THE NORTHERN HOSPITAL

EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO)

"The School of Athens", Fresco, Raphael, 1510. Stanza della Segnatura, The Vatican.

"You see, there are Plato and Aristotle, and around them is a great school of philosophers...his talent is more God like, than a man".

Giorgio Vasari, "The Life of Raphael of Urbino", 1568.

Despite being a confident, outgoing and charming young man, this morning he was nervous, apprehensive, - in truth terrified beyond measure. As he strode uneasily but briskly along the long freezing corridors of the Papal apartments, hoping he wasn't late for his appointment with destiny, he wondered to himself if he would be up to the task. He prayed silently that he would be. He had studied the great masters in Florence, Michelangelo and da Vinci and he had made quite a name for himself there, but now in Rome, he was to be truly put to the test. Suddenly he saw them - the most powerful and feared man in all of Christendom and the most revered architect of the age! He could see their breath in the frigid air as they were quietly and intensely murmuring together.

"Ah Raphael, there you are! Come here!"

"Good morning Holiness"

"This is Bramante, Raphael, the greatest architect in all of Italy. He thinks very highly of you. I hope you will be able justify his confidence".

"I'm most honoured Holiness, and with God's help I will not let you down".

"This room, Raphael is to be our personal library. I do not care for its current decoration". His eyes flashed fiercely for a brief second, then he whispered, "….it reeks of the Borgia".

"I want you to create a masterpiece that befits the dignity of our office….Here!" With a casual wave of his hand, Julius gestured toward a towering expanse of over 500 square feet of bare plastered wall. Raphael almost fainted - but managed to maintain his composure.

"You will report to master Bramante. I hope that our dealings will prove a little more congenial than the ungoverned agitation that Michelangelo causes us".

Julius was then quiet for a full minute, breathing heavily - looking toward the direction of the Sistine Chapel. Suddenly he thundered, "If he wasn't the greatest master in all of Europe - I would by now have surely sent him to the galleys to fight the Turk! Do not test me Raphael - I have tolerance for very few". With that the interview was ended. Julius strode off briskly, Bramante following frantically in his wake, but just managing to turn back his head briefly to Raphael, and with a silent sparkle in his eye, gave a reassuring nod and a smile.

In the winter of 1508, apogee of the High Renaissance, Pope Julius II, the warrior Pope, made two fateful commissions. Commissions that would culturally define the age for the West. They would be an acknowledgment of the past and would come to define the very soul of Western civilization over the last two and a half millennia - even to the present day. The question of the greatest work of art in history is a vexed one. Of course it depends just on what precisely one means by "great" and indeed there are many different kinds of greatness. Some would say that Michelangelo's image of God's hand reaching out to create Adam would be the one. And possibly so in the context of millennia of religious ages. Yet today in a more secular world, perhaps a somewhat broader view could be taken. Just down from the Sistine chapel in the Vatican apartments, is Raphael's, "The School of Athens". The magisterial Arthur Herman, made a compelling case for this image as ***the*** *defining leitmotif of two and half thousand years of Western civilization. The work defines the age*

old dichotomy of the two natures of the ancient human quest for knowledge - on the one hand the teleology of purpose, the humanities, or human soul, if you will, represented by Plato - on the other hand the ice cold and heartless logic of empirical science, represented by Aristotle. The two great philosophers form the centrepiece of Raphael's masterpiece, locked together in intense debate, surrounded by their principle adherents throughout ancient history. We see Plato on the left with his finger pointed upwards towards the heavens to where he says we must look for transcendental inspiration and purpose of life. He is surrounded by his close adherents in the left half of the work. Near him are his nephew Speusippus and Xenocrates. Beside him is his revered teacher Socrates. We also see the great mathematician and philosopher Pythagoras. Historians have identified Plotinus, the father of Neoplatonism as well as Epicurus the founder of the Epicurean philosophy of life. We see the great Arabian philosopher Averroes and one of the few female figures, Hypatia. On the steps below sitting deep in thought is Heraclitus, which Raphael modelled on his idol Michelangelo. Raphael in fact would try to ingratiate himself with the elder man, and would pathetically try to sneak into the Sistine Chapel to learn from the master at work, but sadly Michelangelo had little time or patience for his eager young colleague. Overseeing the group of Platonists is a massive classical statute of Apollo, Greek god of the Arts. On the right hand side of the work we see Aristotle, modelled from ancient busts that existed in Raphael's time. Aristotle in contrast to Plato points firmly downwards towards the Earth - he is the "down to Earth" voice of reason and logic, the champion of empirical science. He is surrounded by such figures as Eudemus, historian of mathematics, Theophrastus, the father of botany, Ptolemy the great Astronomer and Euclid the geometer. We also see the geographer Strabo, whom some scholars suspect, Raphael modelled on his other idol, Leonardo da Vinci. Diogenes the cynic with his defining begging bowl is seen, as well as a great host of other figures of uncertain identity. Above the adherents of Aristotle is a great statue of Pallas Athena, goddess of reason and science. Raphael's awe inspiring (and here we mean the true sense of awe, not the modern day sense of ceaselessly flogged and totally meaningless political rhetoric) fresco, represents the ageless human quest for knowledge.

Arthur Herman explains in his (awe) inspiring book, "The Light and the Cave": "Mysticism verses common sense. Religion versus science; empiricism versus idealism. "The School of Athens" is in fact an allegorical painting about two contrasting, but highly influential worldviews that have shaped our world, in a perpetual struggle for the soul of Western civilization. Seen in this light, the West's greatest thinkers, theologians, scientists, artists, writers, and even politicians have found themselves arrayed on one side or the other in a twenty four centuries old battle between the ideas of Plato and Aristotle and the two paths to wisdom they represent. At certain critical junctures of history, thinkers have tried to knit the two together into a single system. But each time, the old antagonism reasserts itself and the battle is renewed from generation to generation, century to century. One path, Plato's path, sees the world through the eyes of the religious mystic as well as the artist. It finds its strength in the realm of contemplation and speculation and seeks to unleash the power of human beings' dreams and desires. The path of Aristotle, by contrast, observes reality through the sober eyes of science and reveals the power of logic and analysis as tools of human freedom".

The Platonic struggle has seen on the one hand, religion, Romanticism, the Renaissance itself, the Reformation, great literature and music. It has given meaning and comfort to the lives of the countless generations since Plato's time. It has seen great thinkers like Karl

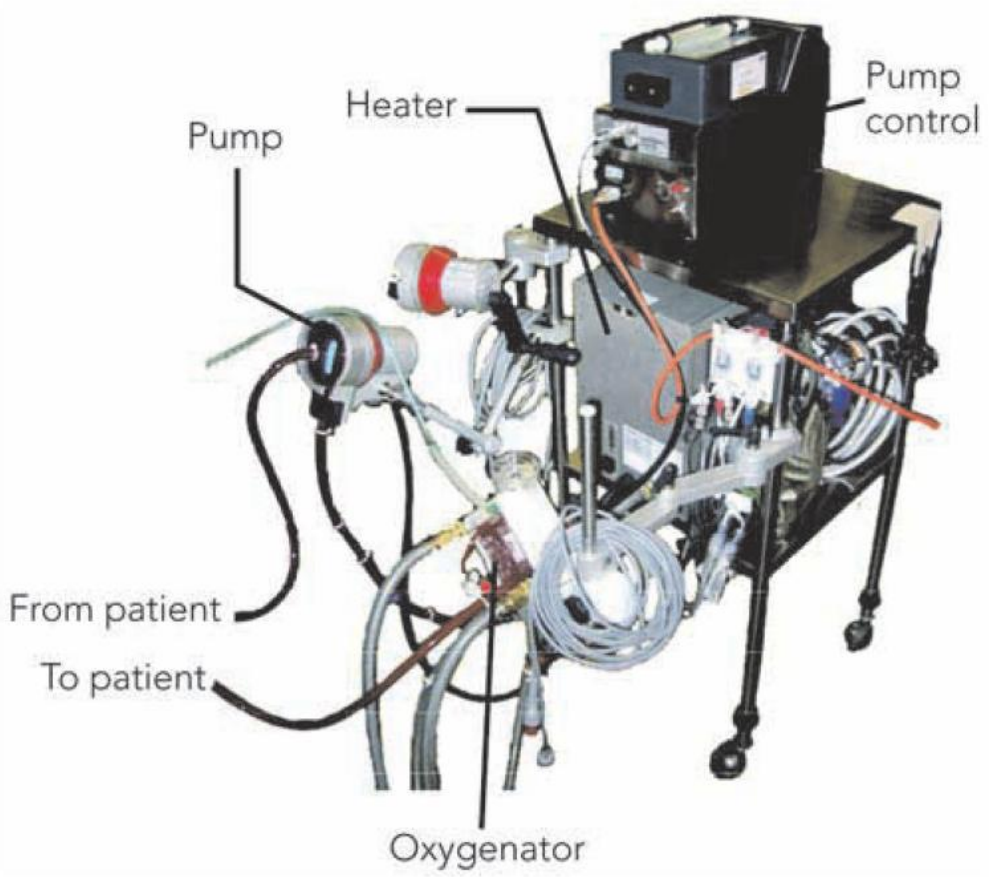
Marx, bring ideals to over half the population of the globe. And yet on the other hand it has also created gulags, had innocents burnt at the stake, created a Thirty Year War and a Holocaust. The Aristotelian struggle has seen unimaginable advances in the sciences and technologies. It has seen the Enlightenment, Darwinism, the Industrial Revolution, the Nuclear age and the first tentative steps of space travel. It has transformed human lives from short, nasty and brutal existences to the comforts, pleasures, good health and wonders of the modern age. And yet it has also killed millions in two World Wars and incinerated hundreds of thousands at the touch of a nuclear button.

When Socrates died in 399 B.C.E his devoted pupil Plato carried on and further developed his work and ideas. However in short time his student Aristotle challenged many of these ideas. He argued not for beginning with ideas of divine and perfect "archetypes", but rather for beginning with empirical facts only. "The fact is our starting point", he said. Two and half thousand years later the cultural and intellectual battle still rages, but in truth no human being is wholly a Platonist or wholly an Aristotelian. Raphael's image is allegorical not only of the two worldviews, but also of the struggle within the very soul of each and every individual who ever lived. It is one thing to create a miraculous piece of technology, but would we want a small Aristotelian oligarchy of the elite scientific priesthood to direct to the rest in a cold and dispassionate and logical manner how this technology is to be used? Something akin to the idea of positive eugenics perhaps springs to mind here! In truth again, the answer lies in the simpler fact that both world views are valid and complementary, the real battle remains, and always has been, to reconcile the two great minds and adversaries - Plato and Aristotle!

In the modern age of medical science the Aristotelian pathway has brought such wonders as the ECMO machine, whereby we can prolong lives - even saving some of them, that in past ages would not have had the slightest hope of survival. Yet such technologies come at very great cost to society. Who is to benefit and how far do we go - and who decides? Is mere cold logic the only necessary consideration - or do we allow a humanistic measure of Platonic ideal? This is the very question that Raphael posed to Pope Julius II in 1508 - a question that still reaches out to us from the "The School of Athens", over five centuries later.

EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO)

Introduction



Extracorporeal membrane oxygenation (ECMO) circuit

Extracorporeal membrane oxygenation (ECMO) involves the oxygenation of blood outside the body and can provide complete or partial support of the heart and/or lungs as a therapy for *selected* patients whose condition is refractory to other management.

This technology is used to support patients with severe but *potentially reversible* respiratory or cardiac failure for days to months while injured tissues recover.

It can be used successfully in both adults and in children.

Advancing ECMO technology and increasing experience with ECMO techniques have improved patient outcomes, reduced complications and expanded the potential applications of ECMO.

Awareness of the indications and implications of ECMO among doctors managing patients with severe but potentially reversible respiratory or cardiac failure may help facilitate better communication between health care teams as well as improving patient outcomes.

Favourable conditions need to be identified early *before hypoxia has produced irreversible changes.*

History

The first successful application of a heart - lung machine was in 1953.

Since then extracorporeal technology has continued to evolve.

In the past, the provision of ECMO was limited by a lack of adequately qualified medical, nursing and perfusion staff, as well as the availability of ancillary services such as echocardiography. Concerns also existed regarding the technique's safety and efficacy.

However, training of intensive care staff to incorporate ECMO into their scope of practice has now been established in Australia.

The therapy is currently offered in most Australian states and in New Zealand, and is internationally accepted as being useful in severe but potentially reversible cases of respiratory or cardiac failure, where other measures are not sufficient.

Types

In basic terms an ECMO circuit consists of:

- Vascular cannulae to access and return blood
- Circuit tubing
- A pump
- A gas-exchange device (oxygenator)
- A heater or heater- cooler that maintains blood temperature via the oxygenator.

Several techniques for ECMO cannulation have been employed, but the most frequently used access sites are the groin vessels in adults, and the common carotid artery and jugular vein in children and infants.

The two major ECMO modalities are:

- Venoarterial system:
    - ♥ The most commonly used form of cannulation for cardiac insufficiency is the venoarterial method.
    - ♥ It effectively reduces high pressures in the right heart, whilst pumping enough oxygenated blood into the aorta to maintain perfusion.

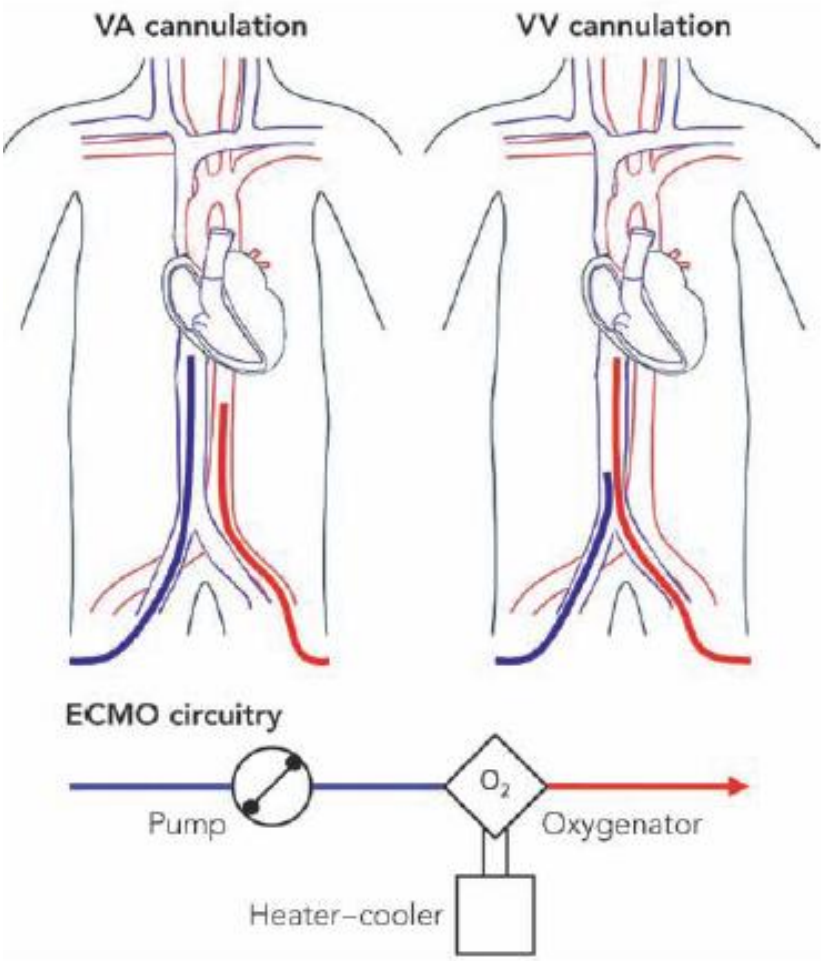
♥ This method will effectively perform the role of BVAD as well as bypassing the lungs.

- Venovenous system:

♥ For respiratory insufficiency, veno-venous cannulation is preferred.

♥ This allows for pre-oxygenation of the venous blood prior to it entering the pulmonary circulation.

♥ This will directly elevate the pO_2 of the blood returning to the left heart, and therefore the blood filling the ascending aorta.



In both the major modalities of ECMO, blood is drained from the venous system (blue). In VA ECMO it is returned (red) to the arterial system, and in VV ECMO it is returned to back to the venous system. The direction of blood flow within the ECMO circuit is indicated by the arrow.

Indications

Selection of patients for ECMO can be difficult.

Favourable conditions need to be identified early *before hypoxia has produced irreversible changes.*

In general terms the relative indications for use of ECMO is based on:

- The failure of more conservative treatments.
- The severity of the condition
- The specific aetiology (including some knowledge of the expected time course of the disease process).
- The reversibility of the condition, including the availability of specific therapies.

The indications and uses for extracorporeal membrane oxygenation include:

1. Respiratory indications:
    - Pneumonias
    - Acute respiratory distress syndrome (ARDS)
    - Support after lung transplantation
    - Fat embolism
    - Some neonatal respiratory conditions:
        - ♥ Meconium aspiration syndrome
        - ♥ Congenital diaphragmatic hernia
        - ♥ Persistent pulmonary hypertension of the newborn
2. Cardiac indications:
    - Support after cardiac surgery
    - Support after heart transplantation
    - Short-term bridge to heart transplantation or ventricular assist device insertion
    - Myocardial infarction - cardiogenic shock
    - Non-ischaemic cardiogenic shock:
        - ♥ Fulminant myocarditis

- ♥ Cardiomyopathy

- Extracorporeal cardiopulmonary resuscitation for in-hospital cardiac arrest refractory to other management
- Massive pulmonary embolism
- Sepsis-induced myocardial depression
- Congenital heart disease.

3. Environmental:

- Life-threatening hypothermia
- Life threatening hyperthermia
- Near-drowning.

4 Selected trauma cases:

- Traumatic lung injury/ Traumatic pulmonary contusion.

5. Some drug overdoses/ toxicities:

- Particularly cardiodepressants, where the drug/toxin can be removed over time without irreversible damage.

Contraindications

These include:

1. Active bleeding:

- Uncontrolled bleeding anywhere in the body.
- Those patients whose haemorrhaging has been controlled can be safely placed on ECMOC under most circumstances.

2. Irreversible central nervous system damage.

3 Chronic severe/ end stage illness

- Malignant disease
- Cardiopulmonary disease (unless a bridge to transplantation).

4. Massive burns.

Complications

Adverse events and potential complications associated with extracorporeal membrane oxygenation include:

1. Infection
2 Haemolysis
3. Thrombocytopenia
4. Mechanical events (eg, failure of the oxygenator, thrombosis)
5. Limb ischaemia and amputation of cannulated limbs
6. Haemorrhage associated with anticoagulation requirements
7. Circuit-associated inflammation or coagulopathy
8. Neurological complications (rare)

Management

Using extracorporeal membrane oxygenation (ECMO), it is now possible to support patients for **days** to **months** while injured tissues recover.

ECMO units are usually based at major tertiary hospitals, but mobile units can also initiate on-site treatment, then transfer to tertiary institutions.

A specialist *perfusionist and team* initiates and maintains at all times, ECMO perfusion.

When a patient is on ECMO, coordination of the patient's LV output, ventilation settings and pump blood and gas flows require intricate and expert manipulation by the perfusionist.

Heparin 100 units/kg (up to 5000 units) is given IV, before the procedure commences. Following initiation of ECMO, the need for a heparin infusion will depend on the exact device that is being used.

After cannulation and meticulous exclusion of air from the circuit, ECMO flow is gradually increased while the RA pressure is monitored by a CVP line.

The **total systemic blood flow** (native ventricular output + ECMO flow) is generally maintained at or above **2.4 L /min / M^2 BSA.**

RA pressure is maintained in the 5-15 mmHg range by volume adjustment.

The adequacy of total systemic blood flow is assessed by ongoing and repeated blood gas analysis

As cardiac output determinations based on **thermodilution** will no longer be valid, acid/base status may be the only quantitative value to assess the adequacy of **total perfusion.**

Assessment of adequate total systemic blood flow will be based largely on indirect measurements, such as **mixed venous blood gases, arterial blood gases, urine output, and peripheral skin colour**

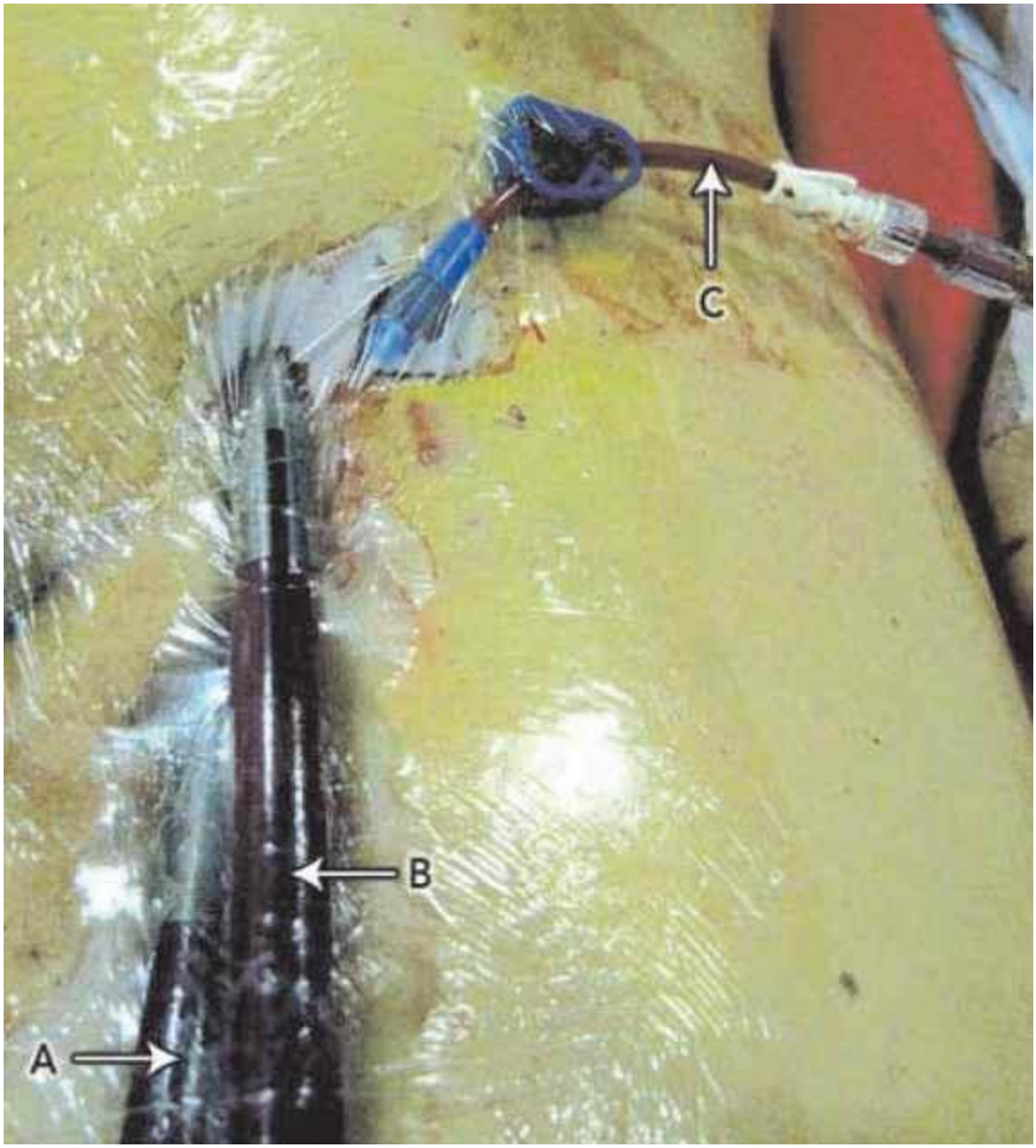
Platelet transfusions are given to keep the platelet count above 100,000 and these are often required daily or even twice daily.

FFP and clotting factors are given as required to achieve and maintain normal coagulation.

It is imperative that no air is allowed to be injected into the patient during administration of fluids or medications as any air entering the patient may enter the ECMO circuit from the RA. Any air that enters the ECMO circuit will most likely be pumped directly into the patient's aorta with significant sequelae.

Advance planning as to the size of doorways, areas required to make turns around corners, width of beds, length and width of elevators, etc, will be essential for the smooth transport of a patient who is on ECMO.

Appendix 1



Photograph showing femoral venous drainage cannula (A), arterial return cannula (B) and a back-perfusion cannula (C) for distal supply of the femoral artery. [2]

"The School of Athens", (Plato and Aristotle, Detail) Fresco, Raphael, 1510. Stanza della Segnatura, The Vatican.

References

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2. Lindstrom S.J, Pellegrino V.A, Butt W.W. Extracorporeal Membrane Oxygenation. MJA 3 August 2009; vol 191: no 3: p. 178 - 182

3. Guidelines for Extracorporeal Life Support, James McMillan, 2003. Perfusion Services Pty. Ltd.

Further reading:

Arthur Herman, "The Cave and the Light - Plato versus Aristotle, and the Struggle for the Soul of Western Civilization", Random House, 2013.

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June 2014.