Te Hononga Whētuki ā-Motu
National Trauma Network

Health Quality & Safety Commission New Zealand
Kupu Taurangi Hauora o Aotearoa

Improving trauma care for critically bleeding patients

A national best-practice critical bleeding bundle of care with associated guidance and massive transfusion protocol

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Contents

List of abbreviations

ABC	assessment of blood consumption
ABG	arterial blood gas
ACC	Accident Compensation Corporation
ACT	activated clotting time
ANZ-MTR	Australian and New Zealand Massive Transfusion Registry
aPTT	activated partial thromboplastin time
BP	blood pressure
Ca	calcium
CFF	citrated functional fibrinogen
CKR	citrated kaolin test reaction time
coag	coagulation
coags	coagulation screen
CPGs	clinical procedures and guidelines
CRT	citrated rapid TEG®
cryo	cryoprecipitate
CT	computerised tomography
DHB	district health board
DOAC	direct oral anticoagulant
dTCT	dilute thrombin clotting time
ED	emergency department
E-FAST	extended focused assessment with sonography for trauma
ERG	expert reference group
ETA	estimated time of arrival
FBC	full blood count
FC	fibrinogen concentrate
FFP	fresh frozen plasma
FC	fibrinogen concentrate
ICU	intensive care unit
IMIST	identification, medical complaint, injuries related to the complaint, signs, treatment and trends
INR	international normalised ratio
IV	intravenous
K	potassium
LY	lysis
MA	maximum amplitude
MTP	massive transfusion protocol
NZBS	New Zealand Blood Service
OR	operating room
PR	prothrombin ratio
RBC	red blood cell
ROTEM®	rotational thromboelastometry
SBP	systolic blood pressure
TAT	turnaround time
TCT	thrombin clotting time
TEG®	thromboelastography
TMS	transfusion medicine specialist
TXA	tranexamic acid
VBG	venous blood gas
VHA	viscoelastic haemostatic assay

Background

The improving trauma care for critically bleeding patients project (also known as the critical haemorrhage project) is a partnership between the National Trauma Network (the Network), the Accident Compensation Corporation (ACC), the Health Quality & Safety Commission (the Commission), the New Zealand Blood Service (NZBS), the Australian and New Zealand Massive Transfusion Registry (ANZ-MTR), ambulance services and district health boards (DHBs), specifically emergency departments (EDs), perioperative teams and intensive care units (ICUs).

The Network is guided by an overarching governance group, the membership of which includes the Ministry of Health, Waka Kotahi New Zealand Transport Agency, DHBs, ACC and the Commission.

This document is the key deliverable from the critical haemorrhage project. Its development has been informed by two expert reference groups (ERGs), to whom the Commission and Network are very grateful for their time and expertise. Appendices C and D list the members of these two groups.

Our earlier publication, *Improving trauma care for critically bleeding patients: A history, evidence summary and proposed quality improvement approach*,[1] also published in 2020, provides the background and evidence for the development of this document.

Because it is based on the earlier publication, this document does not include the evidence or rationale for why it suggests or recommends what it does. Instead, we have written this document as a practical guide for clinical staff to use to inform their care of critically haemorrhaging patients. Each of its images is available as a separate document. This means they can be printed in poster size and displayed on emergency department or operating room walls, for example. To access these images, go to the Commission's major trauma website pages: www.hqsc.govt.nz/our-programmes/national-trauma-network/projects/national-critical-haemorrhage.

We also intend this document to be used to inform clinical governance discussions. Ideally, if existing processes and approaches do not match this guidance, the latter will be used to inform a change process that adjusts pathways so critically haemorrhaging trauma patients receive the best and most timely care possible (within the constraints of the local context, capacity and capability).

1 Health Quality & Safety Commission/National Trauma Network. 2020. *Improving trauma care for critically bleeding patients: A history, evidence summary and proposed quality improvement approach.* Wellington: Health Quality & Safety Commission. URL: www.hqsc.govt.nz/our-programmes/national-trauma-network/publications-and-resources/publication/4119.

Introduction

The critical haemorrhage project began in January 2020. It seeks to reduce mortality and complications in critically haemorrhaging trauma patients by working in partnership with the health sector and experts to:

- support the ambulance sector and hospitals to review and update existing massive transfusion protocols (MTPs) to meet current best-practice trauma care
- develop a national best-practice critical bleeding bundle of care for ambulance services and hospitals to adjust to their local context and implement
- develop associated national critical bleeding best-practice guidance.

These deliverables will support New Zealand health care providers with early recognition and appropriate action for trauma-related critical haemorrhage across ambulance services, EDs, perioperative teams and ICUs. While other types of critical haemorrhage (eg, obstetric haemorrhage, large blood loss surgery, transplants and gastro-intestinal haemorrhage) are out of scope, general hospital haemorrhage patients will benefit from improved guidance and practice.

The critical haemorrhage project's aspirational goal is to achieve zero in-hospital deaths from trauma-related critical haemorrhage. The overall project aim is to eliminate avoidable deaths from trauma-related critical haemorrhage and related multiple-organ failure by 2025.

Data analysis, audit and performance metrics

A key objective of the critical haemorrhage project is to support the identification of high-risk trauma patients with exsanguinating haemorrhage and improve their outcomes. To know whether improvement has occurred, data analysis and performance measurement are needed. To that end, at a national level New Zealand Trauma Registry data will be combined with data from the ANZ-MTR,[2] the NZBS data on transfusion, the pre-hospital data sets from St John Ambulance and Wellington Free Ambulance services and, where possible, data from aero-medical services. This expanded data set will be used to develop national performance metrics that identify the key attributes of a critically bleeding trauma patient and their care.

The intention is to divide the national data collection into three sections related to:

1. patient progress through the care pathway to definitive bleeding control
2. the presence or absence of a system approach to the national best-practice critical bleeding bundle of care
3. the delivery of key therapies to the critically bleeding trauma patient.

We will provide more information about this in due course, via the Commission and Network websites and through communication to key stakeholders.

2 Zatta AJ, McQuilten ZK, Mitra B, et al. 2014. Elucidating the clinical characteristics of patients captured using different definitions of massive transfusion. *Vox Sanguinis* 107(1): 60–70. DOI: 10.1111/vox.12121 (accessed 3 November 2020).

In addition, local audit and measurement can and should occur. A combination of national and local measures will then inform relevant trauma quality assurance and improvement activity.

In the short term, see Appendix B for critical bleeding bundle performance indicators to support local trauma service audit. We offer these as suggestions for consideration.

Implementation, education and system change

To implement a new best-practice critical bleeding bundle of care, it is necessary to consider its fit into existing trauma care models and local contexts. To translate this guidance into practice, it may also be necessary to review local access to the recommended bundle therapy components, equipment and skilled staff. Process improvement may necessitate modification of the bundle for local circumstances.

In addition, we suggest taking a human factor approach to understanding and supporting change, as it enables trauma teams to look at the specific challenges they face in implementing the bundle within their organisation and locality. This approach has proven to be of real benefit in a series of in-situ simulation-based trauma scenarios, first piloted here in New Zealand in 2018 by Trauma NetworkZ®, and now established as part of the NetworkZ programme.[3] This type of educational support will be a key component of success for the implementation of this guidance and bundle.

Finally, the introduction of any change to practice requires a level of monitoring that enables an organisation to know that the change is happening and to what extent the change is an improvement over current practice. To that extent, we encourage teams to apply improvement and implementation science methods in their local context, as these will benefit system change projects that result from implementation of the national best-practice critical bleeding bundle of care.

Purpose and focus of the national best-practice critical bleeding bundle of care

The critical bleeding bundle of care (the bundle) will improve the identification of patients with life-threatening active bleeding so they can benefit from rapid (fast-tracked) assessment and treatment. The purpose of the bundle is to guide health care providers through the ideal, accelerated treatment pathway.

The key aspect of the bundle is to accelerate the treatment pathway (compared with what might otherwise occur), so that definitive control of the bleeding, which usually occurs in an operating room or an interventional radiology suite, occurs as quickly as possible.

It incorporates:

- a bundle of interventions that are standardised, but reflect the uniqueness of the environment
- the activation of a system (using the activation term 'Code Crimson') that is designed to accelerate the patient through the pre-hospital and early hospital (ie, ED) period towards definitive haemorrhage control
- a resuscitative strategy that delivers blood products and antifibrinolytics in a delivery system that limits exsanguination and coagulopathy but embraces permissive hypovolaemia prior to control of bleeding.

3 www.networkz.ac.nz/16.html

The bundle is designed to be applied in parallel with existing trauma pathways. It strengthens the focus on making an early transfer to the operating room or interventional radiology suite and limiting unnecessary delay.

Scope of the national best-practice critical bleeding bundle of care

The bundle is intended for use in all New Zealand trauma systems, which include:

- pre-hospital emergency road ambulances
- pre-hospital emergency air ambulances
- trauma-receiving hospital EDs
- trauma-receiving hospital operating rooms
- ICUs
- interventional radiology departments.

Clinical examples of potential injuries that meet the above criteria include, but are not limited to:

- blunt trauma associated with signs of critical bleeding and any of the following:
  - abdominal trauma with a positive extended focused assessment with sonography for trauma (E-FAST) scan
  - uncontrolled maxillo-facial haemorrhage
  - gross pelvic disruption
  - massive haemothorax
  - traumatic amputation
- penetrating trauma associated with signs of critical bleeding and any of the following:
  - penetrating trauma to the trunk
  - junctional penetrating trauma
  - pericardial tamponade on E-FAST
  - penetrating neck wounds.

Overview of the remainder of this document

The next section defines activation of Code Crimson, the code that begins the accelerated treatment pathway. The sections that follow cover associated key treatment aspects, such as tranexamic acid (TXA), the Code Crimson MTP, blood product delivery, patient warming, resuscitation priorities, rapid investigations, goals of treatment and reversal of anticoagulant drugs.

Appendix A then provides action or cue cards that define roles and functions for key members of the team. These are, in principle, aimed at achieving:

- appropriate expertise so that, on activation of Code Crimson, the required team assembles in the emergency resuscitation room waiting for the arrival of the patient (or as soon as possible after in-hospital activation)

- early (less than 10 minutes after assessment) decision-making on the treatment priorities of the bleeding component of the trauma
- rapid movement of the patient to the location where bleeding control occurs.

Appendix B suggests relevant performance indicators for the critical bleeding bundle. Appendices C and D list the members of the two expert reference groups involved in this project. Appendix E includes acknowledgements.

Activating Code Crimson

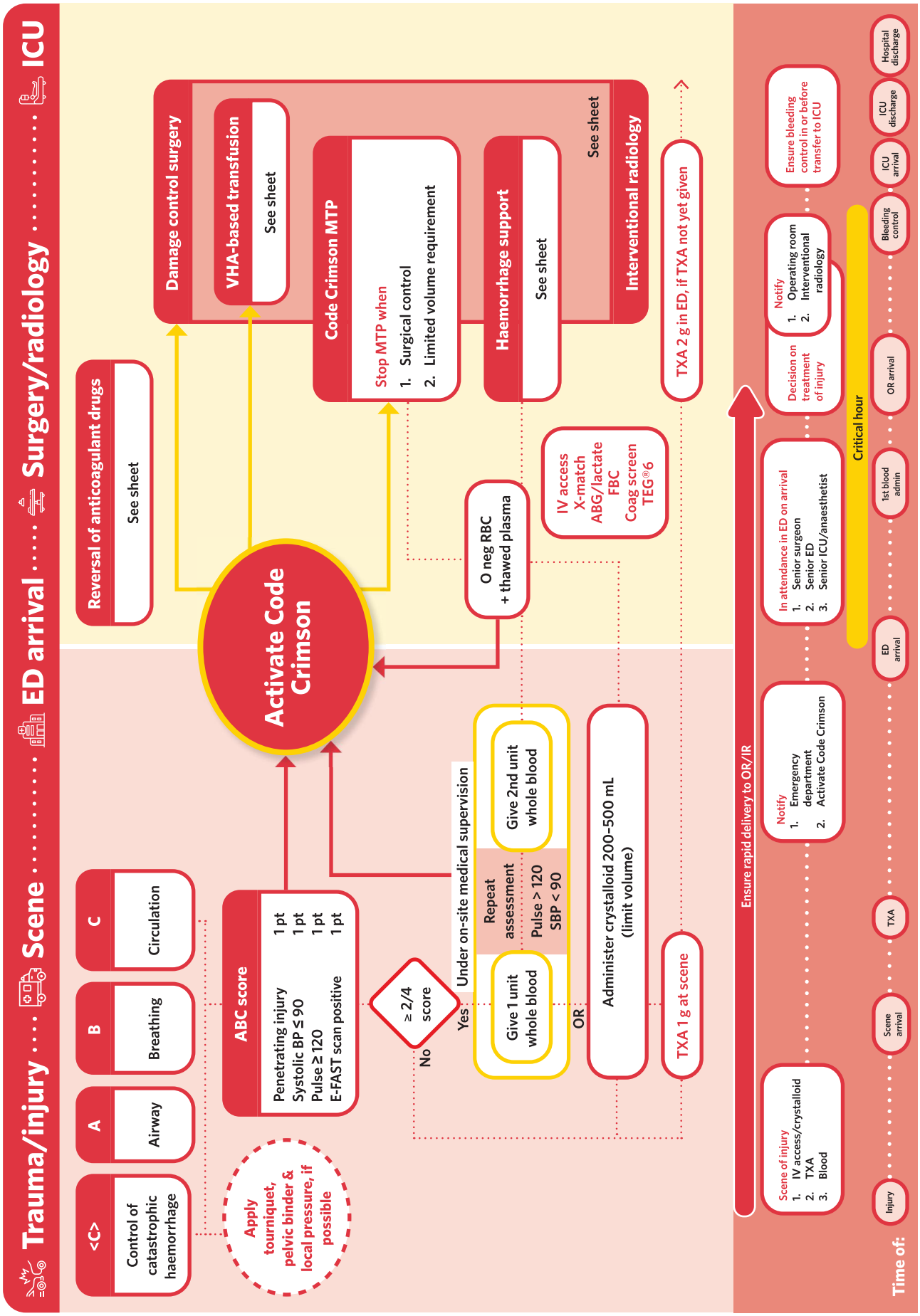
Code Crimson is a suggested activation code for the accelerated treatment pathway. Calling Code Crimson (or equivalent) means the clinical team, whether pre-hospital or within hospital, agrees that the patient's acuity warrants urgent action. It is an agreed elevation in acuity of a trauma patient that can be initiated anywhere during the progress of a patient though the system. Calling Code Crimson should immediately result in faster, more optimal care for the critically haemorrhaging patient.

Activation would apply when the patient **has signs of clinically significant ongoing haemorrhage and any one of the following criteria:**

- an assessment of blood consumption (ABC) score greater than or equal to 2, with:
  - heart rate ≥ 120 bpm
  - systolic blood pressure (SBP) ≤ 90 mmHg
  - penetrating trauma (thoracic, abdominal or junctional)
  - a positive E-FAST scan
- received pre-hospital blood products in a resuscitative strategy
- received ≥ 2 units of red blood cells in the ED as a resuscitative strategy.

Timeline of the accelerated treatment pathway on activating Code Crimson

The following diagram summarises the timeline for the accelerated treatment pathway in the critical bleeding bundle of care. Later sections describe the major components of the bundle in detail.



Note: ABC = assessment of blood consumption; ABG = arterial blood gas; BP = blood pressure; coag = coagulation; E-FAST = extended focused assessment with sonography for trauma; ED = emergency department; FBC = full blood count; ICU = intensive care unit; IV = intravenous; MTP = massive transfusion protocol; OR = operating room; RBC = red blood cell; SBP = systolic blood pressure; TEG® = thromboelastography; TXA = tranexamic acid; VHA = viscoelastic haemostatic assay.

What the activation of Code Crimson initiates

With the activation of Code Crimson, key senior members of the emergency team immediately attend the patient.

A trauma call is made to all of the members of the routine call plus the:

- blood bank
- on-call surgeon
- on-call anaesthetist
- operating room nurse coordinator
- interventional radiologist (or endovascular surgeon).

The activation of these additional key members of the team will by necessity require adjustment to individual hospital structures.

Key outcomes of Code Crimson activation

The key outcomes of Code Crimson activation are that it results in:

- effective primary survey with a focus on stopping controllable haemorrhage
- the application of principles of damage control resuscitation, in line with the critical bleeding bundle
- senior early decision-making to achieve definitive surgical/radiological control
- a facilitated transfer to an operating room or interventional radiology suite without unnecessary delay.

Activating Code Crimson initiates a process that speeds up transfer and releases staff and rooms in the operating room and/or interventional radiology suite, so delays are minimised.

Pre-hospital activation procedure by aero-medical services carrying blood

In summary, the pre-hospital transfusion triggers for pre-hospital Code Crimson activation are when a patient either:

- has a traumatic cardiac arrest, where pelvic binder placement, intubation and bilateral thoracostomy with or without thoracotomy (when indicated) has occurred, or
- in adults, has an ABC score ≥ 2 **and** both the pre-hospital and retrieval medicine doctor and intensive (critical) care paramedic at the scene agree a pre-hospital transfusion is in the patient's best interests.

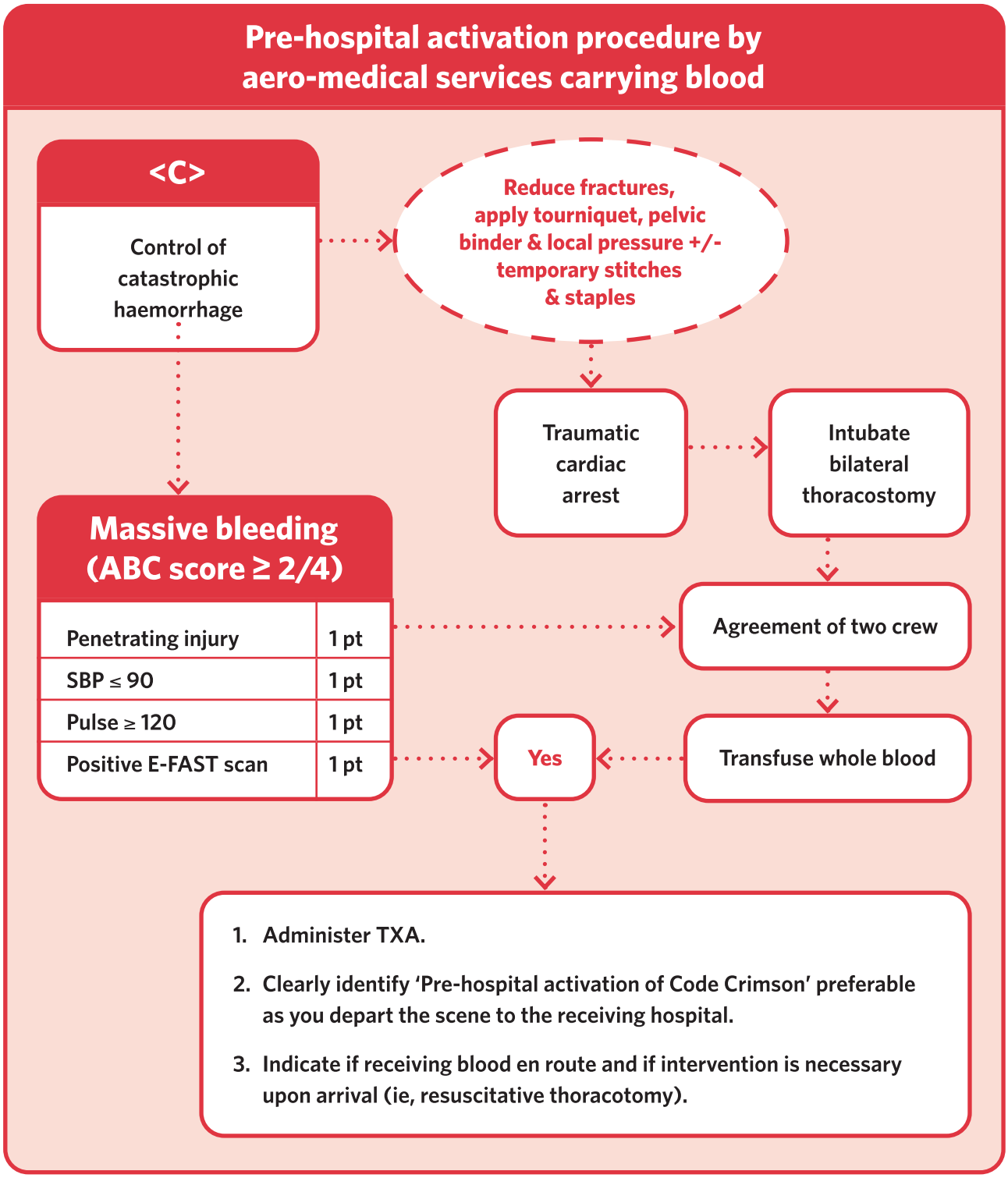
In children with trauma, blood should be transfused in 10 mL/kg boluses if there are signs of shock **and** if both clinicians at the scene agree to the transfusion.

The receiving hospital should be notified as early as possible that the patient is receiving a blood transfusion and that a Code Crimson activation is required.

If the pre-hospital critical care team considers that a specific intervention may be necessary soon after arrival (ie, a resuscitative thoracotomy or rapid transit to the operating room), it should clearly communicate the need for this intervention.

A positive E-FAST scan is the component of the ABC score that most strongly predicts critical haemorrhage. For this reason, the clinical team must carry the ultrasound equipment for, and be competent in performing and interpreting, a pre-hospital E-FAST scan.

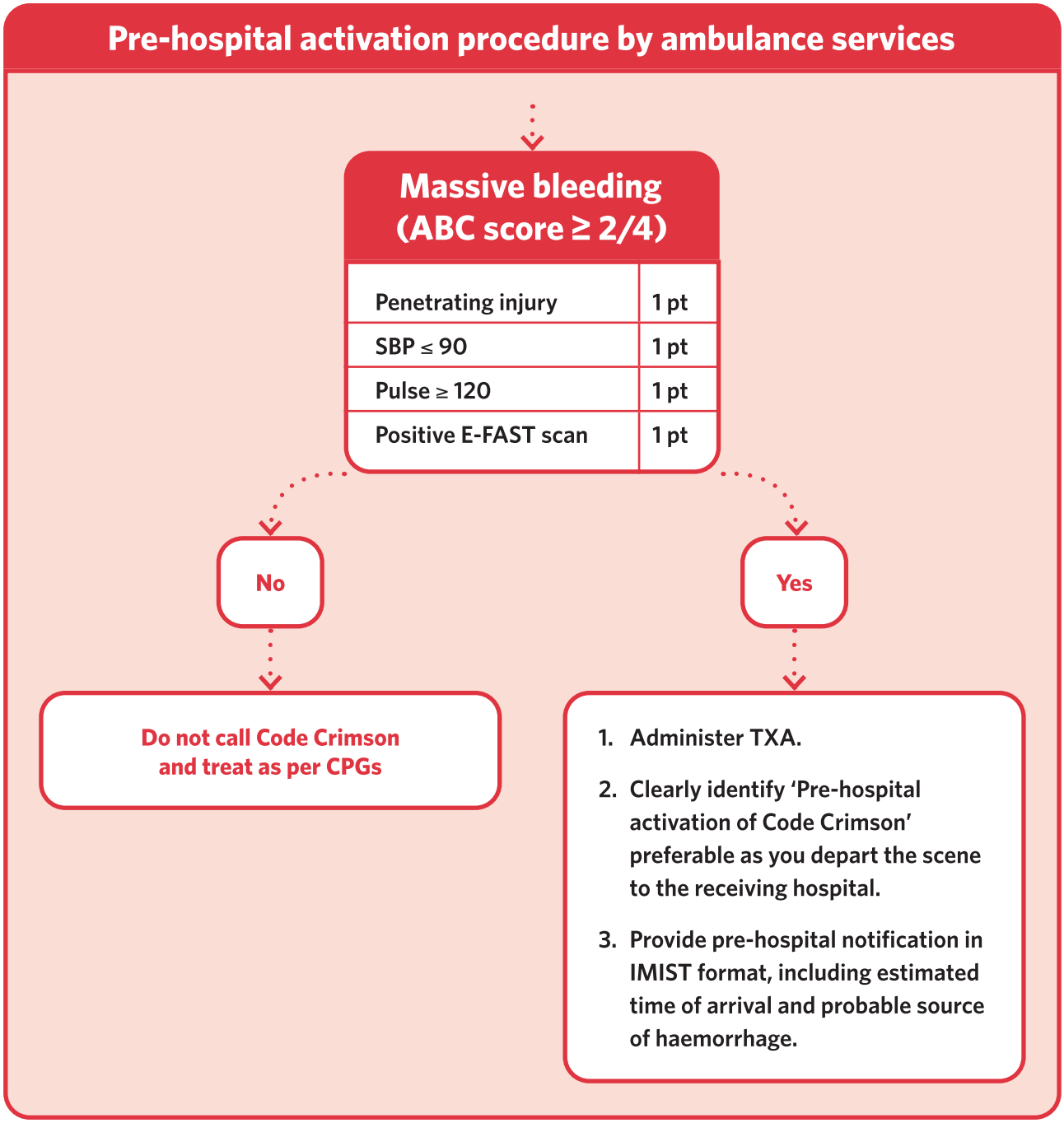
Pre-hospital activation procedure by aero-medical services carrying blood



Note: E-FAST = extended focused assessment with sonography for trauma; SBP = systolic blood pressure; TXA = tranexamic acid.

Pre-hospital activation procedure by ambulance services

Pre-hospital paramedics will inform the receiving hospital of the unstable nature of the patient and the patient's ABC score, suggesting that hospital staff should consider activating Code Crimson.



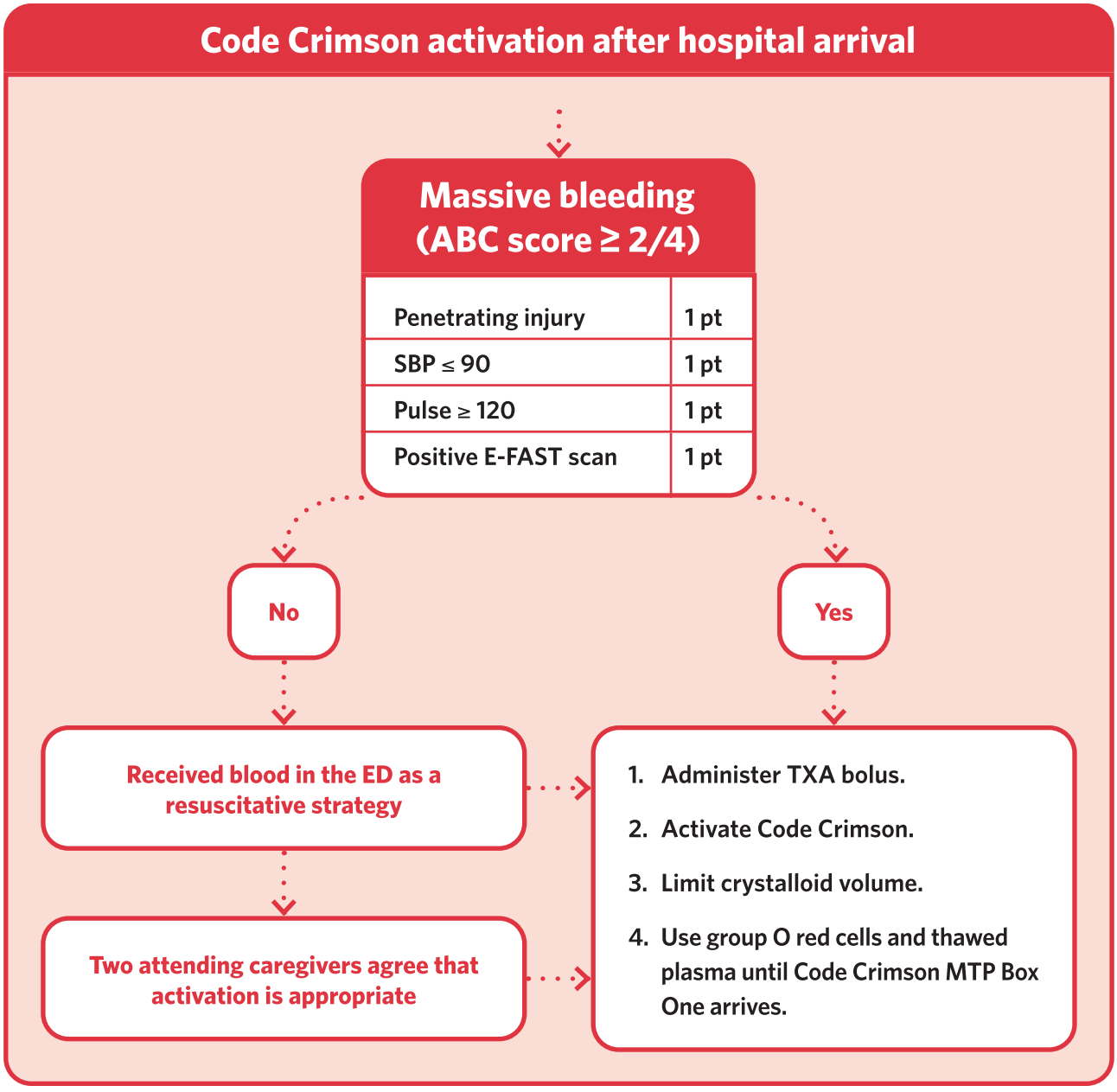
Note: CPGs = clinical procedures and guidelines; E-FAST = extended focused assessment with sonography for trauma; IMIST = identification, medical complaint, injuries related to the complaint, signs, treatment and trends; SBP = systolic blood pressure; TXA = tranexamic acid.

Where pre-hospital clinical guidelines have been developed for the use of vasopressors in trauma patients with hypotension and with ongoing bleeding, you may follow these to maintain a systolic BP at > 80 mmHg with permissive hypovolaemia.

Code Crimson activation after hospital arrival

Code Crimson activation after the patient arrives at the hospital would occur if the pre-hospital team has not activated or requested Code Crimson, but on arrival:

- the patient has:
  - an ABC score greater than or equal to 2, or
  - received ≥ 2 units of red blood cells in the ED as a resuscitative strategy, or
  - significant haemodynamic instability despite maximal crystalloid therapy (heart rate > 120 bpm, BP < 90 mmHg, base excess < –5), and
  - signs of clinically significant ongoing haemorrhage
- two attending caregivers agree that activation is appropriate.



Note: E-FAST = extended focused assessment with sonography for trauma; ED = emergency department; MTP = massive transfusion protocol; SBP = systolic blood pressure; TXA = tranexamic acid.

Tranexamic acid

TXA should be given to critically haemorrhaging patients immediately (ideally within three hours of injury) on Code Crimson activation and as indicated by pre-hospital clinical practice protocols.

Tranexamic acid

Give adults 1 g TXA IV early in intervention or < 3 hours after injury.

Where patients weigh < 45 kg, give 15 mg/kg TXA IV.

On admission to hospital, communicate delivery of TXA.

- **If not yet administered give 2 g TXA bolus.**
- **If 1 g given pre-hospital, consider additional 1 g TXA bolus.**

Note: IV = intravenous; TXA = tranexamic acid.

Resuscitation priorities in the bundle

The critical bleeding best-practice bundle of care has the following resuscitation priorities.

A. In the pre-hospital period

1. Patients with a Motor Score of > 5 can be maintained with a palpable peripheral pulse that allows normal conscious mentation.
2. Consider elevation of systolic BP to > 110 mmHg with vasopressors if Motor Score is ≤ 5.
3. Insert a large bore IV and begin normal saline at a rate that supports points 1 and 2 above, if blood is unavailable; the amount of saline should be limited, if possible.
4. Give 1 g TXA IV as per protocol.
5. Expedite transport to destination hospital as per regional major trauma destination policies.
6. Initiate call to hospital, alerting them Code Crimson or possible activation, patient status, likely injuries and indicate an estimated time of arrival.
7. Two units of whole blood may be given under on-site medical direction.
8. Maintain normothermia, with warmed transport bed, body covering and warm ambulance.

B. In the emergency department

1. Take handover from ambulance personnel.
2. Initiate primary survey, damage control resuscitation and secondary survey.
3. Actively warm the patient and all IV fluids.
4. Activate Code Crimson if the patient meets the criteria and it has not already been activated.
5. Give 2 g dose of TXA IV within three hours of injury, **if TXA not yet given.** If 1 g given pre-hospital, consider additional 1 g IV bolus.
6. Take initial bloods for:
   a. full blood count, including platelet count
   b. coagulation screen, including dilute thrombin clotting time (dTCT) if on a direct oral anticoagulant (DOAC)
   c. arterial or venous blood gas (ABG or VBG) for lactate
   d. crossmatch sample
   e. thromboelastography (TEG®) or rotational thromboelastometry (ROTEM®), if available.
7. Call blood bank to activate Code Crimson MTP.
8. Limit or stop crystalloid fluids.
9. Call for group O negative red blood cells (RBCs) and thawed plasma initially, and begin transfusion to maintain goals if delay in delivery of Code Crimson MTP Box One.
10. If the Motor Score is ≤ 5 as a result of traumatic brain injury, consider elevation of systolic BP to > 110 mmHg with vasopressor.
11. Coordinate early team planning for definitive haemorrhage control, including:
    a. senior surgeon plan for destination and timing
    b. interventional radiologist for options of interventional radiology
    c. senior anaesthetist/intensivist for transfer and operating room availability.
12. Limit delay.

C. In the operating room or interventional radiology suite

1. Ensure resuscitation equipment is available and prepared.
2. Warm the room, and actively warm the patient and all IV fluid.
3. Check that the Code Crimson MTP has been activated and blood product delivery has been initiated.
4. Continue principles of damage control resuscitation (permissive hypovolemia, limited crystalloid, 1:1 blood/plasma ratio) until haemorrhage control achieved.
5. Transfer to viscoelastic haemostatic assay (VHA) guided therapy as soon as practicable and continue to perform a standard coagulation screen at 30–60-minute intervals.
6. Use goal-directed approach, allowing additional fluids to achieve normovolaemia after surgical/radiological control of bleeding has occurred.
7. If damage control surgery limits arrest of bleeding and packing occurs, concentrate on treating hypothermia, acidosis and coagulopathy.

8. Transfer patient to ICU for further stabilisation before considering re-operation.

All of the above actions are aimed at achieving:

- temperature ≥ 36° Celsius
- pH > 7.2
- base excess > –6 mmol/L
- ionised calcium > 1.12 mmol/L
- haemoglobin > 80 g/L
- platelet count > 100 x 10^9/L
- international normalised ratio (INR) < 1.5 or activated partial thromboplastin time (aPTT) < 50
- fibrinogen > 2 g/L
- TEG®
  - TEG-ACT (activated clotting time) < 110 seconds
  - Alpha angle > 55 degrees
  - MA (maximum amplitude) > 51 mm
  - LY-30 (lysis 30 minutes) < 2.2%.

Goals of treatment while bleeding

The critical bleeding best-practice bundle of care has the following goals of treatment.

Goals of treatment while bleeding

Maintain permissive hypovolemia (unless Motor Score ≤ 5 when elevation of systolic BP to 110 mmHg with vasopressor is recommended):

- **palpable radial pulse**
- **normal level of consciousness.**

Use of vasopressor may be appropriate with sedation, anaesthesia or intubation.

Limit crystalloid and avoid synthetic colloids.

Use blood as volume expander:

- **activate Code Crimson MTP**
- **minimum RBC: fresh frozen plasma (FFP) ratio 2:1**
- **consider O neg RBC and thawed FFP**
- **consider whole blood when available**
- **repeat FBC coagulation and VHA every 30 minutes until bleeding controlled.**

Transfusion end points:

- **haemoglobin = 80 g/L**
- **platelet count > 50 x 10^9 or > 100 x 10^9 if ongoing bleeding or intracranial haemorrhage**
- **fibrinogen 2.0 g/L.**

Note: FBC = full blood count; FFP = fresh frozen plasma; MTP = massive transfusion protocol; RBC = red blood cell ; VHA = viscoelastic haemostatic assay.

Code Crimson Massive Transfusion Protocol for adults

When Code Crimson has been activated, the Code Crimson MTP should also be activated.

Code Crimson Adult Massive Transfusion Protocol

Team leader responsibilities

- Notify coagulation lab and send coagulation requests.
- Activate protocol by ringing blood bank and saying 'I am activating the Code Crimson Massive Transfusion Protocol'.
- Call for each box as required.
- Make a decision to cease Code Crimson MTP and contact blood bank. Move to focused transfusion.

Blood bank responsibilities

- Process X-match sample as soon as possible.
- Notify NZBS medical specialist after issuing MTP Box Four.
- Thaw next box in advance and await request.
- Ensure supply of platelets.

Contacts

- Blood bank.
- Coagulation lab.

Additional treatment thresholds

- If PR > 1.5 or aPTT > 40, consider additional 4 units FFP.
- If fibrinogen < 1.5 g/L, consider additional 3 units cryo or 4 units FC.
- If platelets < 75 x 10^9/L, consider additional one pack platelets.
- If ionised Ca++ < 1.2 mmol/L give 10 mL calcium.

Massive bleeding with either shock (ABC ≥ 2) or abnormal coagulopathy

↓

Give tranexamic acid 2 g IV bolus

↓

Ensure delivery of X-match specimen to blood bank

↓

Code Crimson add 2 units FFP or thawed plasma

Administer up to 2 units O-neg or type-specific RBCs

↓

Ring blood bank to activate Code Crimson MTP

↓

MTP BOX ONE
2 whole blood or 2 units RBC and 2 units FFP

Code Crimson add 3 units cryo (or 4 g FC) and one pack platelets

Check coags/ platelets/ FBC/ABGs/ Ca^{++}

↓

MTP BOX TWO
4 RBC
4 FFP
1 adult platelets

Repeat every 30 min

↓

MTP BOX THREE
4 RBC
4 FFP
3 units cryoprecipitate

Check coags/ platelets/ FBC/ABGs/ Ca^{++}

↓

MTP BOX FOUR
4 RBC
4 FFP
1 adult platelets

Repeat every 30 min

↓

and alternate 3 & 4

Check coags/ platelets/ FBC/ABGs/ Ca^{++}

Note: ABG = arterial blood gas; aPTT = activated partial thromboplastin time; Ca = calcium; coags = coagulation screen; cryo = cryoprecipitate; FBC = full blood count; FC = fibrinogen concentrate; FFP = fresh frozen plasma; NZBS = New Zealand Blood Service; PR = prothrombin ratio; RBC = red blood cell.

Blood product delivery as part of the critical bleeding bundle

An important part of the critical haemorrhage best-practice bundle of care is achieving appropriate blood product delivery.

- Activate the Code Crimson MTP.
- When Code Crimson has been activated, stop administering crystalloid.
- If the patient fails to meet resuscitation targets and the MTP blood is unavailable, then give O negative or group-specific RBCs and plasma (emergency/'desperate units') at a rate to maintain adequate perfusion.
- When the Code Crimson MTP blood arrives, start Box One at a rate consistent with the principle of damage control resuscitation, **not** to restore normovolaemia.
- If VHA is available, follow the VHA protocol to the same resuscitative endpoints.

Associated processes

Every hospital with Code Crimson activation should develop and understand a process that covers:

- the staff member who initiates the Code Crimson MTP and their contact details
- the need for 'desperate units' before MTP Box One arrives, the location of the emergency/'desperate units' and the process of checking and delivering these
- where to send the blood and who to notify about a change in location of the patient (eg, blood bank)
- how to terminate the Code Crimson MTP.

Haemorrhage support – patient warming

At all stages of the patient's progress through the bundle, actively manage the patient to reduce hypothermia.

1. Actively externally warm the patient and all IV fluid (goal is patient temperature of 36° Celsius).
2. Maintain hospital room environments at a temperature (21° Celsius) that allows examination without a drop in core body temperature.
3. Warm all blood with an approved high-flow blood warmer designed to safely deliver high flows without air entrainment.
4. In the related education programme, include how to use warming equipment safely and efficiently when Code Crimson is activated.
5. Cover the patient when moving them from one hospital area to another (in transit).
6. Resource operating rooms to deliver:
    a. a suitably warm ambient temperature (21° Celsius)
    b. active external warming of the patient
    c. high-flow rapid infusion devices for blood and fluid delivery.

The whole hospital system should coordinate purchases so that equipment in different areas of the hospital can be used in an efficient and effective manner, allowing warming to continue throughout the patient's entire transit.

Rapid investigations in the Code Crimson patient

Routine investigations should occur in the trauma patient as per local pathways. In addition, a patient that arrives with critical bleeding should receive:

1. an urgent pre-transfusion group and screen sent to the blood bank immediately upon arrival and processed as part of the Code Crimson process. Group O RBCs and group A or AB plasma will be released until typing is confirmed
2. an initial full blood count including platelet count, then repeated every 30–60 minutes
3. a coagulation screen including prothrombin ratio (PR), INR, aPPT, fibrinogen and thrombin time (dTCT, dabigatran or rapid TAT levels) if on a DOAC
4. an ABG or VBG, including base excess and lactate assessment
5. a TEG® or ROTEM® test if available (see algorithm below).

Hospitals should ensure resources and staffing, including point-of-care devices close to the areas of patient treatment, are available to deliver these investigations effectively.

TEG® 6S (trauma) simplified algorithm

Step 1: Maximum amplitude (MA) result in about 10–15 mins

CFF MA < 20 mm

Give cryoprecipitate or fibrinogen concentration

CFF MA	**< 20 mm**	**3 u cryo or 2 g FC**
	< 10 mm	**6 u cryo or 4 g FC**
	< 5 mm	**5–10 u cyro or 4–6 g FC**

To raise the CFF MA by 2 mm requires approx either 5 units of cryo (or 1 plasmapheresis pack) or 1 g FC

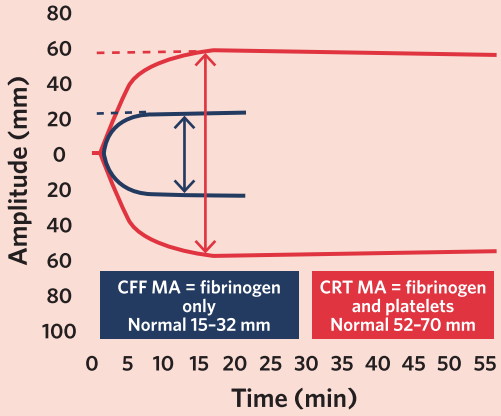
CFF MA normal **CRT MA < 52 mm**

Give pooled platelets

CRT MA	**< 50 mm**	**1 u**
	< 25 mm	**2 u**

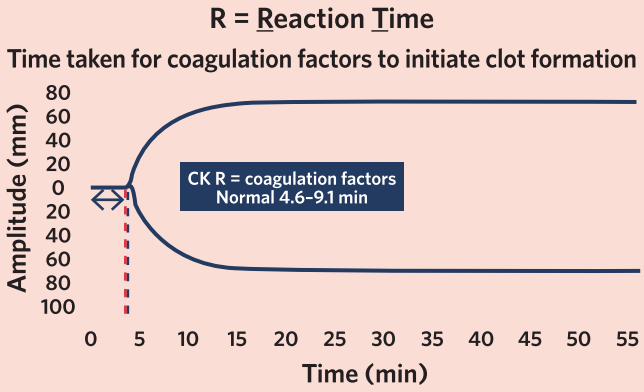
MA = Maximum Amplitude

Strength of clot formed by fibrinogen crosslinking with platelets



Step 2: Reaction time result in about 10–15 mins

CKR	> 9 mins
Give FFP	2–4 u
or prothrombinex	25–35 u/kg



Note: CFF = citrated functional fibrinogen; CKR = citrated kaolin test reaction time; CRT = citrated rapid TEG®; cryo = cryoprecipitate; FC = fibrinogen concentration; FFP = fresh frozen plasma; MA = maximum amplitude.

Paediatric resuscitation

The definition of 'paediatric' in trauma should follow the local hospital guidelines.

If you have any doubt about whether a patient should be covered by the paediatric or adult criteria, we encourage you to consult with an experienced paediatric service or centre.

IV access may be more difficult for paediatric patients. Locally agreed policies should exist that identify alternatives to peripheral IV access if this cannot be found. Intraosseous and femoral venous access (with ultrasound assistance) are practical options but need equipment and education. Volume resuscitation can occur through these.

The routine initial IV dose should be 15 mg/kg (maximum 1 g). If practicable, start an infusion of 15 mg/kg (maximum 1 g) over eight hours.

Recognising the lower rate of operative intervention in paediatric patients, and the increased incidence of radiological investigation in trauma care, senior staff should monitor the child while unstable with full access to and support of the Code Crimson bundle. The child should be monitored in an intensive care environment until stable.

Paediatric massive transfusion protocol

When Code Crimson has been activated for a paediatric patient, the Paediatric MTP should also be activated.

Paediatric Massive Transfusion Protocol

Team leader responsibilities

- Call coagulation lab and send coagulation requests.
- Activate protocol: Call blood bank and say, 'I am activating the Paediatric Massive Transfusion Protocol Alpha, Bravo or Charlie.'
- Call for each box as required and send someone to pick it up.
- Alternate infusions of products to avoid swings in Hb and coagulation.
- Call blood bank when stopping MTP.

Blood bank responsibilities

- Process X-match sample as soon as possible.
- Call NZBS medical specialist after issuing MTP Box One.
- Thaw next box in advance and await request.
- Ensure supply of platelets. If no neonatal platelets for Alpha, contact TMS.
- Provide red cells less than 14 days old whenever possible.

Contacts

- Blood bank.
- Coagulation lab.

Additional treatment

- Ongoing haemorrhage after box three – if PR > 1.5 or aPTT > 40, consider additional 20 mL/kg FFP.
- If fibrinogen < 1 g/L, consider additional 5 mL/kg cryoprecipitate.
- If platelets < 75 x 10^9/L, consider additional 10 mL/kg platelets.
- If ionised Ca^{++} < 1 mmol/L, give 0.3 mL/kg calcium gluconate.
- Watch for hyperkalaemia and treat.

Massive bleeding with either shock or abnormal coagulopathy

Ensure delivery of X-match specimen to blood bank

Alpha 0–10 kg	Bravo 11–20 kg	Charlie 21–45 kg
1 adult RBC O neg or type specific Give 15 mL/kg	1 adult RBC O neg or type specific Give 150 mL	Give 1 unit O neg or type specific RBC

Ring blood bank to activate Paediatric MTP

REQUEST, DELIVER AND TRANSFUSE AS BELOW:

MTP BOX ONE 1 adult RBC 1 adult FFP 1 cryoprecipitate 1 neo platelet Transfuse 10 mL/kg of each in the following order: RBC, FFP RBC, cryo 0.45 mL/kg calcium gluconate RBC, FFP RBC, Plt 0.45 mL/kg calcium gluconate Beware of K^+	MTP BOX ONE 1 whole blood only *or* 1 adult RBC and 1 adult FFP 0.3 mL/kg calcium gluconate	MTP BOX ONE 1 whole blood only *or* 2 adult RBC and 2 adult FFP 0.3 mL/kg calcium gluconate	Check • Coags • FBC • ABGs • K^+/Ca^{++}
	MTP BOX TWO 1 adult RBC 1 adult FFP 1 cryoprecipitate 0.3 mL/kg calcium gluconate	MTP BOX TWO 2 adult RBC 1 adult FFP 2 cryoprecipitate 0.3 mL/kg calcium gluconate	Repeat every 30 min
	MTP BOX THREE 1 adult RBC 1 adult FFP 150 mL platelets 0.3 mL/kg calcium gluconate	MTP BOX THREE 2 adult RBC 2 adult FFP 1 adult platelets 0.3 mL/kg calcium gluconate	Check • Coags • FBC • ABGs • K^+/Ca^{++}
	Beware of K+	Beware of K+	Repeat every 30 min
and repeat	and alternate Boxes Two & Three	and alternate Boxes Two & Three	

Tranexamic acid (TXA)

- Loading dose: 15 mg/kg (max 1 g).
- Consider maintenance infusion: 2 mg/kg/hour.

Typical component volumes

- Red cells: adult: 300
- FFP: adult: 245
- Platelets: neonatal: 50 mL/adult 270
- Cryoprecipitate: 100 mL

Note: ABGs = arterial blood gases; aPTT = activated partial thromboplastin time; Ca = calcium; coags = coagulation screen; FBC = full blood count; FFP = fresh frozen plasma; K = potassium; NZBS = New Zealand Blood Service; PR = prothrombin ratio; RBC = red blood cell; TMS = transfusion medicine specialist; TXA = tranexamic acid.

Reversal of anticoagulant drugs

Consult haematological specialists for advice on reversing DOACs with active bleeding, referring to lab results if possible. If bleeding is life-threatening, administer therapy in addition to MTP or goal-directed therapy, including TXA.

If the patient has life-threatening bleeding and evidence of recent ingestion of warfarin, a DOAC or a platelet-inhibiting agent (except aspirin):

- take coagulation screen blood tests as described under 'Rapid investigations in the Code Crimson patient'
- consider a VHA study if available, especially a DOAC-specific cartridge
- administer relevant antidote early
- retest after administration completed.

Reversal of anticoagulant drugs

If the patient is bleeding and on:

	Send off	Administer
1. Warfarin	**INR**	**10 mg IV vitamin K and Prothrombinex 25–50 units/kg**
2. Dabigatran	**TCT, dabi level and aPTT**	**Idarucizumab 5 g**
3. Rivaroxaban or Apixaban	**INR, TAT and aPTT**	**Prothrombinex 50 units/kg**

Note: aPTT = activated partial thromboplastin time; dabi level = dabigatran level; INR = international normalised ratio; TAT = turnaround time; TCT = thrombin clotting time; IV = intravenous.

Appendix A: Action or cue cards setting out responsibilities of the critical haemorrhage management team

1. Ambulance pre-arrival notification (R40) and activation of Code Crimson

Trauma call criteria met on 'Ambulance pre-arrival notification'

Penetrating mechanism	(1)	☐
Systolic BP ≤ 90 mmHg	(1)	☐
Pulse rate ≥ 120	(1)	☐
Positive trauma E-FAST ultrasound	(1)	☐
	Score	☐

Score 2, 3 or 4

1. ED charge nurse or specialist organises trauma Code Crimson call that includes ETA.
2. ED charge nurse ensures the following teams are contacted with ETA:
   a. anaesthetist
   b. operating room nursing coordinator
   c. blood bank
   d. radiology registrar.
3. Surgical registrar contacts on-call surgical consultant.
4. If ED specialist is not in hospital, the charge nurse contacts them.

Score 0 or 1

If patient meets trauma call criteria, make trauma call with ETA.

Note: BP = blood pressure; E-FAST = extended focused assessment with sonography for trauma; ED = emergency department; ETA = estimated time of arrival.

2. Trauma team leader and emergency department charge nurse

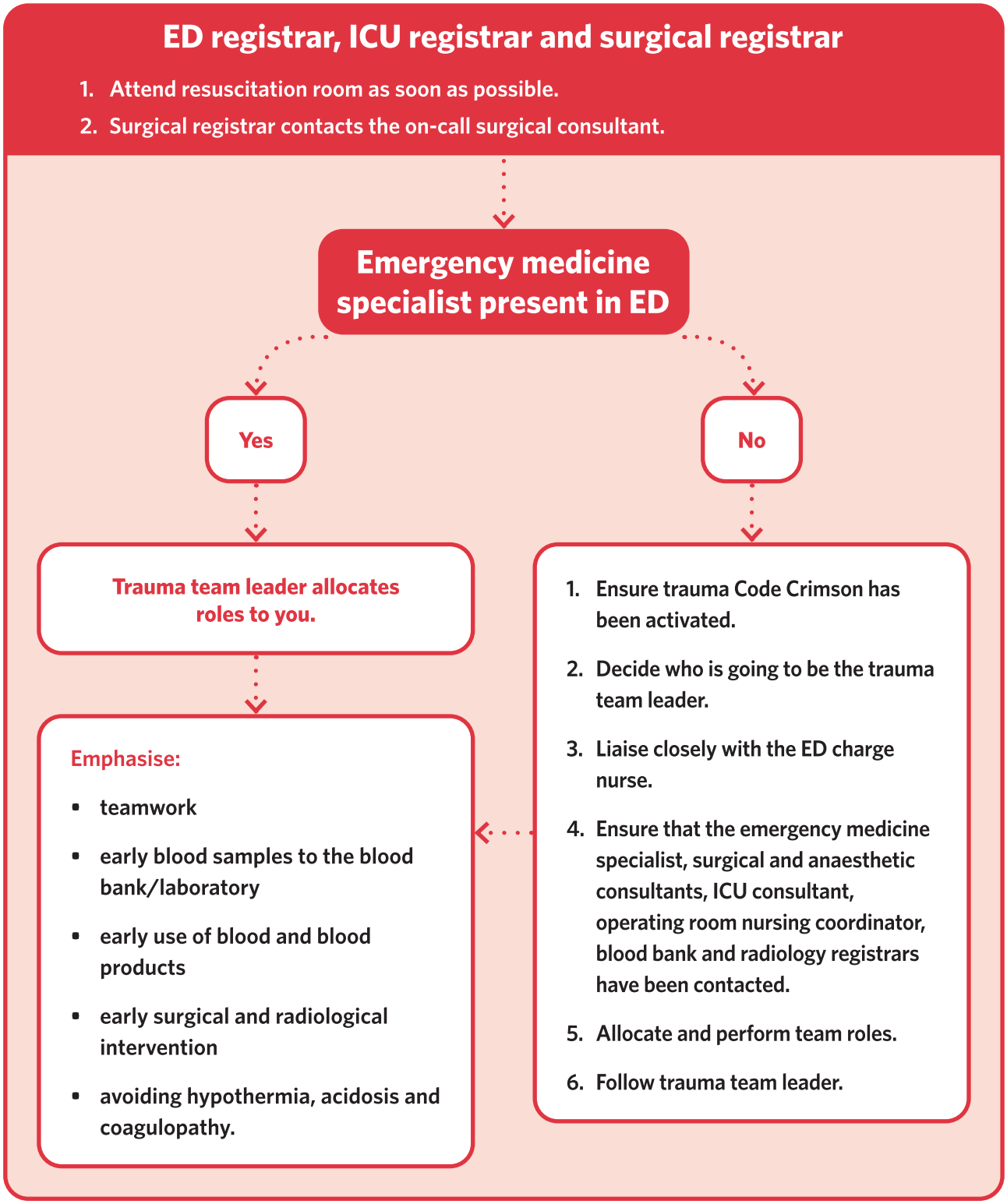
Trauma team leader and ED charge nurse

1. Ensure that Code Crimson has been activated and that the additional teams are contacted:
    a. anaesthetist
    b. nursing coordinator
    c. blood bank
    d. radiology registrar.
2. Check the on-call surgical registrar has contacted the on-call surgical consultant, stating only:

    Trauma Code Crimson in emergency department departing now or in X minutes
3. Allocate roles to the trauma team before the patient arrives and give a pre-arrival briefing. Everyone wears personal protection.
4. Set up resuscitation room appropriately.
    a. Rapid infuser is primed and ready for use.
    b. Ultrasound machine is at bedside.
    c. Pelvic binder is on trauma bed.
    d. Tranexamic acid is available.
    e. Blood products group O neg RBC and thawed plasma are available.
5. Resuscitate and manage as needed.
6. Liaise with inpatient specialty services as needed.

Note: ED = emergency department; RBC = red blood cell.

3. Emergency department registrar, intensive care unit registrar and surgical registrar



Note: ED = emergency department; ICU = intensive care unit.

4. Emergency medicine specialist

Emergency medicine specialist

1. Attend the trauma patient in the resuscitation room.
2. Along with the ED charge nurse ensure all additional teams have been contacted.
3. If you are the trauma team leader follow the action card for trauma team leader and ED charge nurse.
4. If you have come in from home and are not the trauma team leader:
   a. introduce yourself to the trauma team leader
   b. help with ongoing resuscitation and decision-making for this patient
   c. liaise closely with the trauma team leader, surgical and anaesthetic consultants to facilitate optimal management of the patient.
5. Key to optimal patient care and outcome is optimal teamwork.

Emphasise:

- teamwork
- early surgical and radiological intervention
- early use of blood and blood products
- avoiding hypothermia, acidosis and coagulopathy.

Note: ED = emergency department.

5. Senior surgeon

Senior surgeon

1. Attend the trauma patient in the resuscitation room.
2. Introduce yourself to the trauma team leader.
3. In conjunction with the trauma team leader:
   a. confirm surgical diagnosis to team
   b. indicate surgical action and urgency.
4. Key to optimal patient care and outcome is optimal teamwork.

Emphasise:

- teamwork
- early surgical and radiological intervention
- early use of blood and blood products
- avoiding hypothermia, acidosis and coagulopathy.

6. Anaesthetic consultant

Anaesthetic consultant

1. Attend the trauma patient in the resuscitation room.
2. Introduce yourself to the trauma team leader.
3. Assist with:
   a. airway management
   b. intravenous access
   c. resuscitation.
4. Expedite patient transfer to the operating room or the interventional radiology.
5. Key to optimal patient care and outcome is optimal teamwork.

Emphasise:

- teamwork
- early surgical and radiological intervention
- early use of blood and blood products
- avoiding hypothermia, acidosis and coagulopathy.

7. Radiology registrar

Radiology registrar

1. Liaise with CT medical radiation technologist to facilitate urgent trauma CT imaging.
   a. There may only be a very narrow window of opportunity to get CT imaging on these patients.
2. Contact the on-call interventional radiologist to let them know a trauma Code Crimson has been activated.
3. Communicate any imaging results early to the trauma team leader.
4. Communicate again with the trauma team leader if there are interpretive or management changes after interventional radiology imaging review.

Emphasise:

- teamwork
- early surgical and radiological intervention
- early use of blood and blood products
- avoiding hypothermia, acidosis and coagulopathy.

Note: CT = computerised tomography.

8. Blood bank

Blood bank

1. Send 2 units of O negative red cells and 2 units of thawed plasma to the resuscitation area.
2. Start to thaw the first box of the Code Crimson Massive Transfusion Protocol (MTP).
   a. Do not send the first box to the resuscitation room unless MTP is activated by the trauma team leader.
3. Facilitate early availability of blood and blood products as per Code Crimson MTP.

Emphasise:

- teamwork
- early surgical and radiological intervention
- early use of blood and blood products
- avoiding hypothermia, acidosis and coagulopathy.

Note: MTP = massive transfusion protocol.

9. Operating room nursing coordinator

Operating room nursing coordinator

1. Review procedures in operating rooms and facilitate early access as required.
2. Liaise closely with anaesthetic consultant/coordinator to facilitate staffing and access.

10. Emergency department health care assistant or orderly

Emergency department health care assistant or orderly

1. You are an integral part of the trauma team.
2. Deliver blood samples to blood bank/laboratory.
3. Retrieve blood and blood products for the blood bank.
4. Deliver the blood and blood products to the resuscitation room.
5. Facilitate transfers to radiology or operating room as requested.

Appendix B: Relevant critical bleeding bundle performance indicators

1. These structures are recommended for a hospital receiving trauma patients for Code Crimson or similar response.
    a. All hospitals should have a massive transfusion protocol to guide the management of a critically bleeding trauma patient.
    b. A multidisciplinary team should develop the protocol and the hospital or DHB transfusion committee should approve it.
    c. The protocol should consider the available resources at the institution.
    d. The protocol should be reviewed at a minimum every three years.
    e. The protocol should be called the 'Code Crimson Massive Transfusion Protocol' or similar.
    f. Participating team members should have access to formal training and drills to increase their awareness of and adherence to the Code Crimson MTP so they can deliver it more effectively.
    g. All team members should have ready access to the written Code Crimson MTP as a reference tool.
    h. The protocol must specify the team members required to respond when it is activated.
    i. The protocol should specify how the lead clinician at the bedside is designated.
    j. The protocol should specify the team member(s) designated to be responsible for blood component and sample transport.
    k. The laboratory must be notified of all Code Crimson MTP activations.
    l. All critical laboratory results and important coagulation parameters (haemoglobin, platelet count, INR and fibrinogen) must be communicated by phone to the clinical team as soon as they are available.
    m. The timing of protocol activation and termination must be recorded in the patient's chart.
    n. The collection and testing of the group and screen sample must be prioritised in the protocol to mitigate the impact on group O red blood cells (RBCs) and thawed plasma stocks.
    o. A critical haemorrhage trauma programme multidisciplinary committee should review Code Crimson MTP activations for quality assurance.
2. The following are recommendations for auditing patient care.
    a. All massively bleeding patients should have a temperature measured within 15 minutes of arrival or protocol activation, and then at a minimum of every 30 minutes (or continuously where available) until the protocol is terminated.
    b. All patients should receive interventions to prevent hypothermia and achieve normothermia (≥ 36° Celsius).
    c. All patients should receive warmed intravenous fluids, red blood cells and plasma to avoid hypothermia.
    d. RBCs should be delivered in a validated container to prevent wastage.
    e. Uncrossmatched RBCs should be available at the bedside within 10 minutes of MTP activation.

f. In bleeding patients who need RBC transfusion, uncrossmatched group O negative RBCs should be transfused until crossmatch compatible RBCs are available.

g. Pretransfusion bedside patient and product identification check must be performed before transfusion of any component to avoid mistransfusion.

3. Suggested quality metrics that should be tracked on all activations of the protocol are the:
   a. number of activations of Code Crimson pre-hospital with an ABC score greater than or equal to 2
   b. proportion of patients receiving TXA within 1 hour of protocol activation
   c. proportion of patients in whom RBC transfusion is initiated within 15 minutes of protocol activation
   d. proportion of patients achieving temperature ≥ 36° Celsius on termination of the protocol
   e. proportion of patients with appropriate activation (≥ 5 RBC units in first 24 hours, > 40 mL/kg per 24 hours of RBCs in paediatric patients) or before this level in patients dying due to haemorrhage within 24 hours
   f. proportion of patients that receive a ratio of RBC to plasma of 1:1 prior to definitive bleeding control
   g. proportion of patients without any blood component wastage (including plasma that is thawed and not used within the five-day limit on another patient)
   h. proportion of patients meeting pre-hospital activation criteria whose status is notified to the receiving emergency department
   i. proportion of patients meeting activation criteria on arrival at the emergency department who have Code Crimson activated within 10 minutes
   j. proportion of patients activated to Code Crimson who have a definitive bleeding management plan completed
   k. proportion of patients who begin movement from the emergency department to definitive bleeding control location within 30 minutes.

These suggested performance indicators have been drawn from work of the Ontario Regional Blood Coordinating Network.[4]

4 Callum JL, Yeh CH, Petrosoniak A, et al. 2019. A regional massive hemorrhage protocol developed through a modified Delphi technique. *CMAJ Open*. DOI: 10.9778/cmajo.20190042 (accessed 3 November 2020).

Appendix C: Core expert reference group

The core expert reference group (ERG) was formed in early 2020 and had six meetings throughout 2020, with developing this document a key focus.

Its terms of reference define its purpose as being:

> a 'safe' group that the project team can consult and debate with, in confidence. It will also be an 'expert' group and members have been appointed because their knowledge and skills are recognised in the sector (both locally and internationally). Finally, it will be a group that champions the project and its deliverables in the sector, both during their development and during their implementation.

The Health Quality & Safety Commission and the National Trauma Network would like to thank the core ERG members for their efforts and enthusiasm in guiding the work to improve trauma care for critically bleeding patients. The table below lists these members.

Name	Role	Organisation
Andy Swain	Medical director	Wellington Free Ambulance
Caroline Gunn	Consumer representative	N/A
Chris Jephcott	Anaesthetist	Waikato DHB
David Drower	Quality improvement advisor	Health Quality & Safety Commission
David Lang	Emergency medicine specialist	Nelson Marlborough DHB
David O'Byrne	Emergency medicine specialist	Hutt Valley DHB, Wellington Free Ambulance
Dominic Fleischer	Emergency medicine specialist	Canterbury DHB
Gabrielle Nicholson	Project manager	Health Quality & Safety Commission
Ian Civil	Clinical lead, National Trauma Network (vascular and trauma surgeon)	National Trauma Network
Jack Hill	Māori representative (anaesthetist)	Auckland DHB
James Moore	Intensivist	Capital & Coast DHB
Kerry Gunn (Chair)	Clinical lead, critical haemorrhage project (anaesthetist)	Health Quality & Safety Commission
Orla Fowden	Right Care advisor	St John Ambulance Service (South Island)
Paul McBride	Data scientist	Health Quality & Safety Commission

Name	Role	Organisation
Renate Donovan	Trauma nurse	Capital & Coast DHB
Richard Aickin	Paediatric emergency medicine specialist, Starship Children's Hospital and representative for the New Zealand Resuscitation Council	New Zealand Resuscitation Council
Richard Charlewood	Transfusion medicine specialist	New Zealand Blood Service
Sandy Ngov	Project coordinator	Health Quality & Safety Commission
Susan Mercer	Transfusion nurse specialist (intensive care unit)	New Zealand Blood Service
Tony Smith	Medical director	St John Ambulance Service

Appendix D: Wider expert reference group

Also crucial to the successful delivery of the critical haemorrhage project is the wider ERG, with which the project team consulted to 'sense check' deliverables and proposals before communicating them publicly.

The Health Quality & Safety Commission and the National Trauma Network would also like to thank the members of the wider ERG for their support of the core ERG and the project. The table below lists the wider ERG members.

Name	Role	Organisation
Andrew Holden	Head of interventional radiology, Auckland City Hospital	Auckland DHB
Angus Jennings	Orthopaedic surgeon	Nelson Marlborough DHB
Annemarie van der Slot-Verhoeven	Blood bank scientist	Wellington Blood Bank
Anthony Buddle	Trauma clinical lead, Southland Hospital	Southern DHB
Christopher Harmston	Surgeon	Northland DHB
Claire Hitchcock	Trauma coordinator	Nelson Marlborough DHB
Dean Bunbury	Anaesthetist/air retrieval	Paediatric anaesthetist at Counties Manukau DHB and pre-hospital retrieval medicine (PHRM) in Auckland
Emma Patrick	Anaesthetist	Chair Hospital Blood Transfusion Committee, Taranaki DHB
Fiona King	Transfusion nurse specialist	New Zealand Blood Service Wellington
Grant Christey	Surgeon	Waikato DHB
James Le Fevre	Emergency medicine specialist	Auckland Rescue Helicopter Trust
James McKay	Trauma surgeon	Canterbury DHB
Jim Faed	Transfusion medical specialist/ haematology	Southern DHB
Kaylene Henderson	Trauma team training	UniServices
Krishna Badami	Sponsor ANZ-MTR	New Zealand Blood Service
Laura Young	Haematologist	Auckland DHB
Mark Friedericksen	Emergency medicine specialist	Auckland DHB

Name	Role	Organisation
Michael Kalkoff	Intensivist	Northland DHB
Mike Hunter	Surgeon	Southern DHB
Murray Cox	Vascular surgeon	Taranaki DHB
Paul Blakemore	Emergency medicine specialist and pre-hospital physician	Bay of Plenty DHB, Auckland Rescue Helicopter Trust
Sarah Morley	Chief medical officer	New Zealand Blood Service
Scott Robinson	Anaesthetist	Waikato DHB
Tracey Clark	Blood bank team leader	New Zealand Blood Service

Appendix E: Acknowledgements

The Health Quality & Safety Commission and the National Trauma Network would like to specifically acknowledge the following individuals and organisations for sharing their expertise and resources:

- Dr Mark Friedericksen, emergency medicine specialist at Auckland DHB, for the Code Crimson templates for communication
- Dr James Le Fevre, for the Auckland Rescue Helicopter Trust 'Prehospital blood standard operating procedures' (SOPs)
- Auckland DHB for the use of the Adult and Paediatric MTP templates.

Te Hononga
Whētuki ā-Motu
National Trauma
Network

Health Quality & Safety
Commission New Zealand
Kupu Taurangi Hauora o Aotearoa