cause and granting them victory.



Union Soldiers, awaiting the order to charge Marye's Heights, December 1863.

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