FROM VEIN TO VICTORIES: MASTERING EQUINE BLOOD TRANSFUSIONS IN THE FIELD

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Objectives

- Review of blood transfusion fundamental principles and indications (**adult horses**, foals, donkeys)
- Summary of practical tools, tips, and formulary for safe and efficient blood transfusion (in the field)

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Contents

- **Preparing for a blood transfusion**
  - When is a blood transfusion needed?
  - Blood donor selection
- **Performing a blood transfusion**
  - Transfusion kit
  - Blood collection
  - Blood processing and storage
  - Blood administration
- **Monitoring after a blood transfusion**
  - Transfusion effectiveness
  - Transfusion reactions
  - Management of the donor

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

In theory…

" Clinically significant decrease in oxygen tissue delivery due to reduced oxygen carrying capacity"

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

In practice…

*" **Clinically significant** decrease in oxygen tissue delivery due to reduced oxygen carrying capacity"*

- Blood loss > 30% **(> 12 liters for 1,100 pounds horse)**

AND/OR

- Visible clinical (and clinicopathological) signs

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

In practice…

*" Clinically significant **decrease in oxygen tissue delivery** due to reduced oxygen carrying capacity"*

Transfusion triggers = signs of hypoperfusion & tissue hypoxia

Clinical signs

- Tachycardia > 60 bpm
- Tachypnea > 30 brpm
- Pale mucous membranes
- CRT > 3 seconds
- Delayed jugular refill
- Lethargy, inappetence
- Cold extremities

Clinicopathological signs
(venous blood gas/pulse oximeter)

- Peripheral lactate > 4 mmol/L
- Azotemia (creatinine > 2 mg/dL)
- Metabolic acidosis (bicarbonate < 20 mmol/l)
- PvO_2 <30 mmHg
- Oxygen extraction ratio ($SpaO_2$ - $SpvO_2$/ $SpaO_2$) > 40-50%

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

In practice…

" Clinically significant decrease in oxygen tissue delivery ***due to reduced oxygen carrying capacity"***

- **Consider and treat (if possible) other concurrent causes of hypoperfusion/tissue hypoxia**
  - Concurrent respiratory disease (reduced oxygen absorption)
  - Concurrent cardiocirculatory disease (hypovolemia, SIRS, cardiac failure)
  - Inability to utilize oxygen (cyanide and carbon monoxide toxicity, smoke inhalation)
- **Evidence of anemia**
  - Sudden PCV drop (10%)
  - PCV < 20% within 12 hours
  - PCV < 12% for 1-2 days or longer
  - Hemoglobin < 5-7 g/dL

In equids:
- **Hemorrhage (+++ acute)**
- **Hemolysis**
- Bone marrow disease

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

Common scenarios in equine practice:

- Life threatening hemorrhage
- Acute hemorrhage/hemolysis
- Chronic anemia
- Planned surgery/procedure with high risk of hemorrhage

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

Common scenarios in equine practice:

- **Life threatening hemorrhage**
  - **Ex: Internal carotid, uterine artery ruptures**
- Acute hemorrhage/hemolysis
- Subacute-chronic anemia
- Planned surgery/procedure with high risk of hemorrhage

➡

- Known blood loss > 30-40% **(12-16 liters)**
- Signs of hemorrhagic/hypovolemic shock
  - Lethargy
  - Profuse sweating
  - HR>80 bpm
  - RR>40 brpm
  - Absent jugular refill
  - Pale mucous membranes
  - Non-detectable CRT
  - Cold extremities

TRANSFUSE!!!!

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

Common scenarios in equine practice:

- Life threatening hemorrhage
- **Acute hemorrhage/hemolysis**
  - **Ex: lacerations, ethmoidal hemorrhage, red maple toxicosis, (acute piroplasmosis)**
- Chronic anemia
- Planned surgery/procedure with high risk of hemorrhage

- Is there known blood loss (15-20%, 6-8 liters)?

AND/OR

- Is there acute anemia (PCV<20% within 12 hours, PCV suddenly dropped 10%)?
- Are transfusion triggers present?

*Correct concurrent causes of tissue hypoxia: **+++ IV fluid resuscitation,** (oxygen therapy)*

Treat primary condition (if possible): ex. stop hemorrhage

- Are transfusion triggers STILL present?

TRANSFUSE!!!!

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

Common scenarios in equine practice:

- Life threatening hemorrhage
- Acute hemorrhage/hemolysis
- **Chronic anemia**
  - **Ex: repeated intermittent hemorrhage, immune-mediated anemia, bone marrow neoplasia/aplasia**
- Planned surgery/procedure with high risk of hemorrhage

- Is there PCV<12% for more than 1-2 days?

AND/OR

- Are transfusion triggers present?
  - Clinical transfusion triggers (+++ inappetence)
  - PvO_2 <30 mmHg
  - Oxygen extraction ratio ($SpaO_2$ - $SpvO_2$/ $SpaO_2$) > 40-50%

TRANSFUSE!!!!

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Preparing for a blood transfusion

- **When is a blood transfusion needed?**

Common scenarios in equine practice:

- Life threatening hemorrhage
- Acute hemorrhage/hemolysis
- Chronic anemia
- **Planned surgery/procedure with high risk of hemorrhage**
  - **Ex: sinus surgery, lung biopsy**

Consider planning for **autologous blood transfusion**

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Preparing for a blood transfusion

- **Blood donor selection**
- Minimize negative impact on donor health
- Minimize negative impact on recipient health
- Minimize risk of blood incompatibility

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Preparing for a blood transfusion

- **Blood donor selection**
- **Minimize negative impact on donor health** ➡
  - Large size (>1,000 pounds at least)
  - Young adult (3-16 years old)
  - Good demeanor
  - Healthy
    - Physical exam
    - CBC, chemistry
    - Up to date in preventative care
  - PCV>35%, TS> 6 g/dL
- Minimize negative impact on recipient health
- Minimize risk of blood incompatibility

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Preparing for a blood transfusion

- **Blood donor selection**
- Minimize negative impact on donor health
  - Healthy
    - Physical exam
    - CBC, chemistry
    - Up to date in preventative care
- **Minimize negative impact on recipient health** ➡
  - Screened for blood-borne pathogens
    - EIA (negative Coggins test)
    - Hepatic viruses (Equine Hepatitis PCR panel, Cornell University)
    - Equine Viral Arteritis
    - Brucellosis
    - Glanders
    - Dourine
    - Anaplasmosis
    - Piroplasmosis
- Minimize risk of blood incompatibility

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Preparing for a blood transfusion

- **Blood donor selection**
  - Minimize negative impact on donor health
  - Minimize negative impact on recipient health
- **Minimize risk of blood incompatibility** → Choosing a "likely compatible" donor
  - Transfusion reactions
  - Transfusion effectiveness
  - Crossmatch

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Choosing a "likely compatible" donor* … IN THEORY
- Blood types
  - No universal donor
  - Aa, Qa highly immunogenic
- Alloantibodies
  - Acquired
  - Natural
    - Up to 10% anti-Ca, anti-Aa

Blood Group Systems, Factors, and Alleles of the Horse Recognized by the International Society for Animal Genetics

System	Factors	Recognized Alleles
A	$a,^a$ $b,^a$ c, d, e, f, g	Aa, Aadf, Aadg, Aabdf, Aabdg, Ab, Abc, Abce, Abc, Ac, Ace, Ae, A–
C	n	Ca, C–
D	a, $b,^1$ $c,^3$ d, e, f, $g,^4$ h, i, k, l, m, n, o, p, q, r	Da, Dadlnr, Dadlr, Dbenq, Dcefgmq, Dcegimnq, Dcfglm, Dcfmqr, Dcgm, Dcilmp, Dcgmq, Dcgmqr, Ddfeklqr, Ddlno, Ddelnq, Ddelq, Ddflkr, Ddghmp, Ddghnoq, Ddghmqr, Ddlq, Ddlnq, Ddlnqr, Ddlqr, Ddno, Dq,(D–)
K	a	Ka, K–
P	$a,^b$ b, c, d	Pa, Pac Pacd, Pad, Pb, Pbd, Pd, P–
Q	$a,^b$ $b,^2$	Qa, Qab, Qabc, Qac, Qb, Qbc, Qc, Q–
U	a^3	Ua, U–

*Most common factors involved in neonatal isoerythrolysis (NI).
†Previously reported to cause NI in at least one case.
From Cothran G. Personal communication, University of Kentucky, Lexington, Ky., 1996.

From: Smith, Large Animal Internal Medicine, 6th edition

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Choosing a "likely compatible" donor* … IN PRACTICE
- Blood types
  - No universal donor
  - Aa, Qa highly immunogenic
  - → Blood typing: Aa, Qa, Ca negative
- Alloantibodies
  - Acquired
    - → Screen for alloantibodies yearly
  - Natural
    - Up to 10% anti-Ca, anti-Aa
    - → Screen for alloantibodies

Journal of Veterinary Internal Medicine

Standard Article

Comparison of Tube, Gel, and Immunochromatographic Strip Methods for Evaluation of Blood Transfusion Compatibility in Horses

D. Lunby, S.D. Owen, O. Sellerstedt, R. Nelas-Walmo, and U. Gigr

https://www.alvedia.com/quick-test-bt-equine/

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Choosing a "likely compatible" donor* … IN PRACTICE

- Blood types
  - No universal donor
  - Aa, Qa highly immunogenic

  → Blood typing: Aa Qa negative
  - Same breed of recipient
  - Quarter Horse (99% Qa -), Saddlebred
- Alloantibodies
  - Acquired

  → Screen for alloantibodies
  - Avoid mares, prefer geldings
  - Avoid horses with previous known exposure heterologous blood products
  - Natural
    - Up to 10% anti-Ca, anti-Aa

  → Screen for alloantibodies
  - Avoid Thoroughbreds (85% Qa +)
  - Be careful when transfusing a Thoroughbred

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Preparing for a blood transfusion

- **Blood donor selection**

- Minimize negative impact on donor health
- Minimize negative impact on recipient health

- **Minimize risk of blood incompatibility** →
  - Transfusion reactions
  - Transfusion effectiveness

  - Choosing a "likely compatible" donor
  - Crossmatch

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Crossmatch … theory*

Type of incompatibility

- Major *(makes the transfusion useless)* → **Clinically significant!!!**
  - Donor RBC + recipient serum
- Minor
  - Donor serum + recipient RBC

Type of reaction

- Agglutination
  - Macroagglutination → **Field cross match (grossly visible!)**
  - Microagglutination → Only laboratory crossmatch (microscopic examination)
- Hemolysis → Only laboratory crossmatch (add source of complement)
- Both

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Crossmatch … in the field*
  - "Standard" and "quick field" cross matching
    - Centrifugation or gravity sedimentation
    - ONLY agglutination
  - Gel Test Equine CrossMatch® (Alvedia Veterinary Diagnostics)
    - Centrifugation
    - ONLY agglutination
    - Similar performances to laboratory crossmatch

https://www.alvedia.com/gel_test_xm_equine/


STANDARD ARTICLE

Journal of Veterinary Internal Medicine ACVIM

Agreement of stall-side and laboratory major crossmatch tests with the reference standard method in horses

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Preparing for a blood transfusion

- **Blood donor selection – minimize risk of blood incompatibility**
- *Crossmatch … interpretation*
  - Positive agglutination at major crossmatch ➡ Transfusion reaction LIKELY to occur and likely to be CLINICALLY SIGNIFICANT
  - Negative crossmatch ➡ Possible false negatives
    - Hemolysis without agglutination
    - Natural alloantibodies in low titers
  - Crossmatch performances affected by factors (and their prevalence, ex. breed)

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Preparing for a blood transfusion

- **Blood donor selection – FOALS**
- Neonatal isoerythrolysis (NI), (1% foals)
  - Dam (Aa-/Qa-) with Aa/Qa alloantibodies (++ multiparous)
  - Sire (Aa+/Qa+)

  ➡ Foal (Aa+/Qa+) + Maternal colostrum (Aa/Qa) alloantibodies ➡ Hemolysis
- *IF PREGNANT MARE HAS KNOWN RISK…*
  - Screen for alloantibodies/crossmatch with sire (within 30 days foaling)
  - Avoid foal nursing for 24 hours/hyperimmune commercial plasma
  - Jaundiced foal agglutination test (colostrum + foal RBC)
- *IF NI IS HAPPENING AND TRANSFUSION IS NEEDED*
  - Ideally: use washed maternal RBCs
  - If not possible: Aa-/Qa- donor screened for alloantibodies + crossmatch

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Preparing for a blood transfusion

- **Blood donor selection – DONKEY AND MULES**
- Donkey Factor
  - RBC antigen
  - Donkeys and mules
  - Very immunogenic
- Additional implications:
  - Mule foals: high incidence (10%) NI
  - Care when transfusing mules/donkeys with equine plasma

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

- Blood tubes (EDTA, serum)
- Syringes/needles
- Pipettes
- NaCl 0.9%
- Slides
- (Centrifuge)
- Stall side commercial blood typing/crossmatch kits

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

- CLOSED KIT (commercially available)
  - Bags (up to 4 liters)/(Bottles)
  - Dry/with pre-measured anticoagulants
- OPEN KIT (“home-made”)
  - Empty IV fluid bags
  - Large bore IV catheter (10-14 Ga)
  - Male-male adapting IV line
  - Needle
- Hemostatic clamps

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

Anticoagulant – preservative	Storage/ Viability
Tri sodium citrate	Rapid deterioration, only 50% cells viable after 1 week.
Heparin	Rapid deterioration. Added disadvantage of being progressively neutralized by plasma. Therefore, most unsuitable for storage.
ACD-A	Storage/viability for 21 days, 24 hrs survival 77%, DPG level better maintained maximum for 1 week
CPD	Storage/viability for 28 days. 24 hrs survival 80%, DPG level better maintained for 10-14 days because of the favourable effect of higher pH.
CPDA-1/2	Storage/viability 35 days - improved storage due to adenine which maintains high ATP level in the RBC

Preservative-free

With storage preservatives

- Preservative free ok for "immediate" transfusion
  - Preferably avoid heparin

Comparison of 4 Blood Storage Methods in a Protocol for Equine Pre-operative Autologous Donation

MARGARET C. MUDGE, DVM, MELINDA H. MACDONALD, DVM, PhD, Diplomate ACVS, PhD, SEAN D. OWENS, DVM, and FERN TABLIN, PhD, DSc

- Storage preservatives for autologous blood transfusion
  - **BEST** : commercial 450 mL plastic bag with premeasured CPDA-1

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

Anticoagulant	Proportion anticoagulant/blood	Volume anticoagulant/ 1L bag
Citrate anticoagulants	1/7	140-150 mL
Heparin	1 (unit):1 mL	1000 Units

- SHELF-LIFE
  - Three years
  - Protect from light
  - Temperatures: 59-86 F

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

- Coolers/insulated containers
- Ice-packs

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
    - IV catheter
    - Filtered IV line (at least 2 or 3)
  - Transfusion monitoring

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

Blood Transfusion Sheet

Recipient information

Name/Case n:	**Signalment:** [Age, sex, breed]
Bodyweight (kg):	**Blood volume (liters):** [BW (kg) X 0.08]
Estimated blood loss (liters):	**Previous blood transfusion (Y/N):**
Blood type:	**PCV/TS (%/g/dL):**
Comments/Other relevant information:	

Donor information

Name/Case n:	**Signalment:** [Age, sex, breed]
Bodyweight (kg):	**Blood volume (liters):** [BW (kg) X 0.08]
Max blood for collection (liters): [Blood Volume (liters) x 0.2] **Volume requiring IV fluids (liters):** [Blood Volume (liters) x 0.2]	**Previous blood transfusion (Y/N):** **Previous foaling: (Y/N):**
Health check: - Physical Exam: Y/N - CBC: Y/N - Chemistry: Y/N - Vaccinations: Y/N - Deworming: Y/N - Coggins: Y/N - Hepatic viruses PCR: Y/N - Others (specify) ***Report relevant results/comments below***	**PCV/TS (%/g/dL):** **Pre-transfusion:** **12-hour post-transfusion:** **Blood type:** **Alloantibody screening (results/date):**
Comments/Other relevant information	

Crossmatch results

Major (RBC donor + serum recipient):

- ☐ NEGATIVE
- ☐ POSITIVE
  - Agglutination Y/N: ☐1 ☐2 ☐3 ☐4
  - Hemolysis Y/N

Minor (RBC recipient + serum donor):

- ☐ NEGATIVE
- ☐ POSITIVE
  - Agglutination Y/N: ☐1 ☐2 ☐3 ☐4
  - Hemolysis Y/N

Transfusion calculations

Transfusion volume

☐ USE BLOOD LOSS: replace 25-50% of the estimated blood lost.

0.25 x estimated blood loss = liters

0.50 x estimated blood loss = liters

☐ USE PCV FORMULA:

[(Desired PCV recipient – Actual PCV recipient)/Donor PCV] x BW (kg) x 0.08 l/kg

= liters

Max volume that can be collected (see donor information):

Volume requiring IV fluid replacement in the donor:

Anticoagulants (if dry bags are used)

Volume bag (mL):	Number of bags:	Type of anticoagulant:
Volume anticoagulant/each bag (14 ml/100 ml blood):		

Transfusion sheet
- Recipient/donor information
- Volume calculations
- Monitored parameters
- Emergency drugs and dosages

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Performing a blood transfusion

- **Transfusion kit/box**
  - Field blood typing/crossmatch
  - Blood collection kit & anticoagulant
  - Blood (short-term) storage
  - Blood administration
  - Transfusion monitoring

Blood collection

Volume collected:	**IV fluid replacement** Y/N **Volume & Type fluids:**
Comments/Complications:	

Transfusion administration and monitoring

Date: **Time started:** **Time finished:**	**Type:** ☐ Whole blood ☐ Packed RBCs ☐ Washed RBCs ☐ Plasma ☐ Other
Volume administered:	
Pre-PCV/TS:	**Post- PCV/TS:**
Comments/Complications:	

General Rule:

Start transfusion rate at 1 ml/kg (approximately 1 dr/sec for a 1100 pounds horse), TPR q 5 min for first 20 min, then—if no evidence of reaction—increase the drip rate up to 15-20 ml/kg/hour (open drip for a 1100 pounds horse) and TPR q 10-15 min for the remainder of the transfusion.

TIME	DRIP RATE	Temp	HR	RR	Fasciculations, Hives, etc.

Emergency drugs

Dexamethasone (2 mg/mL)

0.05-0.1 mg/kg = mg /2 = mL

Epinephrine (1:1000)

0.01-0.02 mL/kg = mL

Transfusion sheet
- Recipient/donor information
- Volume calculations
- Monitored parameters
- Emergency drugs and dosages

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Performing a blood transfusion

- **Blood collection**
  - Volume calculation
  - Collection procedure

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Performing a blood transfusion

- **Blood collection**
  - Volume calculation
  - Collection procedure

General rules:

- NEVER MORE THAN 20% of DONOR BLOOD VOLUME (8 liters in 1100 pounds horse)
- IF MORE THAN 15% OF DONOR BLOOD VOLUME COLLECTED: REPLACE WITH IV FLUIDS

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Performing a blood transfusion

- **Blood collection**
  - Volume calculation
  - Collection procedure

- Acute hemorrhage: *(PCV does not reflect real blood loss…)*

  Replace 25-50% of the estimated blood lost

- Chronic anemia

  Volume (liters) =

  [(Desired PCV – Actual PCV)/Donor PCV] x 0.08L/kg X bodyweight (kg)

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Performing a blood transfusion

- **Blood collection**
  - Volume calculation
  - Collection procedure
    - IV catheter placed aseptically, and directed rostrally
    - Connect the male-male line aseptically (open systems)
    - One person gently mixing the blood while collecting by gravity
    - Clamp bag once filled

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Performing a blood transfusion

- **Blood collection**
  - Autologous blood transfusion
    - Advantages
      - Lower risk of reactions
      - Longer hatflife transfused RBCs
    - Planned surgery/procedure with high risk of hemorrhage
      - Blood collection 2-3 weeks prior to surgery
    - Body cavitary blood effusion (hemothorax, hemoabdomen)
      - Teat-cannula + filtered line (change q2hrs)
      - Less anticoagulant needed
      - NO IF SEPSIS/NEOPLASIA SUSPECTED!!!!

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Performing a blood transfusion

- **Blood processing and storage**
  - Processing
    - Whole blood
    - Separation (sedimentation/centrifugation)
      - Plasma
      - Packed RBCs → Washed RBC
        Wash 2X
        (Centrifugation)

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Performing a blood transfusion

- **Blood processing and storage**
  - Processing

Product	Clinical benefit	Indications	Limitations
Whole blood	*Volume* *Oxygen carrying capacity* *Oncotic pressure and proteins* *Clotting factors & platelets*	*Blood loss*	*Transfusion reactions, volume overload (foals)*
Plasma	*Volume (+/-)* *Oncotic pressure and proteins* *Clotting factors*	*SIRS, protein losing diseases, failure of passive transfer (foals)*	*Transfusion reactions*
Packed RBCs	*Oxygen carrying capacity*	*Euvolemic anemia (i.e. hemolysis, bone marrow neoplasia)*	Transfusion reactions, dilution required for administration
Washed RBCs	*Oxygen carrying capacity*	*Neonatal isoerythrolysis*	*Dilution required for administration, required centrifugation*

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Performing a blood transfusion

- **Blood processing and storage**
  - Storage
    - Negative effects
      - Risk of bacterial growth (+++ open systems)
      - Decreased RBC viability, increased lactate, potassium
      - Decreased cross match compatibility (1 week)
      - Increased inflammatory transfusion reactions (leukoreduction)

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Performing a blood transfusion

- **Blood processing and storage**
  - Storage
    - Room temperature – whole heterologous blood
      - Administer **within 4 hours** (++ open systems)

    } **MOST COMMON IN THE FIELD!**

    - Blood bank refrigerator (4°C, 39 F)
      - Heterologous blood: administer **within 24 hours**
      - Autologous blood (with CPDA-1): **max storage 2-3 weeks**

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Performing a blood transfusion

- **Blood administration**
  - Administration
    - Aseptic IV catheter placement
    - Warm up bags to room/(body) temperature
    - Filtered IV line (replaced every 3-4 liters)
  - Rate
    - 1 ml/kg first 20 minutes
      - 1 drop/sec 1,100 lbs horse
      - 1 drop/2-3 sec foal
    - 15-20 ml/kg/hour (< 4 hours total)
      - Fully open drip 1,100 lbs horse
      - 2 drop/sec foal
  - Monitoring (transfusion sheet)
    - Baseline TPR
    - TPR every 5 min (first 20 min)
    - TPR every 15 min (after 20 min)

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Monitoring after a blood transfusion

- **Transfusion effectiveness**
- Improvement in clinical and clinicopathological perfusion variables
  - Post-hemorrhage anemia: 58% horses show improvement in HR, RR but not PCV
  - PCV increase takes time (2-3 weeks at least, 10-28 days erythropoiesis)
- Effectiveness depends on transfused RBCs halflife (fresh whole blood)
  - Autologous blood: 45 days
  - Heterologous blood (compatible crossmatch): 20-35 days
  - Heterologous blood (not compatible crossmatch): 3-5 days

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Monitoring after a blood transfusion

- **Transfusion reactions**

TABLE 1: Timing and mechanisms of common types of adverse reactions and complications associated with whole blood transfusion (Leo and Pedal 2010; Tocci 2010)

	Immune-mediated	Nonimmune-mediated
Immediate (Minutes-hours)	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)	• Transfusion-associated sepsis • Transfusion-associated circulatory overload • Haemolysis (due to mishandling) • Metabolic and haemostatic complications with large volume transfusion ○ hypocalcaemia due to citrate toxicity ○ hyperkalaemia with RBC lysis ○ hypothermia if cold blood is administered ○ coagulopathies due to excess anticoagulant administration
Delayed	• Haemolysis	• Transmission of other blood-borne infections • Haemosiderosis, with repeat or large volume transfusions

- Incidence 16% in equine practice
- Not always predicted by crossmatch/compatibility EVEN IF IMMUNE MEDIATED

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Monitoring after a blood transfusion

- **Transfusion reactions**

TABLE 1: Timing and mechanisms of common types of adverse reactions and complications associated with whole blood transfusion (Leo and Pedal 2010; Tocci 2010)

	Immune-mediated	Nonimmune-mediated
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Delayed	• Haemolysis	• Transmission of other blood-borne infections • Haemosiderosis, with repeat or large volume transfusions

(Minutes-hours)

- Incidence 16% in equine practice
- Not always predicted by crossmatch/compatibility EVEN IF IMMUNE MEDIATED

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Monitoring after a blood transfusion

- **Transfusion reactions**

TABLE 1: Timing and mechanisms of common types of adverse reactions and complications associated with whole blood transfusion (Leo and Pedal 2010; Tocci 2010)

	Immune-mediated	Nonimmune-mediated
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)	• Transfusion-associated sepsis • Transfusion-associated circulatory overload • Haemolysis (due to mishandling) • Metabolic and haemostatic complications with large volume transfusion ○ hypocalcaemia due to citrate toxicity ○ hyperkalaemia with RBC lysis ○ hypothermia if cold blood is administered ○ coagulopathies due to excess anticoagulant administration
Delayed	• Haemolysis	• Transmission of other blood-borne infections • Haemosiderosis, with repeat or large volume transfusions

(Days)

- Incidence 16% in equine practice
- Not always predicted by crossmatch/compatibility EVEN IF IMMUNE MEDIATED

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Monitoring after a blood transfusion

- **Transfusion reactions**

	Immune-mediated
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)
Delayed	• Haemolysis

Most common in equine practice

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Monitoring after a blood transfusion

- **Transfusion reactions**

	Immune-mediated
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)
Delayed	• Haemolysis

TYPE 2 hypersensitivity reaction:

- Fever
- Intravascular/Extravascular hemolysis
- Icterus

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Monitoring after a blood transfusion

- **Transfusion reactions**

	Immune-mediated	
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)	→ +++ acquired alloantibodies, predicted by MAJOR CROSSMATCH
Delayed	• Haemolysis	→ +++ low titer natural antibodies, usually crossmatch is not sensitive enough!

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Monitoring after a blood transfusion

- **Transfusion reactions**

	Immune-mediated	
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)	→ • Common, +++ fever • NOT predicted by crossmatch • Increased risk with storage • Minimized by leukoreduction
Delayed	• Haemolysis	

Cytokines, inflammatory mediators, type 2 hypersensitivity against donor WBC

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Monitoring after a blood transfusion

- **Transfusion reactions**

Immune-mediated	
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)
Delayed	• Haemolysis

TYPE 1 HYPERSENSITIVITY (IgE-mast cells)

- Triggered by plasma proteins
- Not predicted by crossmatch

(… can happen also with plasma transfusion)

- Local allergy
  - Urticaria, pruritus, rhinitis
- Anaphylaxis (respiratory + GI)
  - Respiratory distress, colic, diarrhea
  - Shock, sudden collapse

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Monitoring after a blood transfusion

- **Transfusion reactions**

Immune-mediated	
Immediate	• Haemolysis • Febrile nonhaemolytic reactions • Allergic reactions • Post transfusion purpura (alloantibody-mediated thrombocytopaenia) • Transfusion-related acute lung injury (TRALI)
Delayed	• Haemolysis

TYPE 1 HYPERSENSITIVITY (IgE-mast cells)

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  - Respiratory distress, colic, diarrhea
  - Shock, sudden collapse

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Monitoring after a blood transfusion

- **Transfusion reactions**

Nonimmune-mediated	
• Transfusion-associated sepsis	Contamination during collection, prolonged storage
• Transfusion-associated circulatory overload	
• Haemolysis (due to mishandling)	
• Metabolic and haemostatic complications with large volume transfusion ○ hypocalcaemia due to citrate toxicity ○ hyperkalaemia with RBC lysis ○ hypothermia if cold blood is administered ○ coagulopathies due to excess anticoagulant administration	
• Transmisison of other blood-borne infections	EIA, Serum hepatitis (Theiler disease)
• Haemosiderosis. with repeat or large volume transfusions	

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Monitoring after a blood transfusion

- **Transfusion reactions**

Nonimmune-mediated
• Transfusion-associated sepsis
• Transfusion-associated circulatory overload
• Haemolysis (due to mishandling)
• Metabolic and haemostatic complications with large volume transfusion
○ hypocalcaemia due to citrate toxicity
○ hyperkalaemia with RBC lysis
○ hypothermia if cold blood is administered
○ coagulopathies due to excess anticoagulant administration
• Transmisison of other blood-borne infections
• Haemosiderosis, with repeat or large volume transfusions

FOALS!!!!

>4 liters of blood, 20 times higher risk of liver failure

Monitoring after a blood transfusion

- **Transfusion reactions**

Nonimmune-mediated
• Transfusion-associated sepsis
• Transfusion-associated circulatory overload
• Haemolysis (due to mishandling)
• Metabolic and haemostatic complications with large volume transfusion
○ hypocalcaemia due to citrate toxicity
○ hyperkalaemia with RBC lysis
○ hypothermia if cold blood is administered
○ coagulopathies due to excess anticoagulant administration
• Transmisison of other blood-borne infections
• Haemosiderosis, with repeat or large volume transfusions

- Inappropriate handling/storage

Monitoring after a blood transfusion

- **Transfusion reactions**

Nonimmune-mediated
• Transfusion-associated sepsis
• Transfusion-associated circulatory overload
• Haemolysis (due to mishandling)
• Metabolic and haemostatic complications with large volume transfusion
○ hypocalcaemia due to citrate toxicity
○ hyperkalaemia with RBC lysis
○ hypothermia if cold blood is administered
○ coagulopathies due to excess anticoagulant administration
• Transmisison of other blood-borne infections
• Haemosiderosis, with repeat or large volume transfusions

- Side effects of anticoagulants

Monitoring after a blood transfusion

- **Transfusion reactions**
  - If reaction occurs while administering transfusion
    - Don't panic!
    - STOP TRANSFUSION
    - Monitor closely/provide supportive care
    - Administer ER drugs, if needed (pre-calculated!)

Emergency drugs

Dexamethasone (2 mg/mL)

0.05-0.1 mg/kg = mg /2 = mL

Epinephrine (1:1000)

0.01-0.02 mL/kg = mL

  - Don't forget DELAYED and NON-IMMUNOMEDIATE reactions
    - Re-evaluation within 24 hours (PE, PCV, TS, blood gas)
    - Re-evaluation after 3-5 days (PE, PCV, TS)

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Monitoring after a blood transfusion

- **Clinical case**

9 year-old Thoroughbred gelding
Repeated severe hemorrhage hind fetlock wound (in 48 hours)

Severe subacute anemia (PCV=10%), azotemia
Persistent tachycardia (66 bpm), lethargy, weakness

Blood transfusion

Donor blood type Ab Ca Ka Ua
Compatible crossmatch (major & minor)
Theoretical volume (PCV formula): 12 liters

8 liters administered overnight (15 hours)

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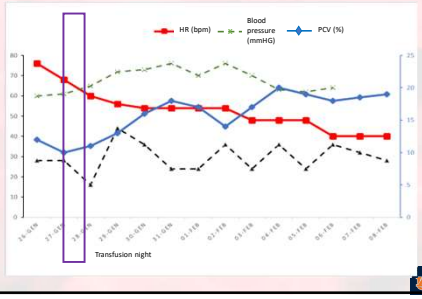
Monitoring after a blood transfusion

- **Clinical case**



Transfusion was effective

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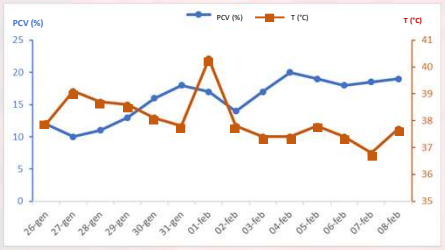
Monitoring after a blood transfusion

- Clinical case



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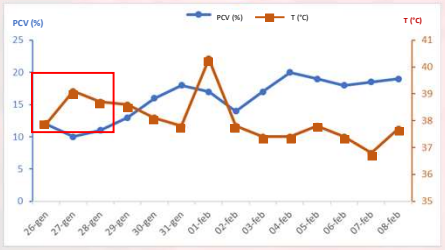
Monitoring after a blood transfusion

- Clinical case



Time	T° (F)
Before transfusion	100.5
1 h	100.9
5 h	101.3
7 h	101.8
11h	102.3
13h	101.6
15h	101.4
2 h after the end	101.6
6 h after the end	100.9
10h after the end	100.5

Febrile non-hemolytic transfusion reaction

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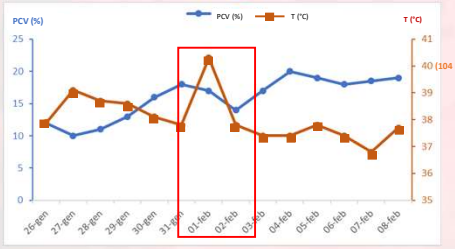
Monitoring after a blood transfusion

- Clinical case



Febrile delayed hemolytic transfusion reaction

Donor blood type: Ab **Ca** Ka Ua

Recipient: Thoroughbred

Natural low titer anti-Ca alloantibodies??

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Monitoring after a blood transfusion

- **Management of the donor**
  - Unused blood can be re-administered to the donor (if properly stored)
  - Ensure availability of feed/water:
    - Feed 1-3 pounds complete feed & free choice hay
    - Free choice, clean water
  - Monitor during following 24 hours
    - PE, PCV, TS
    - Catheter site

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Take home messages

- Clinical more than clinicopathological parameters to define if transfusion is necessary and useful
- Large, healthy gelding, same breed of the recipient, EIA negative is best ER donor
- Crossmatch!!!!(Field crossmatch better than nothing)
- Have a "ready to go" transfusion kit, a checklist, and calculations/procedure/transfusion sheet in the truck/clinic (see proceedings)
- Monitor the recipient until 5-7 days after transfusion
- Don't forget the donor!

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FORMULARY – EQUINE TRANSFUSIONS

Is transfusion necessary?

Normal horse blood volume (liters): 8% bodyweight (kg)

- Adult horse (approx. 1100 lbs, 500 kg): 40 liters
- Foal (approx. 110 lbs, 50 kg): 4 liters

Transfusion triggers

- Blood loss >30% (12 liters in 1100 lbs horse)
- Clinical parameters
- Clinicopathological parameters

Clinical			**Clinicopathological**	
Parameter	Trigger	Shock	Parameter	Trigger
HR (bpm)	>60	>80	Peripheral lactate (mmol/l)	>4
RR (brpm)	>30	>40	Creatinine (mg/dL)	>2
CRT (sec)	>3	absent	Bicarbonate HCO3- (mmol/l)	<20
Mucous membranes	Pale	Pale	PvO2 (mmHg)	<30
Jugular refill	Delayed	absent	Oxygen Extraction Ratio (%)*	>40-50
Extremities	Cold	Cold	*($SpaO_2$ - $SpvO_2$/ $SpaO_2$)	
Attitude	Lethargy Inappetence	Obtunded Sweating		

Anemia thresholds:

- Acute
  - Known blood loss 15-20% of blood volume (6-8 liters, 1100 lbs horse)
  - PCV < 20% in less than 12 hours
  - Sudden PCV drop of 10%
- Subacute/Chronic
  - PCV <12% for more than 1-2 days

Blood donor selection

Laboratory resources

- Hepatitis Viruses PCR screening (Cornell University)
  - https://app.vet.cornell.edu/ahdc-portal/test-fee
  - Look for "Equine Hepatitis Virus PCR Panel 2 | (EQHEPPCRPNL2)"

- Blood typing and alloantibodies screening

Box 1
Equine blood typing laboratories

Central Laboratory Receiving

Room 1033, Veterinary Medical Teaching Hospital

One Garrod Drive

University of California, Davis

Davis, CA 95616

Phone: 530-752-8684

http://www.vetmed.ucdavis.edu/vmth/small_animal/laboratory/local-assets/pdfs/UC_Davis_VMTH_EQUINE_BLOOD_TYPING-NI_Submission_Form.pdf

University of Kentucky

Animal Genetic Testing & Research Laboratory

108 Gluck Equine Research Center

Lexington, KY 40546-0000

Phone: 859-218-1212

http://www2.ca.uky.edu/gluck/AGTRL.asp

Rood and Riddle Veterinary Laboratory

2150 Georgetown Road

Lexington, KY 40511

Phone: 859-233-0331

http://www.roodandriddle.com/laboratory.html

Hagyard Equine Medical Institute

4250 Iron Works Pike

Lexington, KY 40511-8412

Phone: 859-259-3685

http://www.hagyard.com/Hagyard-Laboratory.html

- Rapid stall side commercial Ca blood typing kit
  - https://www.alvedia.com/quick-test-bt-equine/

- Stall side commercial crossmatch kit
  - https://www.alvedia.com/gel_test_xm_equine/

Crossmatch procedures

Standard crossmatch

1. Collect an EDTA and red top (clot tube) blood sample from both donor and recipient.
2. Centrifuge the EDTA and clot tubes from both donor and recipient. Remove the plasma from both EDTA tubes and save the pRBCs. Extract and save the serum from both clot tubes.
3. For a major crossmatch, take 1-2 drops of donor pRBCs (EDTA tube) and wash several times with sterile saline.
    1. Add 3-4 drops of sterile saline to the pRBCs, centrifuge, and decant the saline. Repeat 3 times.
4. After the third wash, add 10-20 drops of saline to the washed RBCs to give a 2-4% suspension.
5. Add 2 drops of recipient serum (clot tube) to 1 drop 2-4% donor RBC solution.
6. For minor cross-match: repeat steps 3-5 with recipient RBCs and donor serum.
7. Include negative controls (donor serum and donor washed RBCs, recipient serum and recipient washed RBCs).
8. Incubate all reactions for 20 minutes at 37°C.
9. Centrifuge for 15 seconds and evaluate for macroscopic and microscopic agglutination or hemolysis (rarely seen without adding complement).

Agglutination is scored 0-4.

0. No clumps seen
1. 3-5 small microscopic clumps
2. Multiple small and large microscopic clumps, but individual cell still seen
3. Many large and small microscopic clumps
4. Clumps seen macroscopically

Saline dilution can be used to distinguish Rouleaux formations from agglutination. When assessing for hemolysins, rabbit complement is added to each mixture of washed RBC suspension and serum. The major, minor, and 2 negative controls are agitated on a vibrating plate mixer. Hemolysis is read at 30 minutes and again at 3 hours and is graded 1-4. This is only done by select veterinary clinical pathology laboratories (see Laboratory Resources).

1. Partial hemolysis
2. Intermediate hemolysis
3. Strong, almost complete hemolysis
4. Complete hemolysis[29]

Quick Field Cross-match

1. Collect EDTA and red top (clot tube) blood samples from both donor and recipient.
2. Gravity-sediment or centrifuge (preferred) EDTA tubes and remove plasma to give pRBCs.
3. Combine 1 drop of donor pRBCs to 2 drops of recipient serum (centrifuged) or plasma (gravity separated) for a major cross-match, or vice versa for a minor cross-match (recipient RBCs and donor plasma or serum).
4. Evaluate for macroscopic agglutination.

Jaundiced foal agglutination test

1. Do not allow the neonate to nurse immediately after foaling. Collect colostrum.
2. Collect an EDTA blood sample from the foal.
3. Add 1 ml of saline to 6 test tubes.
4. Add 1 ml of colostrum to 1 of the 6 saline tubes. Label this tube "1:2 Dilution" and mix.
5. Take 1 ml of the "1:2 Dilution" mixture and add it to the second saline tube. Label this tube "1:4 Dilution" and mix. Repeat for all 6 tubes. There should be 1:2, 1:4, 1:8, 1:16, and 1:32 dilutions produced.
6. Add 1 drop of the foal's whole blood to each tube and mix. Centrifuge for 2-3 minutes.
7. Remove the supernatant of the tubes. Macroscopically and microscopically observe for agglutination.

If a there is any agglutination, the mare's RBC should be tested as a control. A positive result at a dilution of 1:16 or higher is considered significant; the foal should not be allowed to consume the mare's colostrum, and plasma or donor colostrum should be given. This test does not allow for detection of hemolytic and non-agglutinating antibodies; however, it is well-correlated with standard hemolysis assays.

Blood transfusion kit – checklist

- ☐ COOLER/INSULATED CONTAINER (LIGHT PROTECTED)
- ☐ ICE-PACKS
- ☐ NECESSARY FOR CROSSMATCH
  - 10 mL syringes/needles
  - EDTA (purple top) tubes
  - Serum (red top, dry) tubes
  - Pipettes
  - NaCl 0.9% (20-50 mL)
  - Centrifuge
  - Slides or commercial crossmatch kit
- ☐ IV CATHETER PLACEMENT KIT (DONOR/RECIPIENT)
  - Razor or clippers
  - Chlorhexidine gauzes
  - Alcohol gauzes
  - Non-sterile gloves
  - Sterile gloves
  - Suture material
  - NaCl 0.9% or heparinized flush
  - Infusion plug
  - IV catheters (10-12 ga for collection/14 ga for administration)
- ☐ BLOOD COLLECTION
  - Closed blood collection kit: bag+line+catheter/needle
  - Open system:
    - IV fluid bag
    - Male to male IV line
    - Large needle
  - Hemostatic clamps
  - Double bag/transfer set (if separate plasma is needed)
- ☐ BLOOD ADMINISTRATION
  - Filtered IV line
- ☐ MONITORING
  - Stethoscope
  - Thermometer
  - Transfusion formulary/sheet

Blood processing and storage

Packed RBCs (centrifuge not necessary)

1. Allow RBCs to sediment by gravity (30 min) or centrifuge at 3000 rpm for 20 minutes.
2. Remove the supernatant plasma.
3. Dilute with isotonic crystalloid fluid until viscosity allows flowing through the filtered IV line.

Washed RBCs (centrifuge necessary)

1. Centrifuge at 3000 rpm for 20 minutes.
2. Remove the supernatant plasma.
3. Add a volume of isotonic crystalloid fluid (sterile NaCl 0.9%) similar to removed plasma volume and gently mix
4. Centrifuge at 3000 rpm for 20 minutes
5. Repeat step 3 and 4 other two times (total of three washing cycles)
6. Replace the last wash isotonic with "new" isotonic crystalloid (until viscosity allows flowing through the filtered IV line)

Blood Transfusion Sheet

Recipient information

Name/Case n:	**Signalment:** [Age, sex, breed]
Bodyweight (kg):	**Blood volume (liters):** [BW (kg) X 0.08]
Estimated blood loss (liters):	**Previous blood transfusion (Y/N)**:
Blood type:	**PCV/TS (%/g/dL):**
Comments/Other relevant information:	

Donor information

<table>
<tr><td>Name/Case n:</td><td>Signalment: [Age, sex, breed]</td></tr>
<tr><td>Bodyweight (kg):</td><td>Blood volume (liters): [BW (kg) X 0.08]</td></tr>
<tr><td>Max blood for collection (liters):
[Blood Volume (liters) x 0.2]

Volume requiring IV fluids (liters):
[Blood Volume (liters) x 0.2]</td><td>Previous blood transfusion (Y/N):

Previous foaling: (Y/N):</td></tr>
<tr><td rowspan="2">Health check:
- Physical Exam: Y/N
- CBC: Y/N
- Chemistry: Y/N
- Vaccinations: Y/N
- Deworming: Y/N
- Coggins: Y/N
- Hepatic viruses PCR: Y/N
- Others (specify)
-
Report relevant results/comments below</td><td>PCV/TS (%/g/dL):

Pre-transfusion:
12-hour post-transfusion:</td></tr>
<tr><td>Blood type:

Alloantibody screening (results/date):</td></tr>
<tr><td colspan="2">Comments/Other relevant information</td></tr>
</table>

Crossmatch results

Major (RBC donor + serum recipient):

- □ NEGATIVE
- □ POSITIVE
  - Agglutination Y/N: □ 1 □ 2 □ 3 □ 4
  - Hemolysis Y/N

Minor (RBC recipient + serum donor):

- □ NEGATIVE
- □ POSITIVE
  - Agglutination Y/N: □ 1 □ 2 □ 3 □ 4
  - Hemolysis Y/N

Transfusion calculations

Transfusion volume

□ USE BLOOD LOSS: replace 25-50% of the estimated blood lost.

0.25 x estimated blood loss = liters

0.50 x estimated blood loss = liters

□ USE PCV FORMULA:

[(Desired PCV recipient – Actual PCV recipient)/Donor PCV] x BW (kg) x 0.08 l/kg

= liters

Max volume that can be collected (see donor information):

Volume requiring IV fluid replacement in the donor:

Anticoagulants (if dry bags are used)

Volume bag (mL):	Number of bags:	Type of anticoagulant:
Volume anticoagulant/each bag (14 ml/100 ml blood):		

Blood collection

Volume collected:	**IV fluid replacement** Y/N **Volume & Type fluids**:
Comments/Complications:	

Transfusion administration and monitoring

Date: **Time started:** **Time finished:**	**Type:** □ Whole blood □ Packed RBCs □ Washed RBCs □ Plasma □ Other
Volume administered:	
Pre-PCV/TS:	**Post- PCV/TS:**
Comments/Complications:	

General Rule:

Start transfusion rate at 1 ml/kg (approximately 1 dr/sec for a 1100 pounds horse), TPR q 5 min for first 20 min, then—if no evidence of reaction—increase the drip rate up to 15-20 ml/kg/hour (open drip for a 1100 pounds horse) and TPR q 10-15 min for the remainder of the transfusion.

TIME	DRIP RATE	Temp	HR	RR	Fasciculations, Hives, etc

Emergency drugs

Dexamethasone (2 mg/mL)

0.05-0.1 mg/kg = mg /2 = mL

Epinephrine (1:1000)

0.01-0.02 mL/kg = mL

Common immune mediated blood transfusion reactions

Reaction	Type	Clinical signs	Treatment
Febrile hemolysis	Type 2 hypersensitivity Immediate (hours) Delayed (3-7 days)	Fever, icterus, (hemoglobinemia, hemoglobinuria if intravascular)	d/c transfusion, fluid therapy, steroids
Febrile non-hemolytic reaction	Type 2 hypersensitivity, Inflammatory Immediate (hours)	Fever	d/c transfusion, antiinflammatories
Allergic reactions	Type 1 hypersensitivity, Immediate (minutes)	Local: urticaria, pruritus, rhinitis Anaphylaxis: respiratory distress, colic, diarrhea, collapse	d/c transfusion, steroids d/c transfusion, steroids, epinephrine, IV fluid resuscitation

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