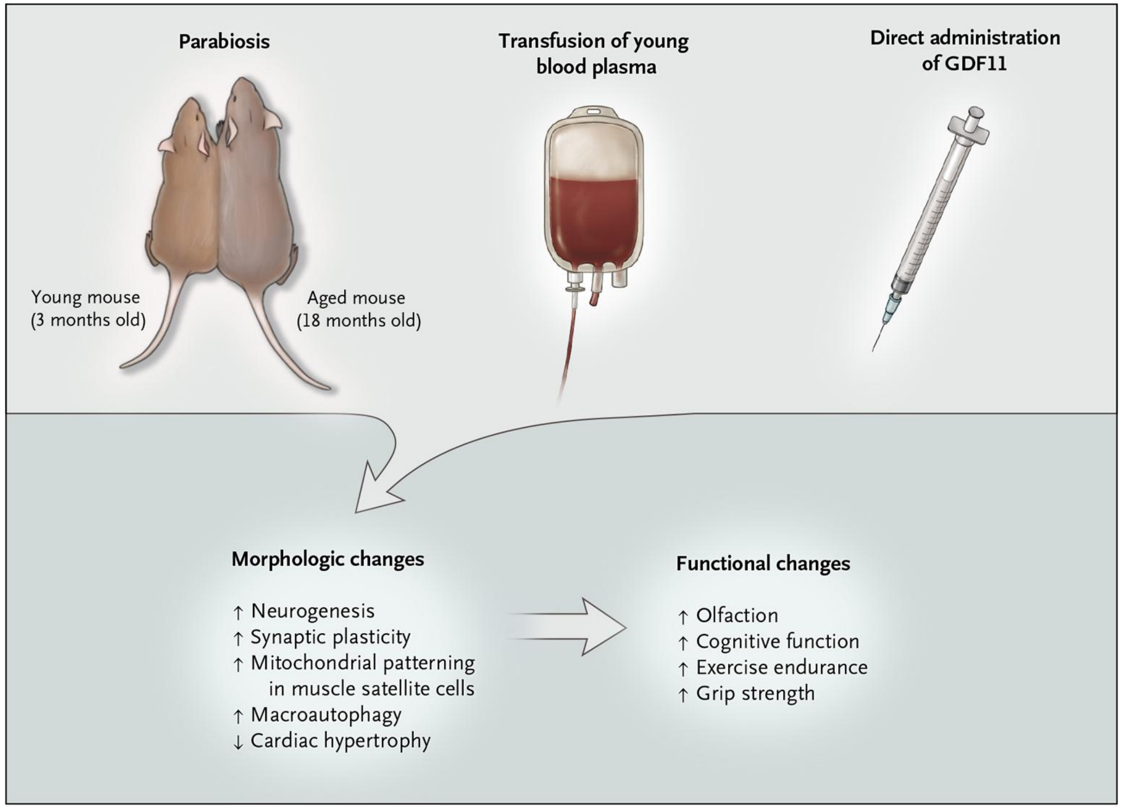
Effect of donor, component, and recipient characteristics on hemoglobin increments following red blood cell transfusion

Nareg Roubinian, MD MPH
Vitalant Research Institute
Kaiser Permanente Division of Research

Background: RBC effectiveness studies

- RBCs are a complex biological product with variation between units
- Known differences in stress-induced hemolysis at end of RBC storage
- Prior studies have focused on the impact of prolonged RBC storage on morbidity and mortality
- Recent studies are using “big data” approaches
  - Evaluate blood donor, component, and recipient variables



Parabiosis

Young mouse
(3 months old)

Aged mouse
(18 months old)

Transfusion of young blood plasma

Direct administration of GDF11

Morphologic changes

- ↑ Neurogenesis
- ↑ Synaptic plasticity
- ↑ Mitochondrial patterning in muscle satellite cells
- ↑ Macroautophagy
- ↓ Cardiac hypertrophy

Functional changes

- ↑ Olfaction
- ↑ Cognitive function
- ↑ Exercise endurance
- ↑ Grip strength

NEWS

FEATURES

Young blood

Young animals' blood holds rejuvenating powers. Amy Wagers wants to know why

By **Stephen S. Hall**

Amy Wagers was about halfway through a 90-minute talk to a group of Boston-area science teachers last July when she showed her Arnold Schwarzenegger slides. One picture depicted the former governor of California as a buff young bodybuilder; the other showed a more recent, flabbier, and stooped version of the Terminator playing tennis. If a picture is worth a thousand words, the slide served as a two-volume treatise illustrating the point that Wagers, a Harvard University stem cell scientist, wanted to make: As humans age, our muscles fail to maintain and regenerate as they once did.

"I'm not saying aging is a disease," Wagers hastened to add, once her audience had stopped laughing. "But it is associated with increased incidence of particular types of diseases."

Wagers's quiet voice barely carried over an aspirating aquarium at the side of the science lab at Dover-Sherborn High School. But the 30 or so educators gathered at the Summer Science Institute avidly followed the narrative of her recent work—especially when Wagers moved on to her "fountain of youth" slides.

In a series of experiments that have captivated both the field of regenerative medicine and its many lay spectators, Wagers and a diverse army of collaborators have shown that when the blood of a young mouse circulates through the murine equivalent of an old geezer, startling physiological changes occur. Many of the trademark depredations of old age—withering muscles; stiff, oversized hearts; cognitive decline; and even the fraying of the myelin coating that insulates nerve fibers—are slowed, repaired, or even reversed.

"We became convinced that there was something in the blood" responsible for the dramatic effects, Wagers told the teachers. Indeed, after a difficult search, she and colleagues have recently isolated a molecule from "young blood," growth differentiation factor 11 (GDF11), that appears to rejuvenate the architecture of the heart, the vasculature of the brain, and the bulk of skeletal muscle—at least in animals. As Wagers told the group, "GDF11, which is this 'fountain of youth' kind of factor for the heart, is also a fountain-of-youth factor for the skeletal muscle and for the brain. It is generally a good protein for rejuvenation."

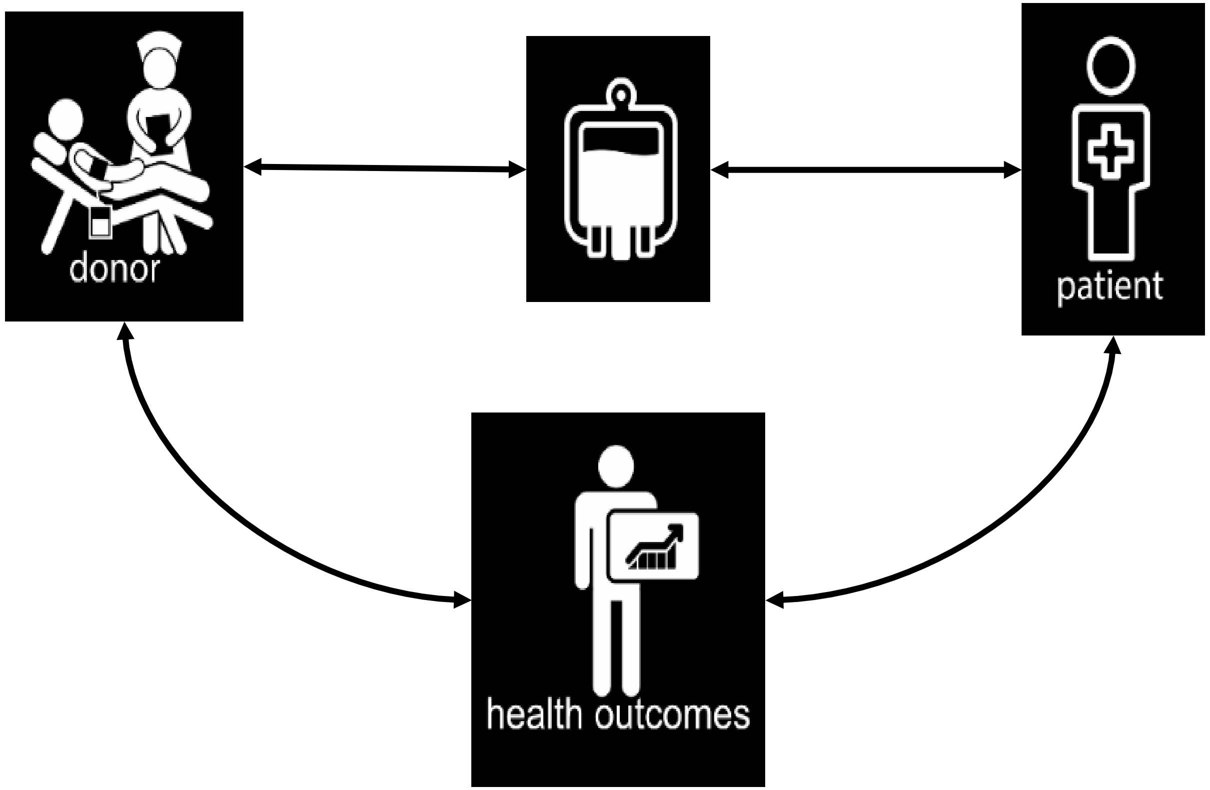
"Rejuvenation" has always been a loaded crossover term in biology. Quickly raising her hand, one young high school science teacher from Walpole could barely spit out the question on everyone's mind. "You have to wonder, given what you're seeing ... I mean,

1234 12 SEPTEMBER 2014 • VOL 345 ISSUE 6202 sciencemag.org **SCIENCE**

Published by AAAS

Laviano. NEJM 2014

Donor-Component-Recipient Linkages



Collection, manufacturing
and processing data

Demographics,
social behavior,
medical history
on each donation

Electronic
health records,
registries,
claims data

Blood donor-component-recipient databases

- Canada
  - TRUST (Hamilton/McMaster)
  - Ottawa (OHRI)
- Sweden/Denmark
  - SCANDAT
  - Dutch Blood Donor Study (DBDS)
- Netherlands
  - DTD
- United States
  - REDS-III/IV (Recipient Epidemiology Donor Evaluation Study)
  - Kaiser Permanente Northern California

Donor-Component-Recipient Linkages

Donor

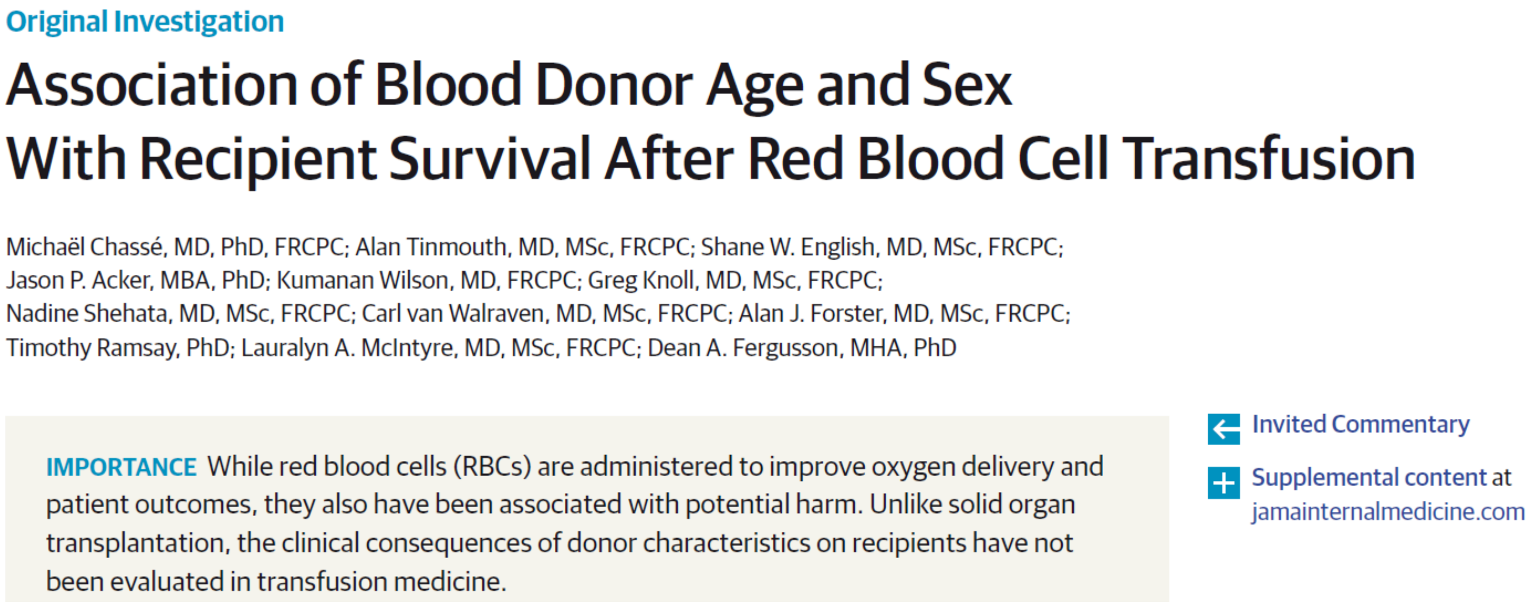
- Sex, age, BMI, race/ethnicity, ABO/Rh, h/o pregnancy
- Fingerstick hemoglobin level
- *In vitro* measures of hemolysis
- Donor genetic polymorphisms
- Donation history, ferritin, iron/MVI, tobacco, alcohol, caffeine use

Component

- Collection method
- Leukoreduction, washing, volume reduction
- Additive solution
- Gamma irradiation
- Pathogen reduction
- Storage duration

Recipient

- Sex, age, BMI, race/ethnicity, ABO/Rh
- Number of transfusion exposures, allo-immunization
- Co-morbidities and immune function
- Concomitant platelet / plasma TX
- Hemoglobin, creatinine, bilirubin levels
- Organ failure, length of stay, death



Original Investigation

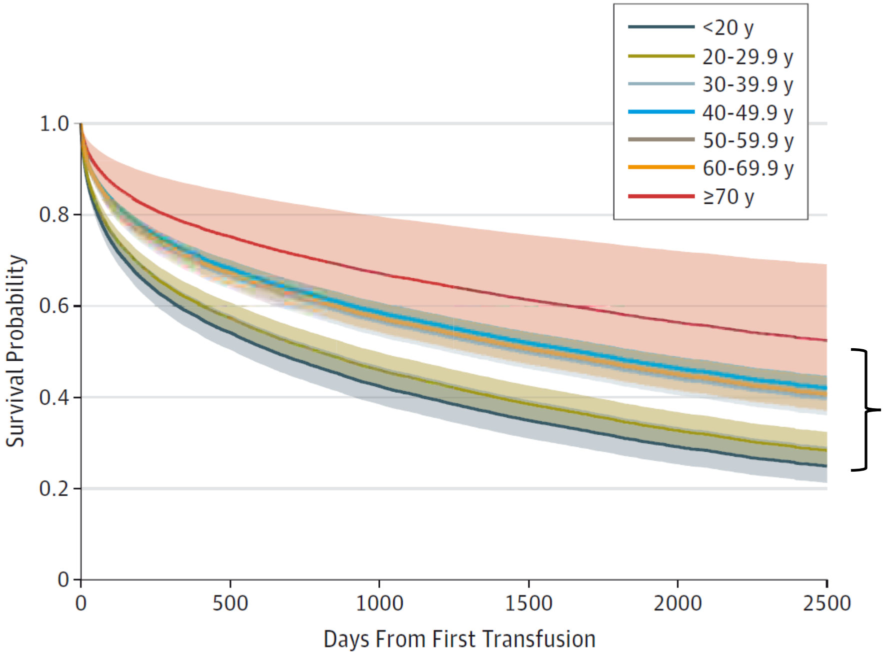
Association of Blood Donor Age and Sex With Recipient Survival After Red Blood Cell Transfusion

Michaël Chassé, MD, PhD, FRCPC; Alan Tinmouth, MD, MSc, FRCPC; Shane W. English, MD, MSc, FRCPC;
Jason P. Acker, MBA, PhD; Kumanan Wilson, MD, FRCPC; Greg Knoll, MD, MSc, FRCPC;
Nadine Shehata, MD, MSc, FRCPC; Carl van Walraven, MD, MSc, FRCPC; Alan J. Forster, MD, MSc, FRCPC;
Timothy Ramsay, PhD; Lauralyn A. McIntyre, MD, MSc, FRCPC; Dean A. Fergusson, MHA, PhD

IMPORTANCE While red blood cells (RBCs) are administered to improve oxygen delivery and patient outcomes, they also have been associated with potential harm. Unlike solid organ transplantation, the clinical consequences of donor characteristics on recipients have not been evaluated in transfusion medicine.

Invited Commentary

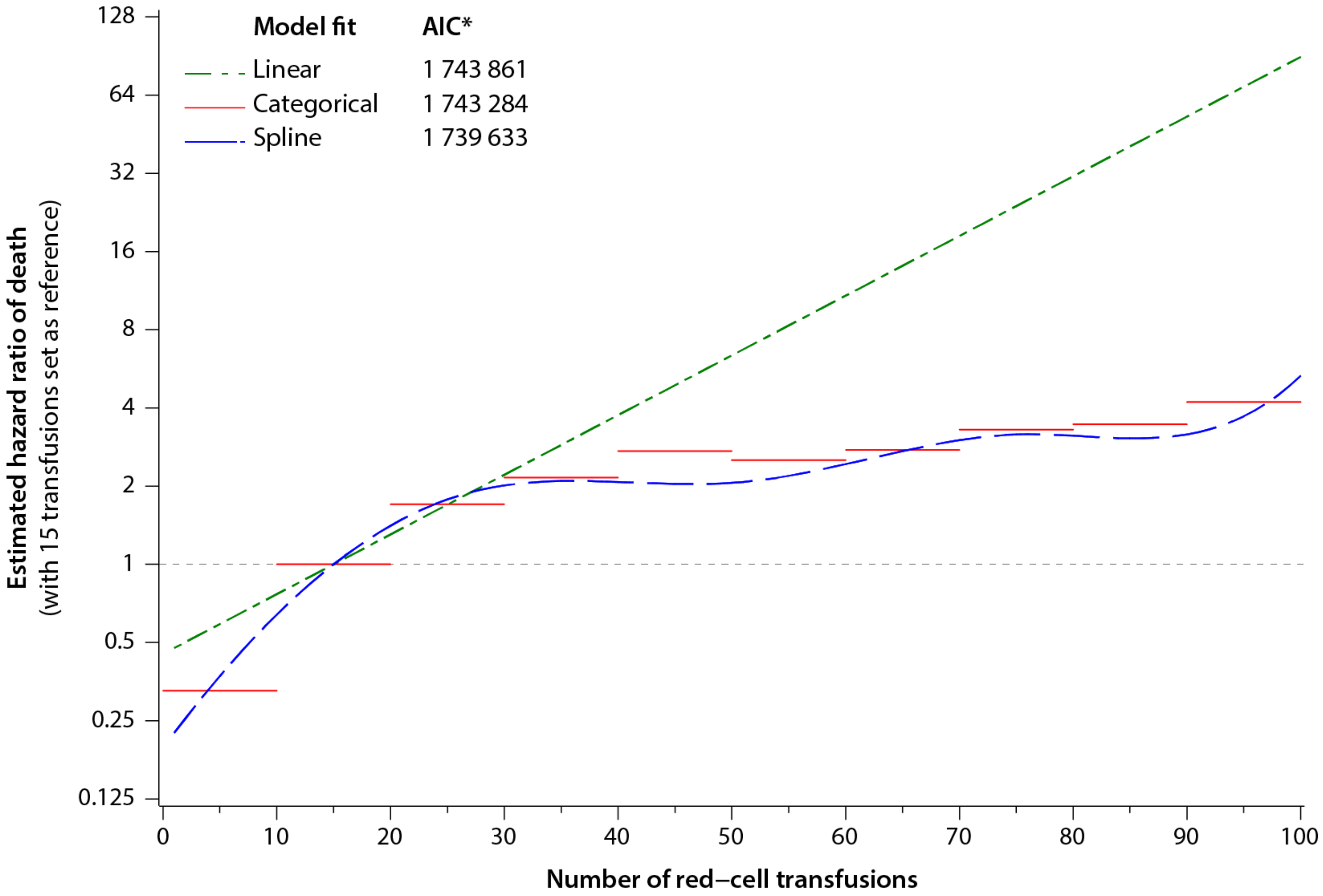
Supplemental content at jamainternalmedicine.com



>25% absolute mortality difference

Chassé M et al. JAMA Int Med 2016

of RBCs & mortality: non-linear association



Edgren et al. JAMA Int Med, 2017

Donor age & patient mortality: adjustment for number of RBC transfusions

Donor age	**Number of RBC units (%)**	**Log-linear adjustment**	**Restricted cubic splines**
		Hazard ratio (95% CI)	
<20 years	126 847(1.9)	1.04 (1.03-1.04)	1.01 (1.00-1.01)
20-29 years	1 104 248(16.3)	1.02 (1.02-1.02)	0.99 (0.99-1.00)
30-39 years	1 464 872(21.6)	1.00 (1.00-1.00)	0.99 (0.99-1.00)
40-49 years	1 889 084(27.9)	1.00 (ref)	1.00 (ref)
50-59 years	1 600 320(23.6)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
60-69 years	578 194(8.5)	1.00 (1.00-1.01)	1.01 (1.01-1.02)
≥70 years	3 238(0.0)	0.85 (0.83-0.87)	0.96 (0.91-1.01)

Edgren et al. JAMA Int Med, 2017

Associations between donor sex, prior pregnancy & mortality

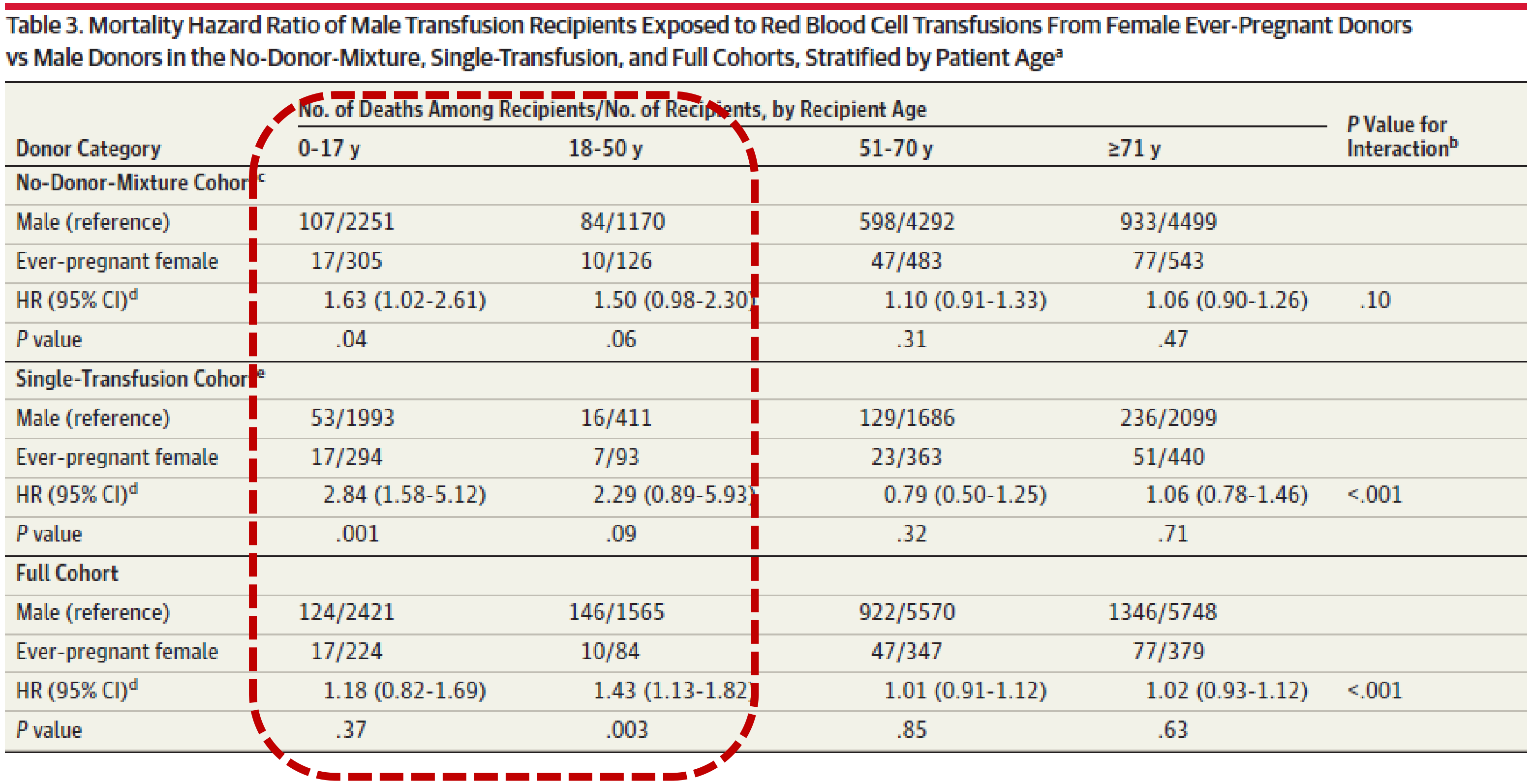
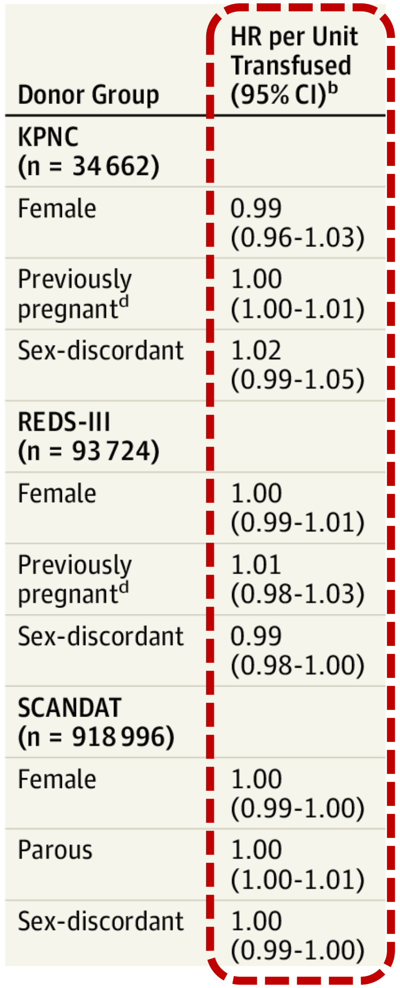


Table 3. Mortality Hazard Ratio of Male Transfusion Recipients Exposed to Red Blood Cell Transfusions From Female Ever-Pregnant Donors vs Male Donors in the No-Donor-Mixture, Single-Transfusion, and Full Cohorts, Stratified by Patient Age[a]

Donor Category	No. of Deaths Among Recipients/No. of Recipients, by Recipient Age				*P* Value for Interaction[b]
	0-17 y	18-50 y	51-70 y	≥71 y	
No-Donor-Mixture Cohort[c]					
Male (reference)	107/2251	84/1170	598/4292	933/4499	
Ever-pregnant female	17/305	10/126	47/483	77/543	
HR (95% CI)[d]	1.63 (1.02-2.61)	1.50 (0.98-2.30)	1.10 (0.91-1.33)	1.06 (0.90-1.26)	.10
P value	.04	.06	.31	.47	
Single-Transfusion Cohort[e]					
Male (reference)	53/1993	16/411	129/1686	236/2099	
Ever-pregnant female	17/294	7/93	23/363	51/440	
HR (95% CI)[d]	2.84 (1.58-5.12)	2.29 (0.89-5.93)	0.79 (0.50-1.25)	1.06 (0.78-1.46)	<.001
P value	.001	.09	.32	.71	
Full Cohort					
Male (reference)	124/2421	146/1565	922/5570	1346/5748	
Ever-pregnant female	17/224	10/84	47/347	77/379	
HR (95% CI)[d]	1.18 (0.82-1.69)	1.43 (1.13-1.82)	1.01 (0.91-1.12)	1.02 (0.93-1.12)	<.001
P value	.37	.003	.85	.63	



Donor Group	HR per Unit Transfused (95% CI)[b]
KPNC (n = 34 662)	
Female	0.99 (0.96-1.03)
Previously pregnant[d]	1.00 (1.00-1.01)
Sex-discordant	1.02 (0.99-1.05)
REDS-III (n = 93 724)	
Female	1.00 (0.99-1.01)
Previously pregnant[d]	1.01 (0.98-1.03)
Sex-discordant	0.99 (0.98-1.00)
SCANDAT (n = 918 996)	
Female	1.00 (0.99-1.00)
Parous	1.00 (1.00-1.01)
Sex-discordant	1.00 (0.99-1.00)

Caram-Deelder et al, JAMA, 2017

Edgren et al, JAMA, 2019

Changes in donor parity over time

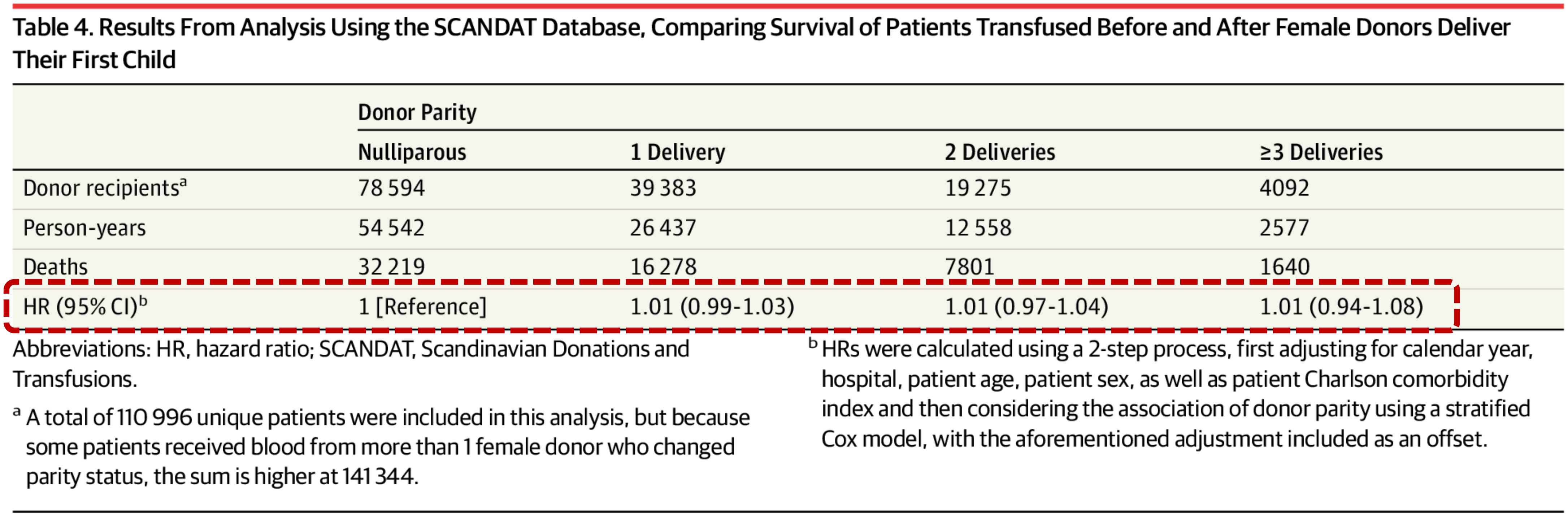


Table 4. Results From Analysis Using the SCANDAT Database, Comparing Survival of Patients Transfused Before and After Female Donors Deliver Their First Child

	Donor Parity			
	Nulliparous	1 Delivery	2 Deliveries	≥3 Deliveries
Donor recipients[a]	78 594	39 383	19 275	4092
Person-years	54 542	26 437	12 558	2577
Deaths	32 219	16 278	7801	1640
HR (95% CI)[b]	1 [Reference]	1.01 (0.99-1.03)	1.01 (0.97-1.04)	1.01 (0.94-1.08)

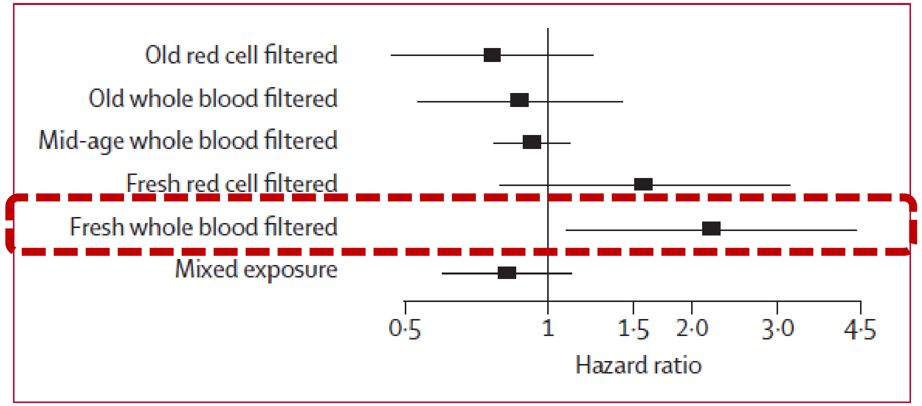
Abbreviations: HR, hazard ratio; SCANDAT, Scandinavian Donations and Transfusions.

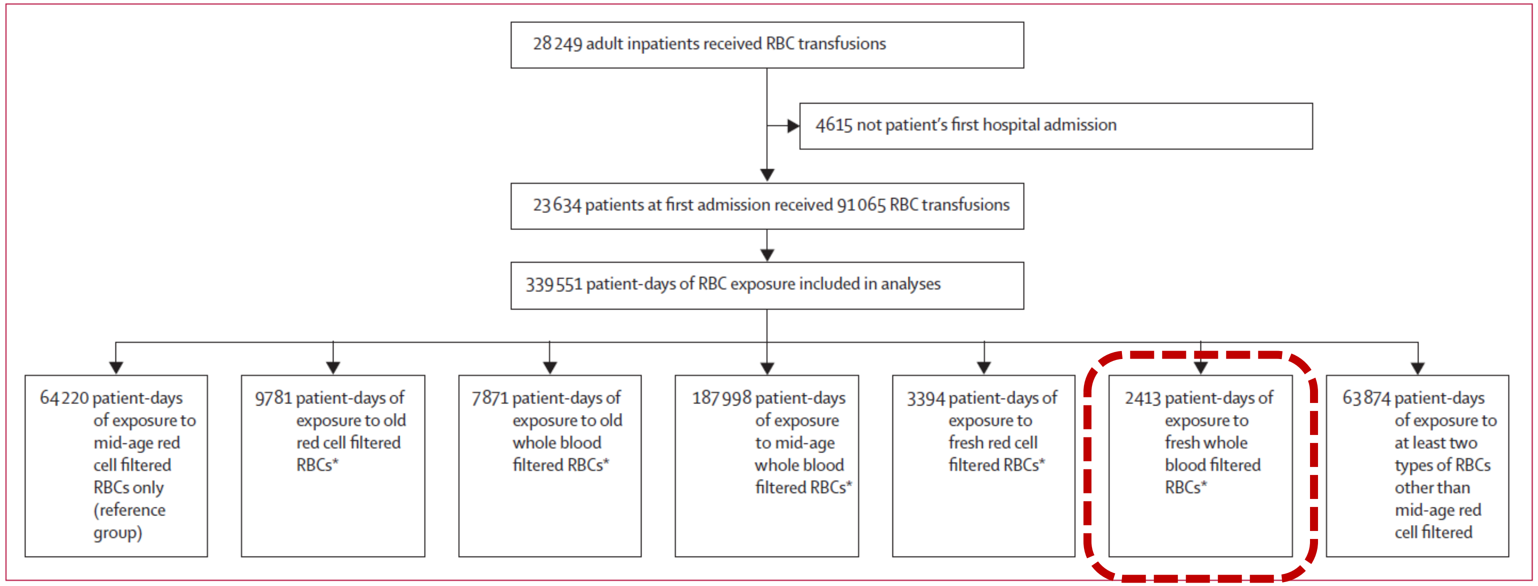
[a] A total of 110 996 unique patients were included in this analysis, but because some patients received blood from more than 1 female donor who changed parity status, the sum is higher at 141 344.

[b] HRs were calculated using a 2-step process, first adjusting for calendar year, hospital, patient age, patient sex, as well as patient Charlson comorbidity index and then considering the association of donor parity using a stratified Cox model, with the aforementioned adjustment included as an offset.

Edgren et al, JAMA, 2019

Component modifications & mortality?





28 249 adult inpatients received RBC transfusions

4615 not patient's first hospital admission

23 634 patients at first admission received 91 065 RBC transfusions

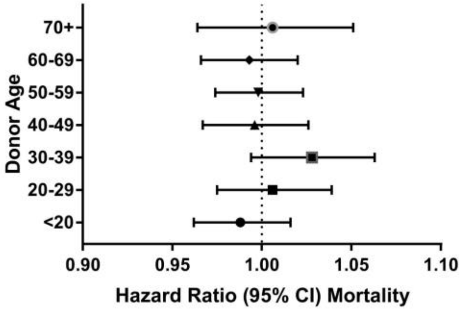
339 551 patient-days of RBC exposure included in analyses

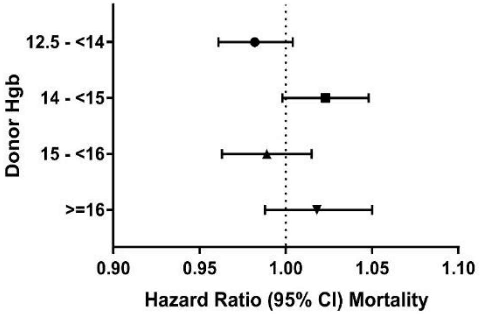
- 64 220 patient-days of exposure to mid-age red cell filtered RBCs only (reference group)
- 9781 patient-days of exposure to old red cell filtered RBCs*
- 7871 patient-days of exposure to old whole blood filtered RBCs*
- 187 998 patient-days of exposure to mid-age whole blood filtered RBCs*
- 3394 patient-days of exposure to fresh red cell filtered RBCs*
- 2413 patient-days of exposure to fresh whole blood filtered RBCs*
- 63 874 patient-days of exposure to at least two types of RBCs other than mid-age red cell filtered

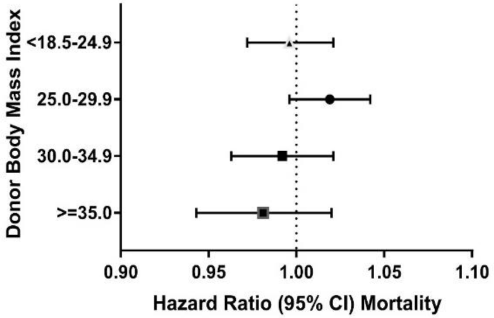
Heddle et al, Lancet Haemotology, 2016.

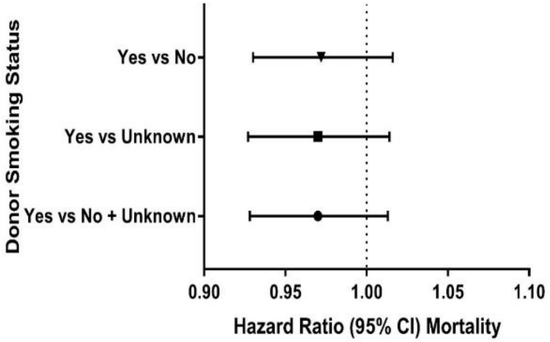
Other blood donor factors or outcomes?

Mortality

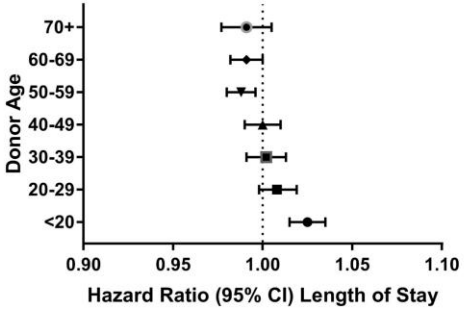


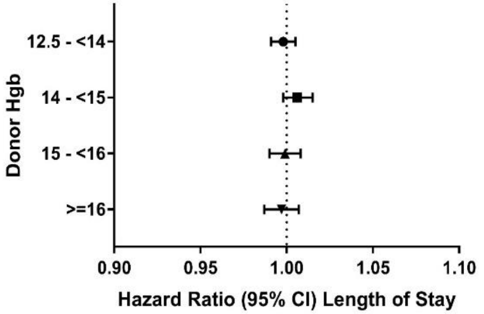


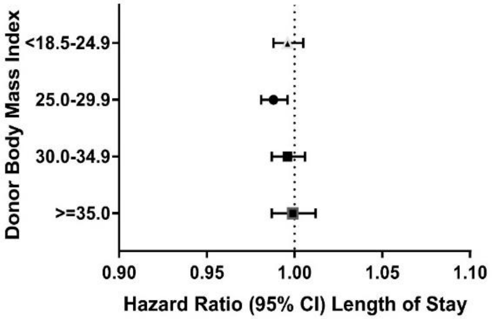


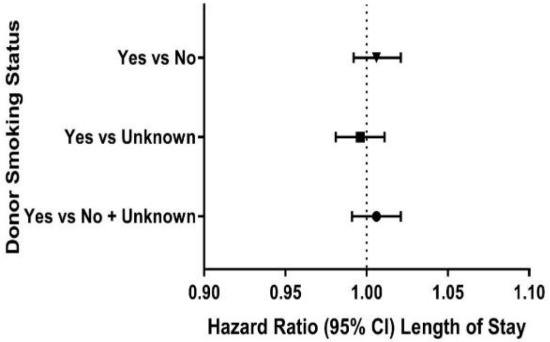


Length of Stay









Donor age

Donor hemoglobin

Donor body mass index

Donor smoking

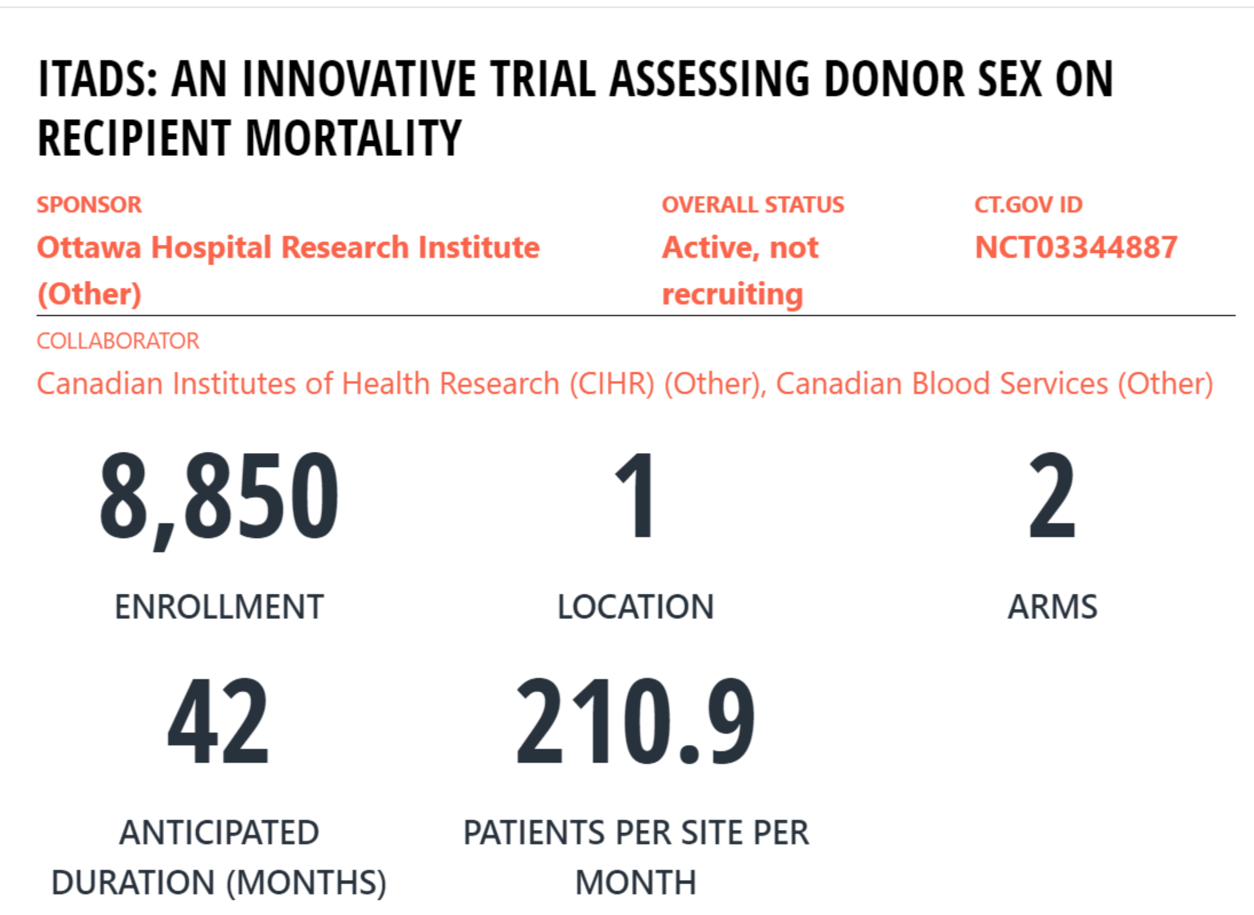
Roubinian et al, Transfusion, 2019

Open access **Protocol**

BMJ Ope

mised
d blood
tality in
n: the
or Sex

son P Acker,[5]
ehata,[9]
an,[1]



ITADS: AN INNOVATIVE TRIAL ASSESSING DONOR SEX ON RECIPIENT MORTALITY

SPONSOR
Ottawa Hospital Research Institute (Other)

OVERALL STATUS
Active, not recruiting

CT.GOV ID
NCT03344887

COLLABORATOR
Canadian Institutes of Health Research (CIHR) (Other), Canadian Blood Services (Other)

8,850
ENROLLMENT

1
LOCATION

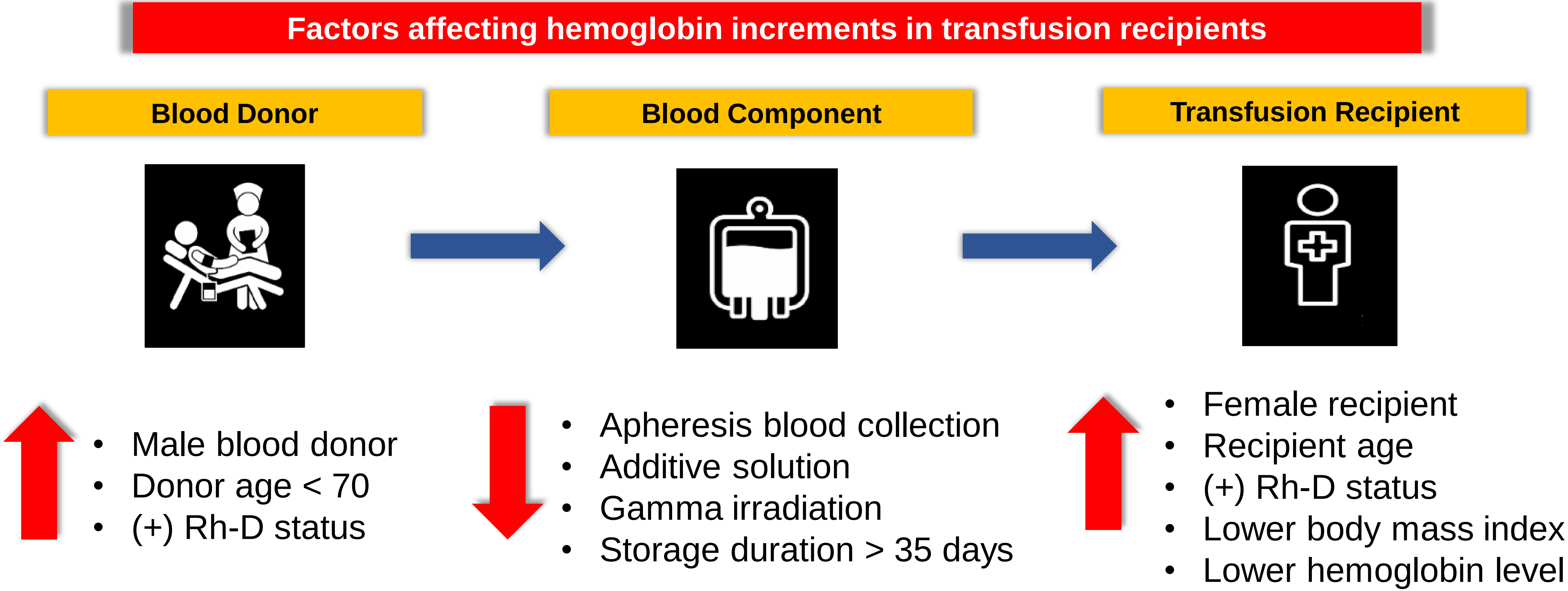
2
ARMS

42
ANTICIPATED DURATION (MONTHS)

210.9
PATIENTS PER SITE PER MONTH

Fergusson et al, BMJ Open, 2021

Retrospective cohort study using EHR data on 23,194 transfusion recipients who received one or more single-unit RBC transfusions from 2008-2016 at a Kaiser Permanente Northern California facility



Factors affecting hemoglobin increments in transfusion recipients

Blood Donor

↑

- Male blood donor
- Donor age < 70
- (+) Rh-D status

Blood Component

↓

- Apheresis blood collection
- Additive solution
- Gamma irradiation
- Storage duration > 35 days

Transfusion Recipient

↑

- Female recipient
- Recipient age
- (+) Rh-D status
- Lower body mass index
- Lower hemoglobin level

Roubinian et al, Blood, 2019

Gamma Irradiation and Storage Duration

Un-irradiated				
Storage Duration (days)	1-21 (n=9,580)	22-28 (n=11,791)	29-35 (n=7,738)	36-42 (n=6,433)
Pre-TX Hb	8.10 (0.88)	8.04 (0.87)	8.04 (0.85)	7.92 (0.87)
Post-TX Hb	9.14 (1.17)	9.08 (1.15)	9.09 (1.12)	8.97(1.12)
Post-TX Inc	**1.05 (0.90)**	**1.05 (0.89)**	**1.07 (0.87)**	**1.07 (0.85)**
Irradiated				
Storage Duration (days)	1-21 (n=828)	22-28 (n=643)	29-35 (n=539)	36-42 (n=467)
Pre-TX Hb	7.65 (0.82)	7.77 (0.78)	7.78 (0.81)	7.78 (0.80)
Post-TX Hb	8.59 (1.12)	8.76 (1.19)	8.68 (1.06)	8.69 (1.07)
Post-TX Inc	**0.96 (0.82)**	**1.03 (0.96)**	**0.96 (0.73)**	**0.98 (0.79)**

Roubinian et al, Blood, 2019

KPNC - Donor-component-recipient linkage

Hemoglobin increments for donor & recipient sex and gamma irradiation – mean in g/dL (SD)				
	Male Blood Donor		Female Blood Donor	
	Unirradiated	Irradiated	Unirradiated	Irradiated
Female Recipient				
Hb Increment	**1.23 (0.93)**	**1.18 (0.96)**	**1.14 (0.89)**	**1.08 (0.84)**
Male Recipient				
Hb Increment	**0.93 (0.83)**	**0.88 (0.79)**	**0.88 (0.84)**	**0.74 (0.77)**

Hemoglobin increments for donor & recipient sex and collection method – mean in g/dL (SD)				
	Whole blood collection		Apheresis collection	
	Male Donor	Female Donor	Male Donor	Female Donor
Female Recipient				
Hb Increment	**1.29 (0.93)**	**1.14 (0.89)**	**1.10 (0.90)**	**1.04 (0.82)**
Male Recipient				
Hb Increment	**0.97 (0.82)**	**0.88 (0.83)**	**0.85 (0.82)**	**0.79 (0.86)**

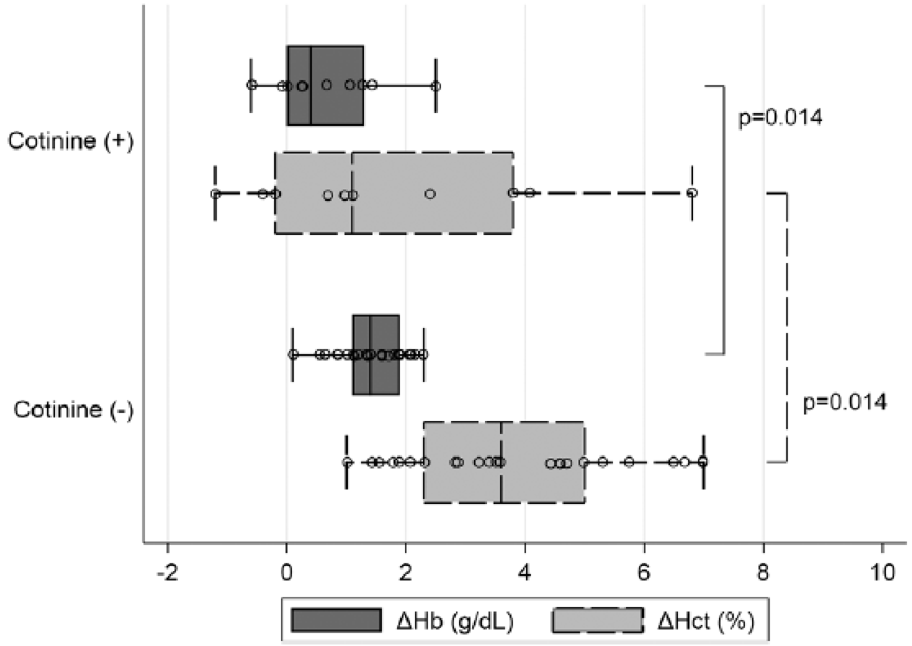
Roubinian et al, Blood, 2019

Modeling hemoglobin increments

Hb increment (g/dL) after transfusion for Hb level of 7 g/dL	
• Female donor (0)	• Male donor (+0.1)
• Don/Rec Rh-D neg (-0.06)	• Don/Rec Rh-D pos (0)
• Apheresis collection (0)	• Whole blood coll. (+0.16)
• Irradiated unit (-0.08)	• Unirradiated unit (0)
• Additive solution 3 (-0.06)	• Additive solution 1 (0)
• 60-yo old male recip. (0)	• 85-yo old female (+0.4)
• BMI – 30 (-0.5)	• BMI – 18 (-0.3)
0.59 g/dL Hb increment	**1.65 g/dL Hb increment**

Roubinian et al, Blood, 2019

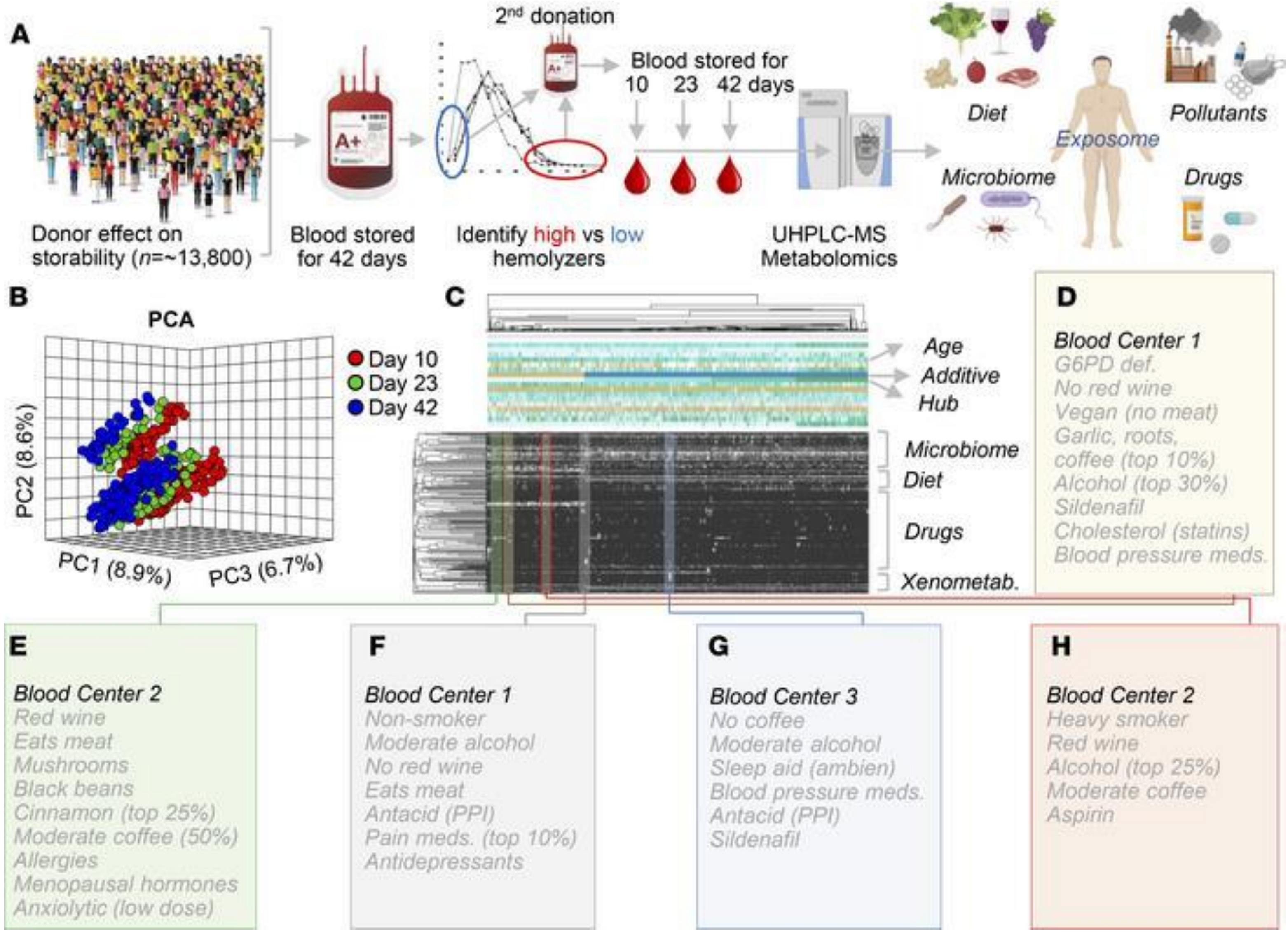
Donor behaviors: smoking & RBC transfusion



Donor & component factor	Δ Hemoglobin, g/dL (SD)
Non-smoker, unirradiated	1.03 (0.92)
Smoker, unirradiated	1.05 (0.98)
Non-smoker, irradiated	0.94 (0. 83)
Smoker, irradiated	0.74 (0.80)

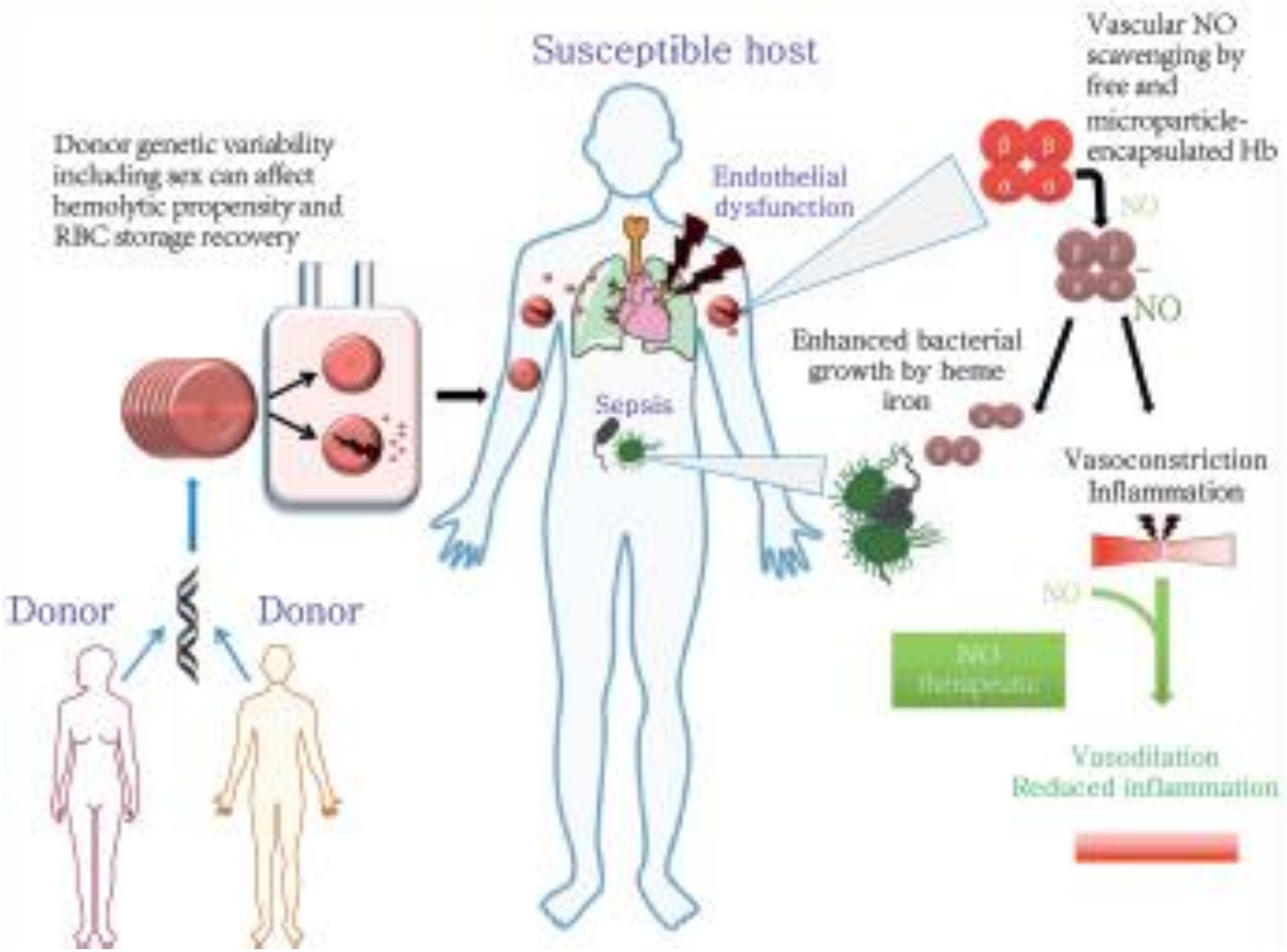
De Simone et al, Transfusion, 2020
De Simone et al, Transfusion, 2019

Blood donor “Exposome”



Nemkov et al. JCI Insight 2021

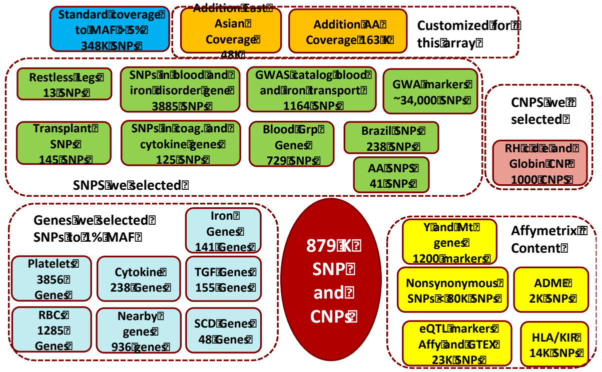
Donor genetic variations can affect the hemolytic propensity and recovery of RBC



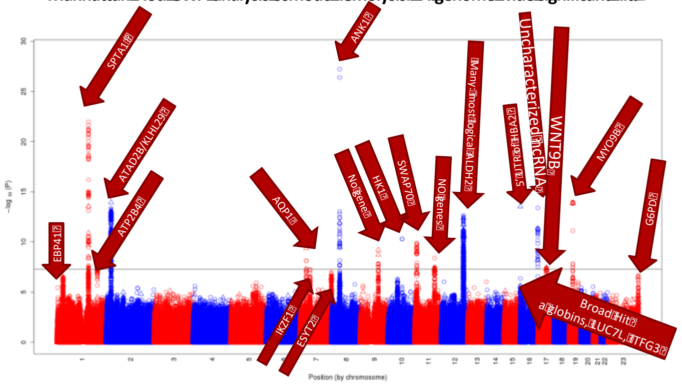
Kanias and Gladwin, Transfusion, 2014

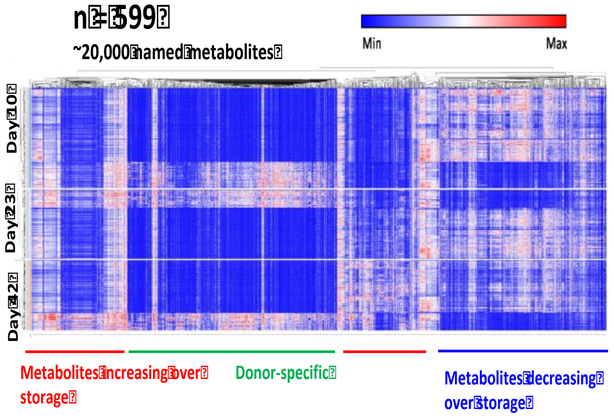
REDS-III RBC-Omics Study

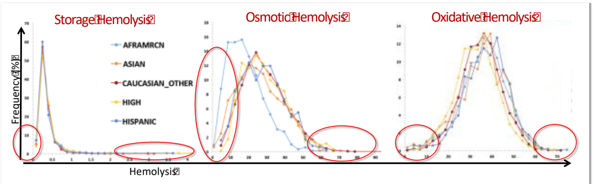
Affymetrix Axiom genome wide SNP array



Manhattan Plot: GWA analysis osmotic hemolysis. 14 genome wide significant hits

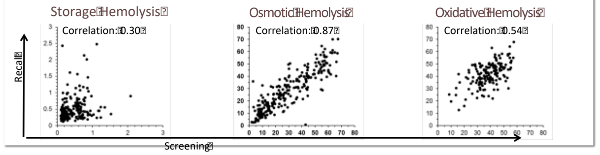






To identify extreme hemolyzers < 5th and > 95th percentile of the hemolysis assay
→ GWAS and Metabolomics

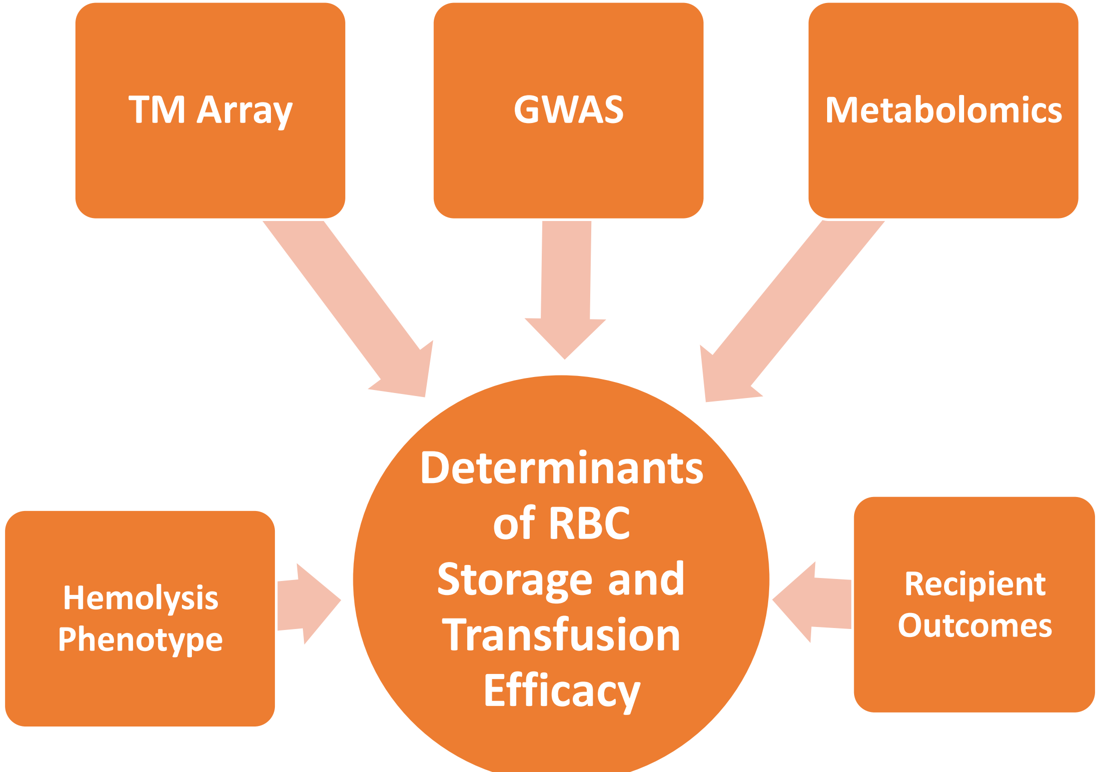
Intra-assay correlations for screening vs recall results in transfer bags



	Storage Hemolysis	Osmotic Hemolysis	Oxidative Hemolysis
African Americans	↑ 0.0078	↓ <0.0001	↑ 0.0008
Asians	0.69	↓ <0.0001	0.41
Hispanics	0.89	0.10	↑ <0.0001
High-intensity	↑ <0.0001	0.84	↓ <0.0001

↑ > hemolysis vs Caucasian donors

↓ < hemolysis vs Caucasian donors


TM Array

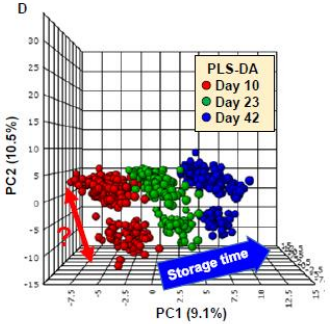
GWAS

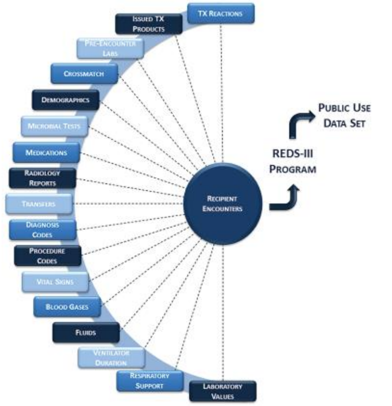
Metabolomics

Hemolysis Phenotype

Determinants of RBC Storage and Transfusion Efficacy

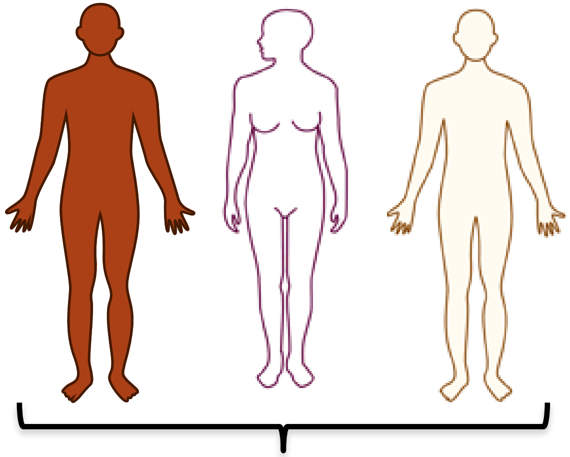
Recipient Outcomes





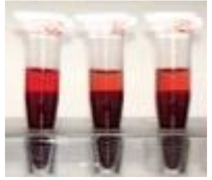
Associations between RBC-omics donors & hemolysis with storage

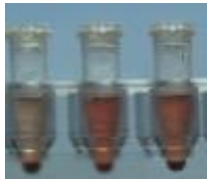
Blood donors
(n=13,403)



Red blood cell storage (39-42 days)

⬇

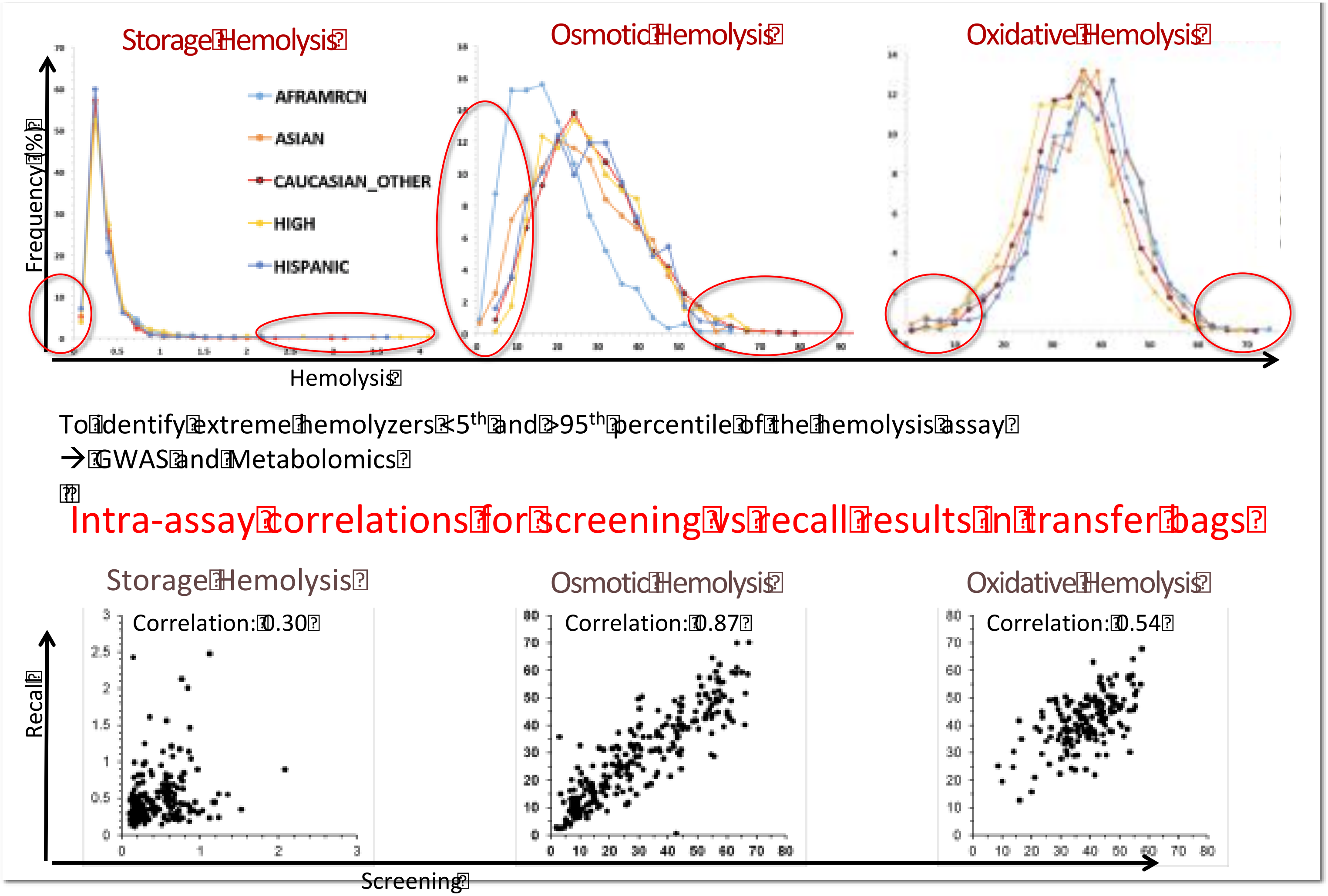




	Storage hemolysis	Osmotic hemolysis	Oxidative hemolysis
Lower hemolysis ↓	- Sex (female)	- Ethnicity (African American) - Sex (female)	- Sex (female) - Donor age - Prior donation
Higher hemolysis ↑	- Sex (male) - Ethnicity (Asian/African American)	- Sex (male) - Donor age	- Sex (male)

Kanias et al. Blood Advances, 2017
Kanias et al. Transfusion, 2019

Extreme hemolyzers during screening – Reproducibility at recall



To identify extreme hemolyzers <5th and >95th percentile of the hemolysis assay

→ GWAS and Metabolomics

Intra-assay correlations for screening vs recall results in transfer bags

Correlation: 0.30

Correlation: 0.87

Correlation: 0.54

Lanteri et al. Transfusion, 201

REDS-III Transfusion Medicine Array

Standard coverage to MAF > 5% 348K SNPs

Customized for this array

- Addition East Asian Coverage 48K
- Addition AA Coverage 163 K

SNPS we selected

- Restless Legs 13 SNPs
- SNPs in blood and iron disorder gene 3885 SNPs
- GWAS catalog blood and iron transport 1164 SNPs
- GWA markers ~34,000 SNPs
- Transplant SNPs 145 SNPs
- SNPs in coag. and cytokine genes 125 SNPs
- Blood Grp Genes 729 SNPs
- Brazil SNPs 238 SNPs
- AA SNPS 41 SNPs

CNPS we selected

- RH c d e and Globin CNP 1000 CNPS

Genes we selected SNPs to 1% MAF

- Iron Genes 141 Genes
- Platelets 3856 Genes
- Cytokine 238 Genes
- TGF Genes 155 Genes
- RBCs 1285 Genes
- Nearby genes 936 genes
- SCD Genes 48 Genes

879 K SNP and CNPs

Affymetrix Content

- Y and Mt genes 1200 markers
- Nonsynonymous SNPs < 80K SNPs
- ADME 2K SNPs
- eQTL markers Affy and GTEX 23K SNPs
- HLA/KIR 14K SNPs

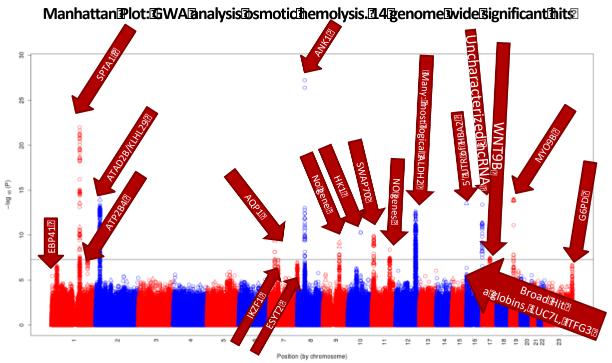
Guo et al. Transfusion, 2019

Candidate genes or SNPs with function or disease association, if known, showing 15 genome wide significant hits ($p < 5 \times 10^{-8}$)* for osmotic hemolysis and 4 genome wide significant hits** for oxidative hemolysis from RBC-Omics donors.

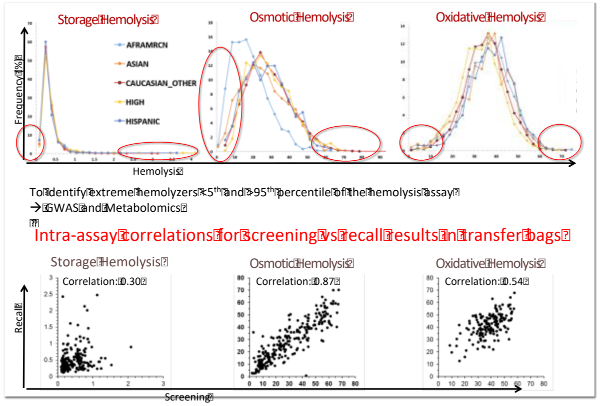
Examples of Candidate Genes or SNPs	Function / Disease Association	Type of Hemolysis
ANK1 (Ankyrin 1)	Hereditary Spherocytosis	Osmotic*
AQP1 (Aquaporin 1)	Water channel protein	Osmotic*
SPTA1 (Spectrin Alpha)	Hereditary Spherocytosis/Elliptocytosis	Osmotic*
PIEZ01	Mechanosensitive ion channel component 2	Osmotic*
HK1 (Hexokinase)	Mitochondrial membrane protein / hemolytic anemia	Osmotic*
SWAP70/LOC440028	SWAP switching B-cell complex	Osmotic*
MYO9B (Myosin IXB)	Myosin	Osmotic*
IKZF2/DDC/GRB10	Zink finger/Centromeric heterochromatin/ cell surface receptor kinases	Osmotic*
MIR4289	MircroRNA of unknown significance	Osmotic*
CNTN5/ARHGAP42	Contactin 5/ Rho GTPase activating protein 42	Osmotic*
SH2B3/BRAP/MAPKAPk5/NAA25/Others	SH2B adaptor protein 3/ BRCA1 associated protein	Osmotic*
HBA2	Hemoglobin subunit alpha 2	Osmotic*
SLC4A1/UBTF	Solute carrier family 4 (anion exchanger)/ Transcription factor, RNA polymerase I	Osmotic*
ANTXRLP1	Pseudogene	Osmotic*
EPB41 (Erythrocyte Membrane Protein Band 4.1)	Elliptocytosis-1	Osmotic*
ESYT2	Extended synaptotagmin-like protein 2	Osmotic
G6PD A-	G6PD deficiency	Oxidative**/Osmotic
GPX4 (Glutathione Peroxidase 4)	Role in oxidative stress	Oxidative**
GLRX (Gluaredoxin)	Role in oxidative stress	Oxidative**
SEC13L4/SEC14L2/SEC14L4	SEC14 like lipid binding 4	Oxidative**
TRAK1/ULK4	Trafficking protein, kinesin binding 1/ kinase 4	Oxidative

Page et al. JCI, 2021

REDS-III RBC-Omics data linkages



Manhattan Plot: GWA analysis osmotic hemolysis. 14 genome wide significant hits



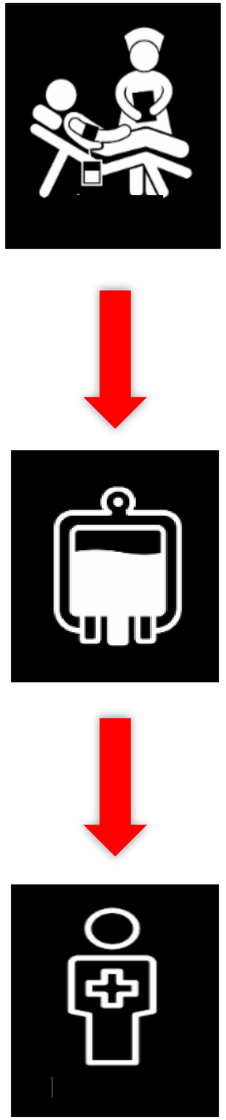
Storage Hemolysis
Osmotic Hemolysis
Oxidative Hemolysis

To identify extreme hemolyzers <5th and >95th percentile of the hemolysis assay
→ GWAS and Metabolomics

Intra-assay correlations for screening vs recall results in transfer bags

Storage Hemolysis
Osmotic Hemolysis
Oxidative Hemolysis

Donor genetic polymorphisms
***In vitro* hemolysis phenotype**



Blood Donor

Component manufacturing

Transfusion Recipient

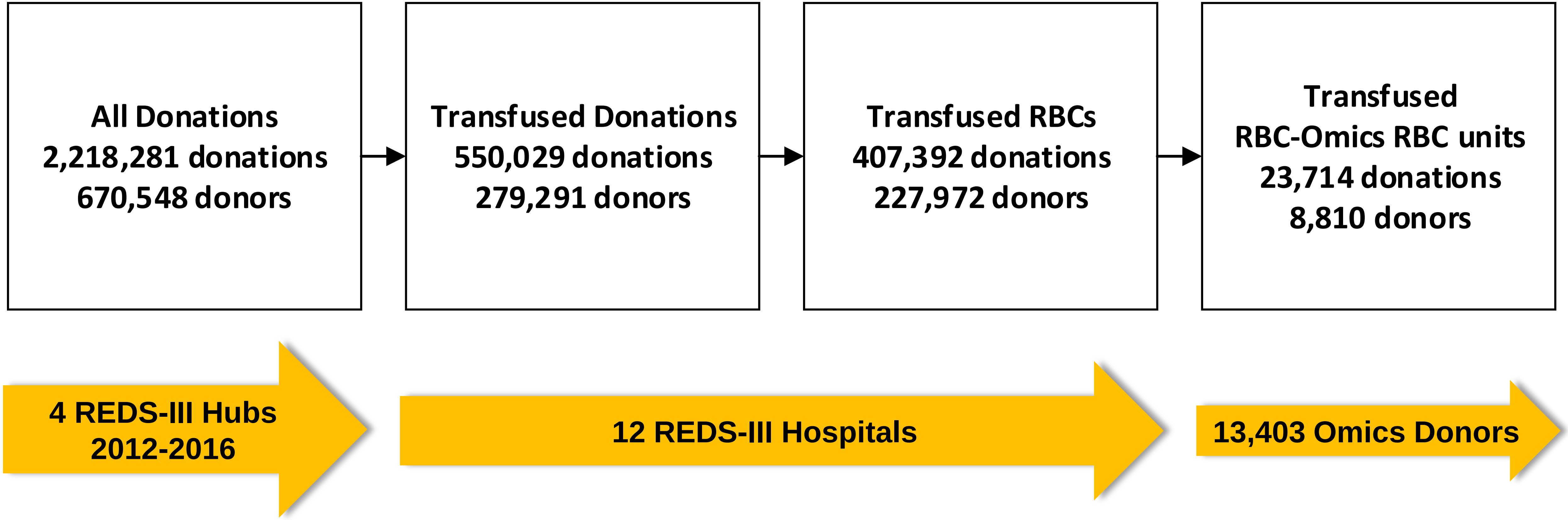
Δ Hemoglobin

Δ Bilirubin

Δ Creatinine

Outcomes

REDS-III donor & donation linkages



All Donations
2,218,281 donations
670,548 donors

Transfused Donations
550,029 donations
279,291 donors

Transfused RBCs
407,392 donations
227,972 donors

Transfused
RBC-Omics RBC units
23,714 donations
8,810 donors

4 REDS-III Hubs
2012-2016

12 REDS-III Hospitals

13,403 Omics Donors

Prevalence of selected SNPs associated with osmotic hemolysis in donors and transfused RBC recipients

	AQP1	**IKZF1**	**ANK1**	**HK1**	**GPX4**	**GLRX**
VRI RBC-Omics donors (n=3,129)						
Homozygous dominant	75.2%	28.8%	48.2%	86.6%	36.1%	91.4%
Heterozygous recessive	22.4%	48.4%	40.1%	12.8%	47.3%	8.3%
Homozygous recessive	2.4%	22.8%	11.7%	0.6%	16.5%	0.3%
KPNC RBC transfusions (n=3,434)						
Homozygous dominant	71.2%	27.9%	51.3%	84.3%	34.9%	89.3%
Heterozygous recessive	25.7%	49.8%	39.6%	15.0%	46.8%	10.5%
Homozygous recessive	3.1%	22.3%	9.2%	0.8%	18.3%	0.3%

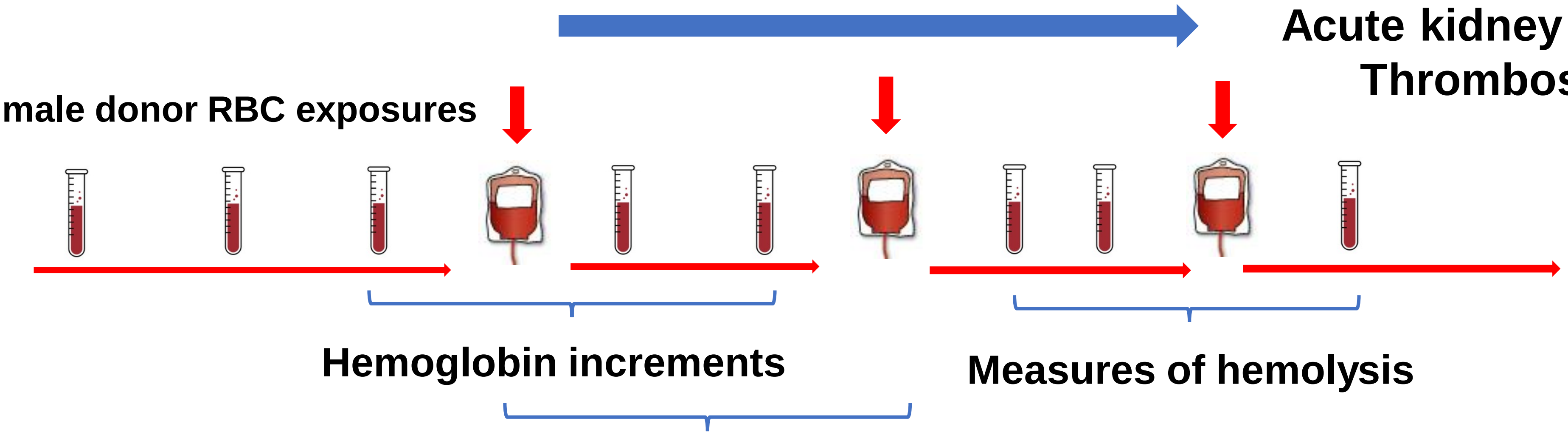
Need for additional RBC transfusion-1 week

Decreased Hb dose	**Increased Hb dose**
• Female donor • Donor age > 70 • Apheresis collection • Irradiated unit **47% transfused - 1 week**	• Male donor • Donor age < 70 • Whole blood collection • Unirradiated unit **28% transfused - 1 week**

19% absolute difference

40% relative rate difference

Longitudinal outcomes of RBC transfusion



Bacteremia
Acute kidney injury
Thrombosis

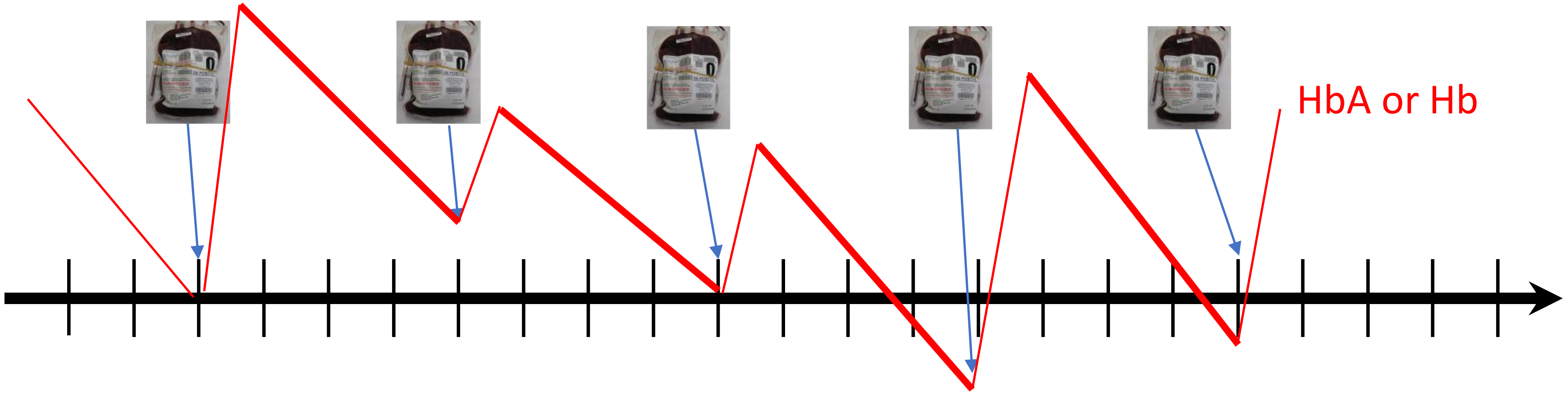
Gamma irradiated, male donor RBC exposures

Hemoglobin increments

Measures of hemolysis

Timing of subsequent transfusion

REDS-IV-P: Red Blood Cell – IMProving trAnsfusions for Chronically Transfused recipients (RBC – IMPACT)



Specific genetic donor factors influence RBC survival of units transfused to patients with SCD (measured by HbA) and Thalassemia (measured by total Hb)

REDS-III Linked donor-component-recipient database (2013-2016)

- 4 blood centers and 12 hospitals
- Donors and donations
  - Over 2 M successful donations from ~ 650,000 donors
    - Demographics, prior donation history
- Components and modifications
  - Over 5.5 M components
    - Collection method, processing and modifications: e.g., leukoreduction, additive solutions, gamma irradiation, volume reduction, storage age
- Recipients (inpatient and outpatients)
  - Over 1.5 M encounters from ~ 750,000 unique patients

www.biolincc.nhlbi.nih.gov

Summary

- Linked blood donor-component-recipient databases provide unique opportunities to study transfusion effectiveness
- Donor genotype and phenotype data will allow us to better understand mechanisms of clinical associations
- Studying granular longitudinal outcomes of transfusion are relevant to understand the role of donor and component covariates
- Ongoing collaboration and corroboration are critical

Acknowledgements

Vitalant / UCSF

Mike Busch
Brian Custer
Ed Murphy
Tamir Kanias

REDS-III/IV

Steve Kleinman
Simone Glynn
Grier Page
Rob De Simone
Angelo D’Alessandro

KPNC Division of Research

Gabriel Escobar
Colleen Plimier
Catherine Lee
Jason Lee

SCANDAT

Gustaf Edgren
Henrik Hjalgrim
Christian Erikstrup
Henrik Ullum