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Development of a massive transfusion protocol and cognitive aid

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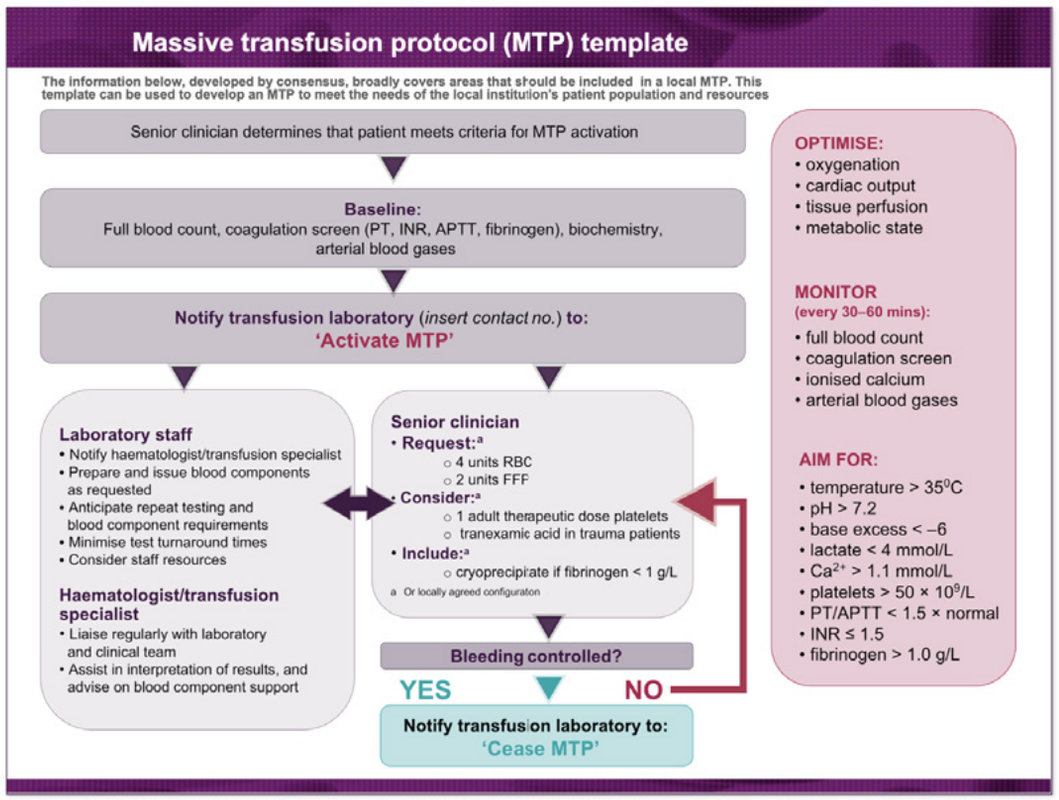
BACKGROUND

Massive Transfusion Protocols (MTPs) have been advocated by the National Blood Authority (NBA) to facilitate the logistic and clinical management of critical bleeding. The Patient Blood Management guidelines for Critical Bleeding[1] were published in 2011 and are currently under review. The MTP template proposed in the NBA Critical Bleeding document outlines the activation process by the senior clinician at the bedside and the responsibilities of the transfusion laboratory. The document also outlines some steps required to facilitate the co-ordination of this process between the clinical team and the transfusion laboratory. In addition, the Critical Bleeding document promotes the development of local MTPs. While "promoted," the development of a locally viable, safe and effective protocol is an important, complex, and collaborative process. Because of the time-critical nature of managing massive transfusion situations, hospitals should delineate the specific processes for MTP activation and management in accordance with the resources available to their institution. In this article, we work to delineate our local experience in undertaking this process, highlighting what our outcomes were, the integral aspects of a well-designed cognitive aid, as well as how and why we came to these determinations. The hope is this will provide support and insight for other institutions considering the same undertaking.

MTPs are designed to rapidly deliver a ratio of blood products mimicking reconstituted whole blood to the critically bleeding patient. The early administration of predefined and balanced ratios of RBC, FFP, and platelets has been shown to be associated with improved patient outcomes in adult trauma patients – the PROPPR trial demonstrated a reduction in mortality from exsanguination in trauma patients receiving 1:1:1 balanced transfusion.[2] Current clinical guidelines similarly promote the use of "1:1:1 ratios" of blood product administration.[3,4]

Clinical settings requiring MTP are time-critical situations, with significant contextual variability between individual hospital sites and Local Health Districts (LHDs). This means that the logistics for clinical management of critical bleeding should be customised into site-specific MTPs and cognitive aids.

Figure 1. The current MTP template from the NBA[1]



CLINICAL GUIDELINE DEVELOPMENT PROCESS

Committee engagement

Stakeholder selection, inclusion, and engagement are crucial to ensure locally effective solutions are developed. Many of the specialities and positions represented within our process will be relevant to your local institution but may vary as well.

The Patient Blood Management Clinical Nurse Consultant (CNC) was tasked by the Northern Sydney Local Health District (NSLHD) Blood Committee with updating the Adult MTP, and creating a NSLHD specific Paediatric MTP. The NSLHD encompasses both Tertiary and District hospitals, but not a dedicated paediatric tertiary referral hospital.

The working group for the revision of the MTP also sought to incorporate the development of a cognitive aid into the process – for both adult and paediatric patients. The vision was to create cognitive aids that were individualised to assist the clinical team at each hospital within the LHD.

It was envisaged the updated MTPs would embed decision support tools to extend the NBA MTP template, seeking to ensure that the appropriate clinical team and logistic resources were mobilised to treat the critical bleeding. The incorporation of the paired priorities of clinical and logistic concerns was an early decision – to ensure that medical management tasks would be completed appropriately, but in conjunction with, logistic considerations around resource mobilisation and coordination to optimise efficiency and minimise human error.

Separate MTP working groups were created to develop the Adult and Paediatric MTPS. This was led by clinicians from patient blood management, anaesthesia, intensive care and emergency medicine – with additional input from the trauma service, haematology, obstetrics, paediatrics, transfusion scientists, and the medical executive unit. The project co-ordinator was the Blood Management CNC, who researched adult and paediatric MTPs throughout Australia and internationally, disseminating the documents through the Blood Committee, and collating feedback. The cognitive aid was developed by anaesthetists with feedback from the working group. There was an early understanding that a single cognitive aid would not be functional across

all hospitals in our LHD. Instead, each individual hospital would be given the opportunity to review and adapt the primary cognitive aid to include local contact numbers and processes. This customisation of the MTP for individual institutions was considered essential to ensure effective clinical management at each site.

Development process

Due to the significant scope of both the proposed revision to the existing MTP and the creation of an accompanying cognitive aid, an iterative process was adopted by the working group. This helped to maintain momentum throughout the development process, and to minimise delays arising from a reluctance to commit to a final version. Instead, there was an understanding that there would be ongoing rounds of revision from user feedback and working group discussions, and subsequent releases of progressive versions.

We found that this approach was effective in mitigating the difficulty that often arises in achieving consensus agreement when creating clinical guidelines that involve multiple stakeholder opinions and viewpoints. It was pleasing to observe that each round of revisions in this iterative process produced cumulative improvements to the MTP and cognitive aids.

The organic process in developing, revising, and refining both the protocol and cognitive aids accommodated the diverse workloads and challenges that naturally arise in attempting to coordinate a large group of professionals across a range of specialties. This approach produced an efficient and consistent engagement, while minimising the need and difficulty involved with coordinating large-group meetings.

Activation criteria

One of the first adaptations to the NBA MTP template was the working group's decision to alter the wording of the activation criteria. We opted to list Major Traumatic Bleeding first, because our tertiary hospital has a trauma "Code Crimson" pathway. This change and comparison can be seen between Figure 1 (the NBA template) and Figure 2 (our first iteration in the development process). Trauma Code Crimson identifies exsanguinating trauma patients in the pre-hospital environment and outlines pre-hospital and in-hospital processes to streamline access to definitive intervention, including an operating theatre or interventional radiology suite.[5] Code Crimson activation occurs via the hospital switchboard for major trauma and mobilises surgical, anaesthesia, and emergency medicine teams. The wording was also simplified to "Major Traumatic Bleeding" from the NBA's "severe thoracic, abdominal, pelvic or multiple long bone trauma".[1]

Another decision was made to change the NBA activation criteria of "actual or anticipated 4 units of Red Blood Cells (RBC) in less than 4 hours".[1] It was determined by the working group that this bleeding rate might not require MTP activation – as this blood loss would usually be insufficient to cause coagulopathy requiring plasma transfusion. Instead, the activation criteria were revised to "actual or anticipated blood loss of greater than 2000 mL". This volume represents approximately 40% of the adult blood volume. While acknowledging the difficulty in estimating actual blood loss, it was considered important to prevent unnecessary MTP activation for lower volume blood loss not requiring plasma transfusion. The shift in wording also changed the assessment criteria from predicted blood replacement, to predicted blood loss – this change was felt to be a more approachable criteria by a broad number of staff. It is important to note that current guidelines discourage the use of plasma transfusion for indiscriminate volume replacement.[3]

LOGISTIC CO-ORDINATION

Massive transfusion situations require co-ordination of both clinical and logistic resources. Upon presentation of a critically bleeding patient, these resources must be rapidly mobilised to facilitate effective management to meet the patient's clinical needs.

Our LHD adopted the new clinical process of MTP activation through a call to switchboard utilising the state-wide 2222 number – as part of a global initiative to use "2222" as the standardised emergency number to activate all medical emergencies.[6] The hospital switchboard obtains details of the patient's location and the contact details of the designated blood co-ordinator (the medical or nursing liaison with Blood Bank). The next step is activation of the MTP paging system by the hospital switchboard – this notifies Blood Bank staff, nursing manager, and a support services officer ("blood runner") who is dispatched to the clinical area. Our institution has experienced problems with MTP activations without a dedicated blood runner to ensure efficient delivery of blood products to the clinical area, and pathology tests to the laboratory. A major advantage of implementing MTP activation via the hospital switchboard (instead of the previous method of directly calling the hospital Blood Bank) is the guaranteed allocation of this blood runner, and a consistent, centralised process for ensuring relevant team members are notified and activated en masse.

The next step is to mobilise the clinical team, which is led by the medical team leader, a critical care physician who assumes responsibility for clinical decision making in the MTP. It is preferable that this team leader is "hands off" – meaning that they are not physically involved in the resuscitation process, but instead physically positioned further back to maintain situational awareness and team oversight.

Additional medical officers (MO) are essential, including a Vascular Access MO to obtain reliable venous and/or arterial access to facilitate the resuscitation. If staffing permits, then an additional MO, or senior nurse delegate, may act as the blood co-ordinator to liaise with Blood Bank to ensure ongoing blood product supply. The appropriate surgical and/or paediatric medical officers must also be alerted, depending on the specific clinical situation. It is also important that sufficient nursing staff are allocated to the ongoing MTP – with at least one nurse allocated to each medical officer.

It is critical that the team leader determines the optimal location for the resuscitation and ensuing MTP. In smaller hospitals, or for paediatric patients, this may require urgent medical retrieval. This may also require transport of the patient to the operating theatre or angiography suite. In addition, all equipment necessary for the resuscitation – including warming devices, rapid infusers, and cell salvage – should be rapidly mobilised to the clinical area.

This discussion around logistics certainly highlights the significant practical differences that exist between individual hospital sites – specifically: personnel, contact numbers, locations, and available equipment. These variations reinforce the need for MTP cognitive aids to be customised for each facility.

CLINICAL MANAGEMENT

While all bleeding situations are different, our working group recognised that there are two essential decision points which must be clarified early in the MTP process. These are the blood volume deficit and the presence of coagulopathy. Following the identification and correction of these initial deficits, the clinical team then moves towards administering the MTP packs, as needed, to deliver reconstituted whole blood. These key decision points are expanded below.

Blood volume deficit

After preparation of the necessary personnel and equipment for resuscitation, the first clinical decision is to determine the estimated blood volume deficit. One of the weaknesses of the MTP process, is that the initial MTP pack may be insufficient to achieve euvolemia in haemorrhagic shock. The NBA has advocated for an MTP pack to contain 4 units of RBC and 2 units of Fresh Frozen Plasma (FFP).[1] This MTP pack only provides a total volume of approximately 1.5 litres. Additionally, at hospitals without Extended Life Plasma (ELP), the clinical team will initially only receive a delivery of 4 units of RBC – with a subsequent delay of up to 30 minutes to allow for thawing of the FFP. This initial volume of one litre of RBC would be inadequate to restore euvolemia in most MTP scenarios. Even accounting for the delayed arrival of the FFP, the standard MTP pack would likely fail to restore blood volume in advanced haemorrhagic shock.

It is also important to note that Blood Bank staff routinely prepare only one MTP pack at a time. Only after dispensing the initial MTP pack are they then required to start preparing the next MTP pack. This means that approximately 30 minutes (to allow for the thawing of FFP) would reasonably elapse before the next MTP pack can be dispensed. This situation emphasises that the standard release of MTP packs will be insufficient to keep pace with critical bleeding occurring at a rate greater than 2 litres in 30 minutes.

To address this logistical challenge, which is not uncommon in our clinical environment, we revised our MTP and proposed that – in critical bleeding situations involving patients with large blood volume deficits, or in situations with rapid rates of blood loss – that both MTP packs are prepared in tandem and dispensed. This adjustment results in the provision of a blood product volume nearing 4 litres – which should be sufficient to restore euvolemia.

Each hospital will have differing preparation and delivery times for MTP packs. It is essential to understand these constraints to ensure the appropriate timing and volume of blood product delivery. This may necessitate overriding the routine MTP pathway in circumstances where the actual blood loss exceeds the rate that blood products would be supplied. Identifying the potential for this need and agreeing on a process for communicating when overriding the routine pathway is needed is also a locally specific process.

Coagulopathy

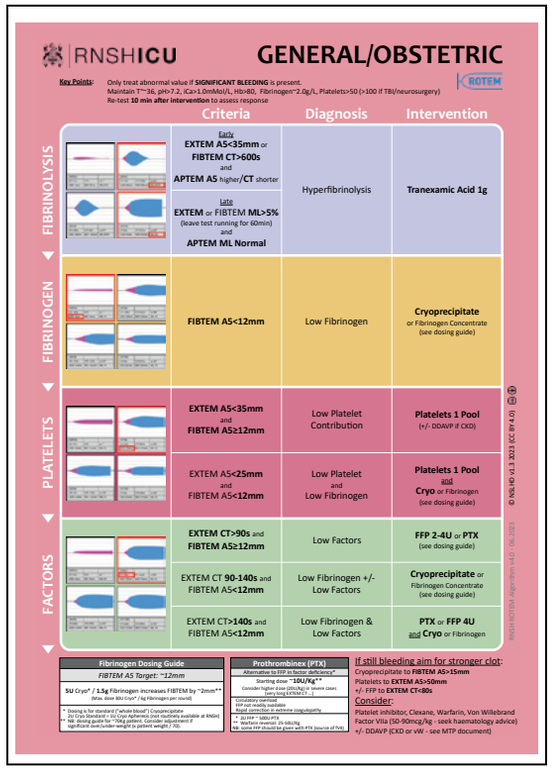
The presence of coagulopathy impacts the ratio of blood products that are necessary to support haemostasis. Clinical guidelines support the use of balanced transfusion ratios of RBC:FFP:Platelets at 1:1:1 for patients during haemorrhage.[3] However, for patients with coagulopathy, this product ratio may fail to restore a favourable coagulation profile.[4] Reconstituted whole blood utilising a 1:1:1 ratio will only have a coagulation factor activity

of 65% of whole blood and a platelet count approximating 88 x 10^9/L.[7] Patients with coagulopathy will likely require a higher proportion of clotting factors (particularly fibrinogen) and platelets – compared to RBC – in order to restore adequate coagulation.

Coagulopathy during massive transfusion can occur due to pharmacological or pathological reasons. Pharmacological coagulopathy occurring as a result of antithrombotic medications should be corrected during the initial phase of resuscitation. This may be with a specific antidote (for example, protamine for heparin, idarucizumab for dabigatran, or vitamin K and prothrombin complex concentrate for warfarin) or with non-specific reversal agents (for example, prothrombin complex concentrates (PCC) for Factor Xa inhibitors, or platelets for aspirin). Pathological coagulopathy may occur as a consequence of the disease process (for example, Trauma Induced Coagulopathy or Placental Abruption), or from consumptive and/or dilutional coagulopathy resulting from the administration of crystalloid, colloid, or RBC infusions. Assessment for pathological coagulopathy needs to be repeated during continued administration of blood products.

Assessment for coagulopathy should be undertaken early in the resuscitation – and be repeated every 30 to 60 minutes. Ideally, this assessment should utilise point-of-care coagulation tests (POCT) (for example, Rotational Thromboelastometry or Thromboelastography), as these provide clinical teams with more rapid results that may better represent in-vivo whole blood coagulation capacity. There was an existing ROTEM-guided pathway at our institution for the assessment and treatment of coagulopathy during critical bleeding (Figure 2). As access to, and clinical familiarity with, the use of ROTEM was already established at our institution, incorporation of this testing was felt to be appropriate for our local protocols.

Figure 2. RNSH ROTEM pathway



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This ROTEM pathway, based upon work disseminated by Fiona Stanley Hospital,[8] was updated and integrated into our new MTP documents. The ROTEM-guided approach is useful in identifying the cause of coagulopathy and guiding the use of clotting factor concentrates to correct for the specific coagulation deficiency. Clinical guidelines advocate the use of cryoprecipitate or fibrinogen concentrate to correct hypofibrinogenemia. They also support the use of PCC over FFP in situations where POCT testing demonstrates clotting factor deficiency.[3] Both of these considerations were subsequently incorporated into our final protocols.

ROTEM Sigma machines are available in both the intensive care unit and operating theatres at our institution. The benefits of utilising ROTEM for coagulation management (compared to standard coagulation testing) are the shorter time for test results and the ability to diagnose specific clotting factor deficiencies. The associated aspects of the cognitive aid included the most frequently utilised elements of these ROTEM pathways to correct coagulopathy – specifically, the dosing details for fibrinogen, platelets, and clotting factor replacement. However, other aspects of the ROTEM pathway pertaining to the assessment for fibrinolysis and residual heparin effect were excluded – instead, our cognitive aid prescribes tranexamic acid and reversal of pharmacological coagulopathy during the Initiation Phase of the MTP.

MTP pack design

General

Unlike the NBA MTP template, which only suggests RBC and FFP, we elected to embed platelets and fibrinogen supplementation into the MTP packs. The combined use of MTP packs 1 and 2 were designed to deliver Reconstituted Whole Blood (RWB) (Table 1). Repeated cycling between these two packs, would deliver an ongoing ratio of blood products approaching the 1:1:1 target for RBC:FFP:Platelets. Our local experience aligns with the findings during the PROPPR trial, where the average volume of RBC and FFP transfused was nine and six units respectively.[2]

Thus, most MTP activations utilise an average of two to three MTP packs. By alternating the presence of cryoprecipitate and platelets between MTP Pack 1 and 2 – with an appropriate ratio of RBC and FFP – we hoped to ensure that RWB would be delivered throughout the MTP activation.

Table 1. Blood products delivered after administration of both Pack 1 and Pack 2 in an adult patient[9]

Blood product	Number of units	Volume per unit	Total volume	Comments
RBC	6	259 mL	1554 mL	
FFP	6	278 mL	1668 mL	Contains 3-3.5 g fibrinogen
Cryoprecipitate	10	36 mL	360 mL	Contains 3-4 g fibrinogen
Platelets	4	273 mL	273 mL	One pack of pooled platelets
Total volume			**3855 mL**	Total fibrinogen ~ 6.5 g (1.7 g/L)

Our MTP packs sought to promote a RBC:FFP ratio of 1:1.[2-4] Consideration was given to the overall volume of blood products in each MTP pack. It was agreed that a total volume of 1.5 to 2 litres would be sufficient in each pack. Three units of RBC and FFP were thus included in each MTP pack.

Fibrinogen

Fibrinogen is the coagulation factor that falls to dangerous levels early in critical bleeding.[10] Current clinical guidelines promote a fibrinogen target of:

- 1.5-2 g/L during perioperative bleeding[3]
- > 1.5 g/L for trauma[4]
- > 1.5 g/L during cardiac surgery[11]
- > 2 g/L for obstetric bleeding[12]

Given these current recommendations, our working group decided to specify a fibrinogen target of 2 g/L across all patient populations. A single fibrinogen target has the benefit of being easily remembered. In addition, aiming for the higher end of the target range would permit a margin of safety, and reduce the likelihood of patients developing fibrinogen levels below 1.5 g/L. A single fibrinogen target also simplified the development of fibrinogen dosing algorithms utilising ROTEM and plasma Clauss fibrinogen concentrations. Our working group elected to incorporate cryoprecipitate into our first MTP pack as a systems-level step to ensure the maintenance of plasma fibrinogen during initial resuscitation in a massive transfusion setting. Plasma transfusion alone with FFP is insufficient to correct for hypofibrinogenemia.[3] Our MTP packs without cryoprecipitate would only result in a fibrinogen concentration of approximately 1.0 g/L (from Table 1). With the addition of cryoprecipitate, the final fibrinogen concentration is approximately 1.7 g/L.

Platelets

Platelet targets during critical bleeding are 50 x 10^9/L and 100 x 10^9/L in intracranial bleeding.[1,4] Given that most critical bleeding situations are resolved with the administration of 2 or 3 MTP packs,[2] it is unlikely that platelet levels will fall below those aforementioned thresholds, unless blood loss significantly exceeds one blood volume. The transfusion laboratory in our LHD provides pooled platelets (platelets from 4 individual donors). Our working group agreed that given the lower likelihood of platelet levels falling to critical levels during the early phases of resuscitation, an overall product ratio of 6 units RBC, 6 units FFP, and 1 Pooled Platelets would achieve an adequate approximation of 1:1:1 reconstituted whole blood. However, additional platelets may be required for patients taking antiplatelet medication, or when directed by ROTEM or formal full blood count.

ROTEM targets

Our working group established a FIBTEM A5 target of 12 mm for all patient groups during critical bleeding. We were not able to find evidence to routinely support a fibrinogen target greater than 2 g/L, nor a FIBTEM A5 target greater than 12 mm.[3] Fibrinogen dosing was thus designed to restore to a FIBTEM A5 of 12 mm, given that 10 units cryoprecipitate, or 3 g fibrinogen concentrate, are required to raise FIBTEM A5 by 4-5 mm.[13]

Platelet transfusion was recommended when poor platelet contribution was suggested by ROTEM (EXTEM A5 < 35 mm) or when thrombocytopenia was detected with formal laboratory testing. FFP or PCC was recommended when ROTEM clotting time was prolonged (EXTEM Clotting Time > 90 seconds), or formal coagulation tests (APTT or INR) were greater than 1.5 times normal.[4] Our ROTEM pathway recommends PCC over FFP in patients with severely prolonged EXTEM clotting times.

For the sites within our LHD without access to ROTEM, we embedded fibrinogen, platelet, and FFP replacement guidelines into their cognitive aids based upon standard coagulation tests. The adaptation and application of these recommendations at your local institution needs to consider a multitude of logistical factors, including the presence and ease of access to some of these POC testing modalities.

COGNITIVE AID DEVELOPMENT

Overview

The cognitive aid was designed to facilitate not only appropriate blood product delivery, but also clinical decision-making in patients with critical bleeding. Effective management of patients requiring massive blood transfusion involves both clinical and logistic considerations. The production of the cognitive aids was facilitated by ASCAR (Anaesthesia Cognitive Aids and Research Group), the organisation based at our institution with a keen interest in human factors and visual design.

The cognitive aid was developed to flow over two pages – initially to accommodate the necessary content, but this two-page design later provided the ability to demarcate the MTP into a two-stage process. The first stage (initiation phase) of the MTP is outlined on the first page. It includes the activation criteria and the logistic coordination tasks required to activate the MTP effectively. This co-ordination includes identifying the optimal location for resuscitation and mobilising the relevant team members and equipment required. It mandates early notification of Blood Bank and requesting the first pack of blood products and medications necessary to reverse pharmacological coagulopathy. Steps completed during this initiation phase are not required during the later phases of resuscitation.

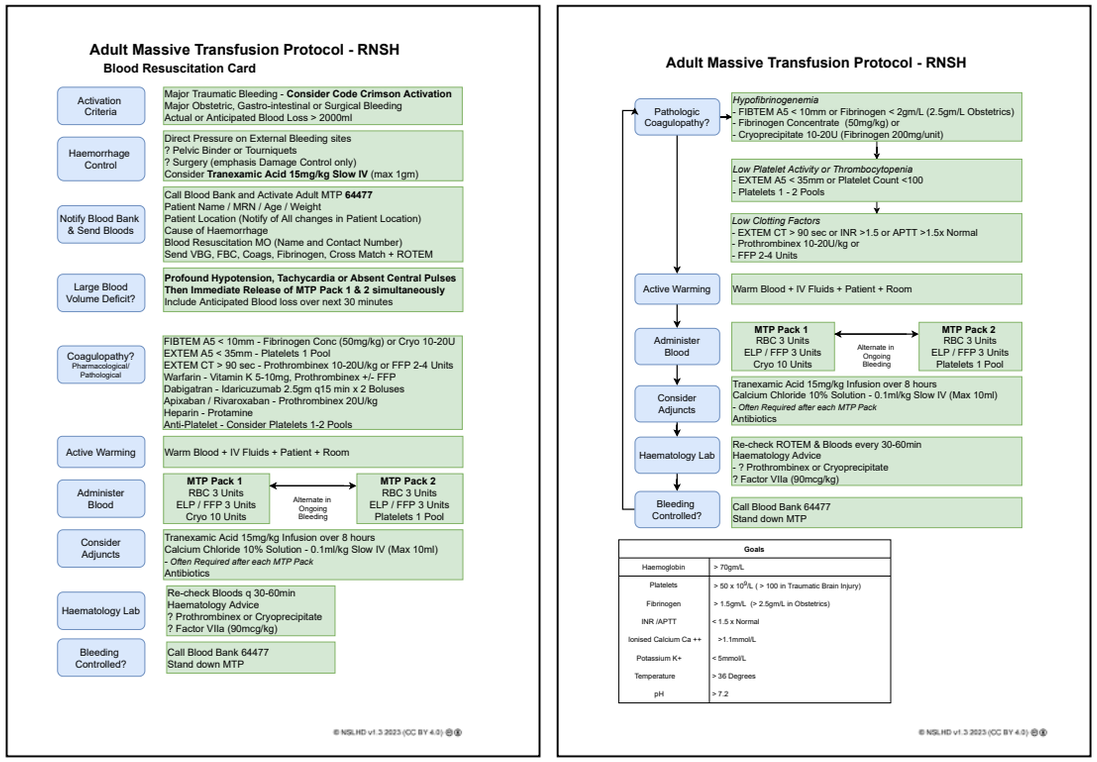
Once the initial phase of the MTP has been completed, clinical care moves into the subsequent cycling (or maintenance) phase until bleeding has been controlled. This is outlined on the second page, allowing clinicians to use a single page to guide this stage of the MTP – where the clinical priorities are to administer blood products and to treat hypothermia and ongoing coagulopathy.

Individualised MTP cognitive aids were created for each hospital within the LHD. The overall content and

visual design were retained, but site-specific customisations were made. This allowed locally relevant contact numbers and processes to be embedded within each cognitive aid. Cognitive aids need to strike a balance of being locally relevant, but also retaining consistent visual formatting to reduce the cognitive load for staff working at multiple locations.

Initial version

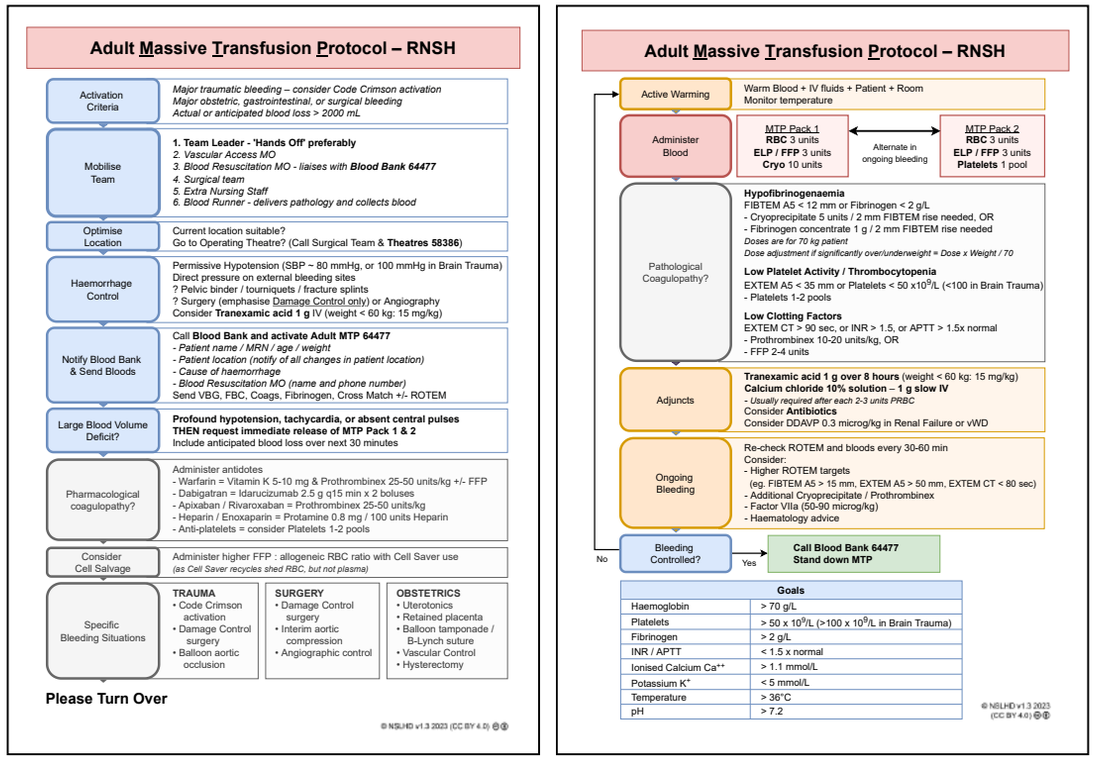
Figure 3. Development stage of MTP cognitive aid



There was an early consensus decision for a linear/flowchart visual layout for the cognitive aids, to harness the intuitive and familiar feel of this format. One of the first drafts for our cognitive aid highlights these components and is shown in Figure 3. The primary steps of the MTP are listed in separate panels on the left-hand side of the page to allow rapid scanning. Explanatory notes are included in a secondary panel on the right-hand side of the page, using succinct and clear language. The initial designs were deliberately simple, with minimal visual design input – instead, the focus was on refining the actual text – a "content-first" approach. This initial draft provided a platform for members of the working group to rapidly provide input and guidance that allowed for the final product to be achieved.

First release

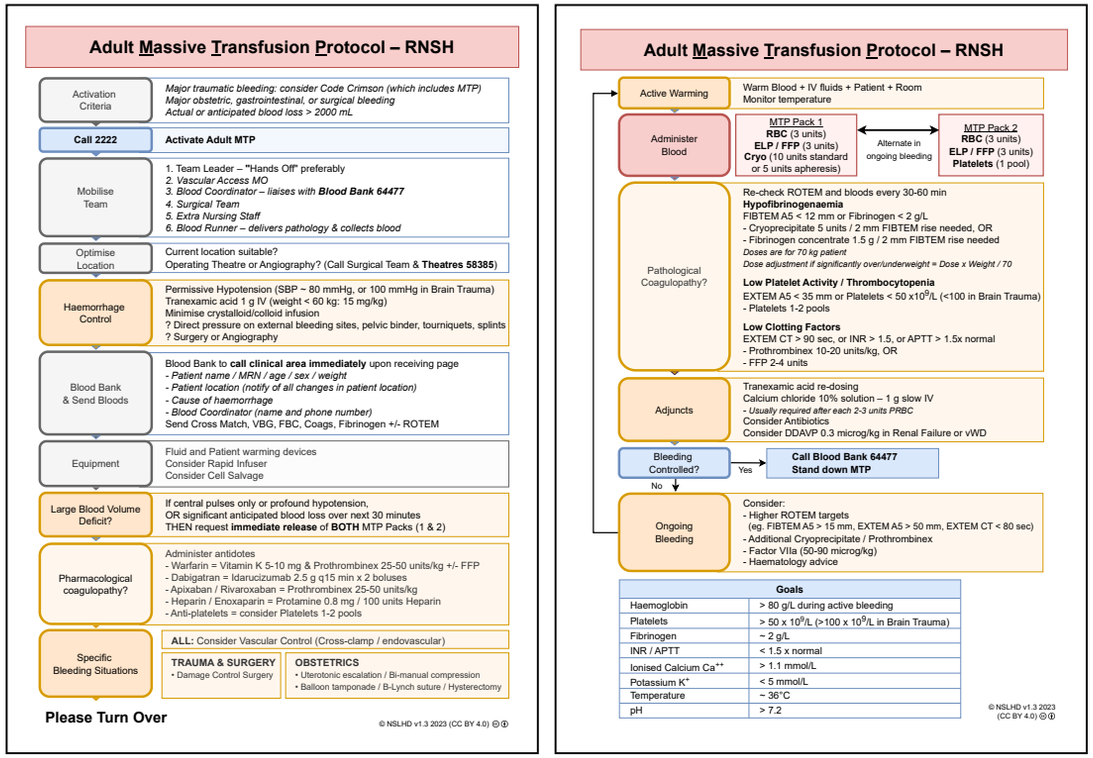
Figure 4. First release version (v1.0) of MTP cognitive aid



After several rounds of development and stakeholder feedback, the content was simplified to increase clarity and reduce duplication. With the content mostly finalised, the visual layout was then refined to improve usability – the size and shape of the panels were adjusted, a simple colour palette was introduced, version numbers were added to the footer, and a header was introduced (Figure 4). Short, numbered lists and dot points were implemented to improve the readability of the aids in a crisis situation. Overall, there were significant changes in both content and visual design between the initial drafts and the first production release (v1.0).

4.4 Current release

Figure 5. More recent version (v1.3) MTP cognitive aid



All clinical resources and publications need ongoing review from user feedback over the course of time and clinical use. This iterative process was continued after the release of v1.0 – with ongoing meetings and feedback discussion about the MTP and accompanying cognitive aids. Further refinements were made to the content and visual design, highlighting the value of the feedback process and engagement with both clinicians and our working group. Some examples include introduction of a new "Activation" panel to reflect this logistic change in our LHD, and the use of colour as a grouping tool for the panels (orange: clinical, grey: logistic, red: blood product administration) (Figure 5).

Production of a cognitive aid, especially for critical events, needs to embed pathways for receiving feedback and correcting errors or issues. Once refined to a functional state, regular reviews should be scheduled to assess its continued relevance, utility, and adherence to current standards. Accordingly, our MTP cognitive aids will continue to be adjusted and refined as this process continues.

PAEDIATRIC MTP

Paediatric MTPs are significantly different from Adult MTPs, both in logistic coordination and in clinical management pathways. Clearly, a cognitive aid designed for an Adult MTP would be inadequate to support clinicians involved in paediatric crisis situations. The development of a Paediatric MTP was novel in our institution, and its activation would likely be a rare occurrence. Hence, every effort was made to simplify the pathway and reduce the cognitive load for clinicians. The key differences in the Paediatric MTP for our institution are outlined below.

Logistics

Involvement of the Newborn and Paediatric Emergency Transport Service (NETS) was embedded early in the MTP management flow as our hospital is not a paediatric trauma nor a tertiary paediatric referral centre. NETS notification automatically activates both the patient retrieval process and access to a paediatric haematologist for telephone advice. Mobilisation of paediatric medical staff was also added to the MTP, to maximise appropriate clinical support for the resuscitation process.

Clinical management

The activation criteria for Paediatric MTP were modified to include weight-based criteria. This aligned the protocol with the Sydney Children's Hospital Network MTP,[14] which is the paediatric referral hospital for our institution. Similarly, all drug dosing was modified to use a weight-based approach, as is common practice for paediatric patients. The clinical signs for detection of significant blood loss in the paediatric population was also emphasised – focusing on the significance of profound tachycardia and late development of hypotension. A table with the clinical signs of paediatric haemorrhagic shock was added to the cognitive aid.

Product ratios

Our paediatric weight-based transfusion ratios were designed to also reconstitute whole blood, mirroring one of the goals in the Adult MTP. The Paediatric MTP differs from the Adult MTP as weight-based transfusion volumes are administered – and are likely to require partial transfusion of any blood product units supplied. Consequently, we de-emphasised the concept of alternating "packs" – Pack 1 and Pack 2, and instead implemented the concept of alternating "boluses" – Bolus A and Bolus B. A subsequent bolus should utilise remaining volume in the blood product bag prior to using blood from another donor. The working group again elected to place cryoprecipitate in MTP Bolus A, along with RBC and FFP boluses.

The weight-based transfusion rules in our Paediatric MTP are RBC 10 mL/kg, FFP 10 mL/kg, and Platelets or Cryoprecipitate at 5 mL/kg. Thus, representing an overall bolus of 25 mL/kg. The NBA promotes boluses of RBC 25 mL/kg, FFP 15 mL/kg, and Platelets 10-15 mL/kg.[15] However, our working group elected to give smaller boluses of RBC, that are balanced with FFP, cryoprecipitate, and platelets. A RBC 25 mL/kg bolus represents one third of total blood volume, and the working group believed that it would be preferable to incorporate FFP to avoid the development of coagulopathy associated with such a large RBC transfusion. After the administration of both Bolus A and Bolus B, the transfused volume closely reflects reconstituted whole blood, with a RBC:FFP:Platelets ratio approximating 1:1:1. The additional cryoprecipitate results in an overall fibrinogen concentration of approximately 1.7 g/L.A practical example of how this regimen would be applied in a 25 kg patient (the average weight of a 7-year-old) is demonstrated in Table 2.

An additional benefit in our final recommendations for the doses of blood products to be administered is the ease in remembering them: "10-10-5" – with Bolus A being RBC 10 mL/kg, FFP 10 mL/kg and cryoprecipitate 5 mL/kg, and Bolus B being RBC 10 mL/kg, FFP 10 mL/kg and platelets 5 mL/kg.

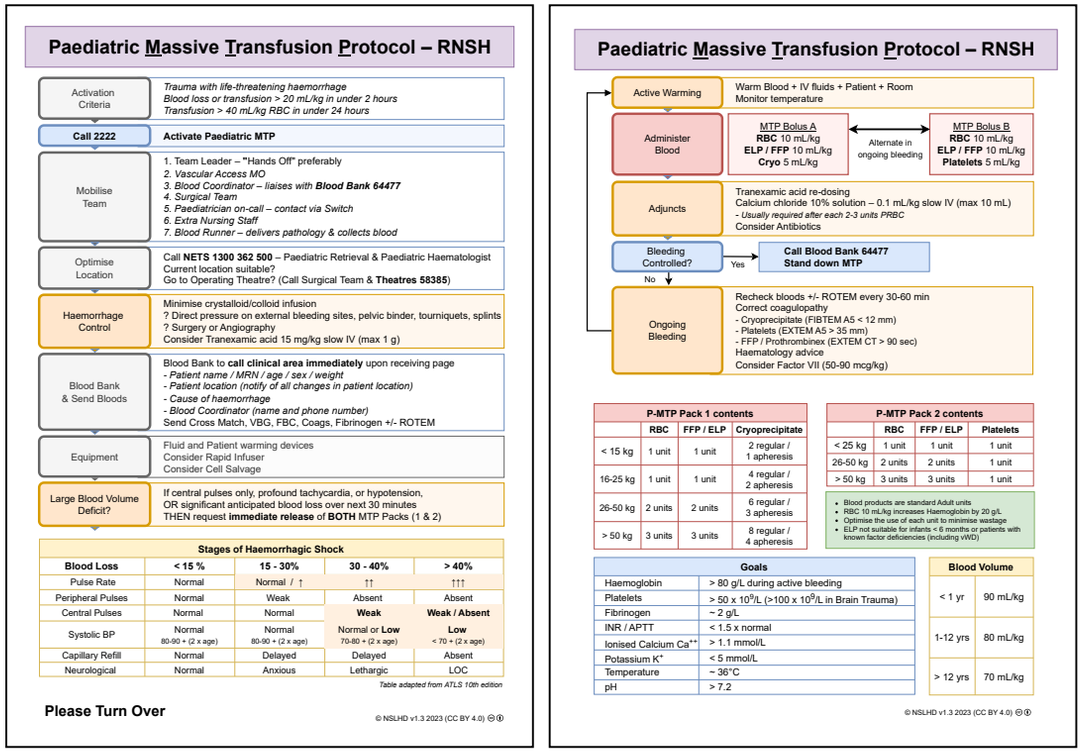
Table 2. Blood products delivered after administration of both Bolus A and Bolus B in a 25 kg paediatric patient

Blood product	Dosage	Volume delivered	Total units required	Comments
RBC	20 mL/kg	500 mL	~ 2 units	
FFP	20 mL/kg	500 mL	~ 2 units	Contains ~1 g fibrinogen
Platelets	5 mL/kg	125 mL	~ 2 units	
Cryoprecipitate	5 mL/kg	125 mL	~ 4 units	Contains ~1.2 g fibrinogen
Total		**1250 mL**		Total fibrinogen ~ 2.2 g (1.7g/L)

The working group elected not to incorporate ROTEM and formal guidance to correct coagulopathy into the Paediatric MTP. The frequency of paediatric MTP activation in our LHD is uncommon, and it was felt that such advice would best be delivered by the consulting NETS paediatric haematologist. However, hospitals with greater experience with paediatric resuscitation may elect to incorporate specific advice for correction of coagulopathy in their MTP pathway.

Cognitive aid

Figure 6. Current version (v1.3) of the Paediatric MTP cognitive aid



Paediatric Massive Transfusion Protocol – RNSH

Activation Criteria	*Trauma with life-threatening haemorrhage* *Blood loss or transfusion > 20 mL/kg in under 2 hours* *Transfusion > 40 mL/kg RBC in under 24 hours*
Call 2222	**Activate Paediatric MTP**
Mobilise Team	1. Team Leader – "Hands Off" preferably *2. Vascular Access MO* *3. Blood Coordinator – liaises with **Blood Bank 64477*** *4. Surgical Team* *5. Paediatrician on-call – contact via Switch* *6. Extra Nursing Staff* *7. Blood Runner – delivers pathology & collects blood*
Optimise Location	Call **NETS 1300 362 500** – Paediatric Retrieval & Paediatric Haematologist Current location suitable? Go to Operating Theatre? (Call Surgical Team & **Theatres 58385**)
Haemorrhage Control	Minimise crystalloid/colloid infusion ? Direct pressure on external bleeding sites, pelvic binder, tourniquets, splints ? Surgery or Angiography Consider Tranexamic acid 15 mg/kg slow IV (max 1 g)
Blood Bank & Send Bloods	Blood Bank to **call clinical area immediately** upon receiving page *- Patient name / MRN / age / sex / weight* *- Patient location (notify of all changes in patient location)* *- Cause of haemorrhage* *- Blood Coordinator (name and phone number)* Send Cross Match, VBG, FBC, Coags, Fibrinogen +/- ROTEM
Equipment	Fluid and Patient warming devices Consider Rapid Infuser Consider Cell Salvage
Large Blood Volume Deficit?	If central pulses only, profound tachycardia, or hypotension, OR significant anticipated blood loss over next 30 minutes THEN request **immediate release** of **BOTH** MTP Packs (1 & 2)

Stages of Haemorrhagic Shock

Blood Loss	< 15 %	15 - 30%	30 - 40%	> 40%
Pulse Rate	Normal	Normal / ↑	↑↑	↑↑↑
Peripheral Pulses	Normal	Weak	Absent	Absent
Central Pulses	Normal	Normal	**Weak**	**Weak / Absent**
Systolic BP	Normal 80-90 + (2 x age)	Normal 80-90 + (2 x age)	Normal or **Low** 70-80 + (2 x age)	**Low** < 70 + (2 x age)
Capillary Refill	Normal	Delayed	Delayed	Absent
Neurological	Normal	Anxious	Lethargic	LOC

Table adapted from ATLS 10th edition

Please Turn Over

Page 1

Paediatric Massive Transfusion Protocol – RNSH

Active Warming	Warm Blood + IV fluids + Patient + Room Monitor temperature
Administer Blood	MTP Bolus A **RBC** 10 mL/kg **ELP / FFP** 10 mL/kg **Cryo** 5 mL/kg Alternate in ongoing bleeding MTP Bolus B **RBC** 10 mL/kg **ELP / FFP** 10 mL/kg **Platelets** 5 mL/kg
Adjuncts	Tranexamic acid re-dosing Calcium chloride 10% solution – 0.1 mL/kg slow IV (max 10 mL) *- Usually required after each 2-3 units PRBC* Consider Antibiotics
Bleeding Controlled?	Yes → **Call Blood Bank 64477** **Stand down MTP**
	No
Ongoing Bleeding	Recheck bloods +/- ROTEM every 30-60 min Correct coagulopathy - Cryoprecipitate (FIBTEM A5 < 12 mm) - Platelets (EXTEM A5 > 35 mm) - FFP / Prothrombinex (EXTEM CT > 90 sec) Haematology advice Consider Factor VII (50-90 mcg/kg)

P-MTP Pack 1 contents

	RBC	FFP / ELP	Cryoprecipitate
< 15 kg	1 unit	1 unit	2 regular / 1 apheresis
16-25 kg	1 unit	1 unit	4 regular / 2 apheresis
26-50 kg	2 units	2 units	6 regular / 3 apheresis
> 50 kg	3 units	3 units	8 regular / 4 apheresis

P-MTP Pack 2 contents

	RBC	FFP / ELP	Platelets
< 25 kg	1 unit	1 unit	1 unit
26-50 kg	2 units	2 units	1 unit
> 50 kg	3 units	3 units	1 unit

- Blood products are standard Adult units
- RBC 10 mL/kg increases Haemoglobin by 20 g/L
- Optimise the use of each unit to minimise wastage
- ELP not suitable for infants < 6 months or patients with known factor deficiencies (including vWD)

Goals

Haemoglobin	> 80 g/L during active bleeding
Platelets	> 50 x 10^9/L (>100 x 10^9/L in Brain Trauma)
Fibrinogen	~ 2 g/L
INR / APTT	< 1.5 x normal
Ionised Calcium Ca^{++}	> 1.1 mmol/L
Potassium K^+	< 5 mmol/L
Temperature	~ 36°C
pH	> 7.2

Blood Volume

< 1 yr	90 mL/kg
1-12 yrs	80 mL/kg
> 12 yrs	70 mL/kg

Page 2

The Paediatric MTP cognitive aid (Figure 6) was designed to complement and resemble the visual flow of our Adult MTP cognitive aid. As with the adult document, it was designed to flow over two pages – with the first page outlining the initiation phase of MTP, and the second page outlining the cycling (or maintenance) phase of resuscitation. A deliberate effort was made to maintain visual consistency between the two aids – to maximise familiarity and minimise cognitive load for the end user.

The key differences for the paediatric cognitive aid are:

- Colour palette: a different colour was used for the header to help distinguish between the two aids, but the remaining panels retain the same colour scheme.
- Removal of panels that were more relevant for Adult MTP
  - Pharmacological coagulopathy
  - Specific bleeding situations
  - Pathological coagulopathy.
- Addition of panels to assist clinical management of Paediatric MTP
  - Stages of haemorrhagic shock (adapted from ATLS 10th edition)[16]
  - Paediatric MTP pack contents
  - Paediatric blood volume formulas
  - Supplementary notes on blood product administration.

FUTURE DIRECTIONS

There are ongoing regular committee meetings regarding the ongoing refinement and optimisations to both the MTP process and MTP cognitive aids at our LHD. There are post-implementation quality assurance plans to review the effectiveness, strengths, and weaknesses of these systems – and their impact on the delivery of safe and quality healthcare in patients requiring massive blood transfusion. These steps of auditing both the MTP process and the utility of the associated cognitive aid are imperative steps at any institution to ensure issues are addressed and content is kept up to date.

CONCLUSION

The process of updating the existing Adult and Paediatric MTPs at our institution has been a valuable and rewarding experience. Early and active engagement of key stakeholders is an essential step to ensuring a relevant and functional collection of resources and recommendations. The additional development of an accompanying cognitive aid to assist the management has been a very worthwhile asset to help translate the MTP into clinical practice. Effective management requires consideration of both clinical and logistic domains, and cognitive aids are an excellent tool to assist clinicians involved in managing an MTP. We hope that this article has been useful in describing the processes and practicalities to consider when implementing similar endeavours at your institution.

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