Data-driven clinical transfusion medicine: looking to the future

Ryan A. Metcalf, MD, CQA
Associate Professor (Clinical), University of Utah School of Medicine
Section Chief, Transfusion Medicine; Medical Director, Transfusion Service/Blood Bank; ARUP Laboratories

DEC 2023

Disclosures

- Inventor – *Sanguine*, data visualization tool

Patient Blood Management (PBM)

- A patient-centered, systematic, evidence-based approach to improve patient outcomes by **managing and preserving the patient's own blood**, while promoting patient safety and empowerment.

Shander et al. Anesth Analg. 2022.

Patient Blood Management (PBM)

- A patient-centered, systematic, evidence-based approach to improve patient outcomes by **managing and preserving the patient's own blood**, while promoting patient safety and empowerment.

Shander et al. Anesth Analg. 2022.

Patient Blood Management (PBM)

- A patient-centered, evidence-based approach to improve patient outcomes by managing and preserving the patient's own blood, while promoting patient safety and
  - Perioperative anemia management
  - Antifibrinolytic agents
  - Recycling of shed blood
  - Avoid unnecessary (optimize) transfusions
  - Improves outcomes and saves money

Shander et al. Anesth Analg. 2022.

Patient Blood Management (PBM) – Why do we care?

- Improves outcomes
- Blood transfusion = most common procedure[1]
- Top 5 most overused[2]
- PBM standard of care[3]

Value = Quality / Cost

1. HCUP Survey
2. Joint Commission Overuse Summit
3. Shander et al. Anesth Analg. 2016.

Improvement Initiatives in Patient Blood Management (PBM)

Implemented Project Examples

- Transfusion guidelines and best practice alert (BPA)
  - » Cost savings = $430,000/year
- Data-driven surgical blood ordering
  - » Cost savings (2017 vs 2022) = >$1,311,612/year
- Reducing unnecessary type & screens in OB
  - » Cost savings = $181,000/year
- Removing unnecessary product modifications
  - » $60,000/year
- **Total cost savings: $1,982,612M/year**

Received: 31 March 2020 | Revised: 1 October 2020 | Accepted: 15 November 2020
DOI: 10.1111/trf.16269

TRANSFUSION MEDICINE ILLUSTRATED

TRANSFUSION

Electronic clinical decision support: Evidence that default settings influence end-user behavior

Ryan A. Metcalf[1,2] | Jason Goodfellow[2] | Kelly Cail[2] | Robert Blaylock[1,2] | Kensaku Kawamoto[3] | Toby Enniss[4] | Charles Galaviz[5] | Ming Lim[6] | Santosh Reddy[6] | Vikas Sharma[4] | Nathan Wanner[6]

[1]Department of Pathology, University of Utah, Salt Lake City, Utah
[2]ARUP Laboratories, Salt Lake City, Utah
[3]Department of Medical Informatics, University of Utah, Salt Lake City, Utah
[4]Department of Surgery, University of Utah, Salt Lake City, Utah
[5]Department of Anesthesiology, University of Utah, Salt Lake City, Utah
[6]Department of Medicine, University of Utah, Salt Lake City, Utah

Correspondence
Ryan A. Metcalf, University of Utah Hospital, 50 N. Medical Drive, Salt Lake City, UT 84132.
Email: ryan.metcalf@path.utah.edu

PATIENT BLOOD MANAGEMENT

The association of inpatient blood utilization and diagnosis-related group weight: implications for risk-adjusted benchmarking

Ryan A. Metcalf[1,2] Sandra K. White,[1] Scott Potter,[1] Reed Barney,[3] Cheri Hunter,[3] Michael White,[3] Toby Enniss,[4] Charles Galaviz,[5] Santosh Reddy,[6] Nathan Wanner,[6] Robert L. Schmidt,[1,2] and Robert Blaylock[1,2]

Clinical Practice and Quality

Transfusion Preparedness in the Labor and Delivery Unit

An Initiative to Improve Safety and Cost

Ashley E. Benson, MD, MA, Ryan A. Metcalf, MD, Kelly Cail, BSc, Mark D. Rollins, MD, PhD, Christine M. Warrick, MD, Dane Falkner, MBA, Erin A.S. Clark, MD, MSCI, Richard E. Nelson, PhD, and Brett D. Einerson, MD, MPH

The Cost of a Transfusion

- Acquisition cost (e.g. ~$250/RBC unit)
- Total activity-based cost (e.g. ~$1000/RBC unit)

- If all hemodynamically stable inpatients treated with restrictive transfusion strategy → significant cost savings and many thousands of complications avoided

Shander et al. Transfusion. 2010.

RBC = red blood cell

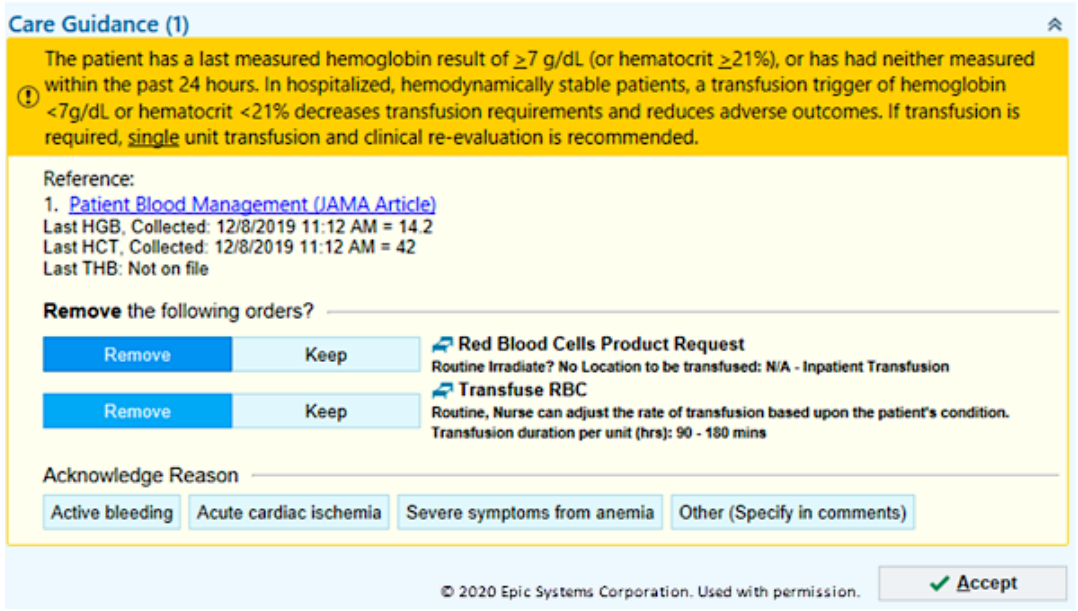
Clinical Decision Support for Transfusion Decisions

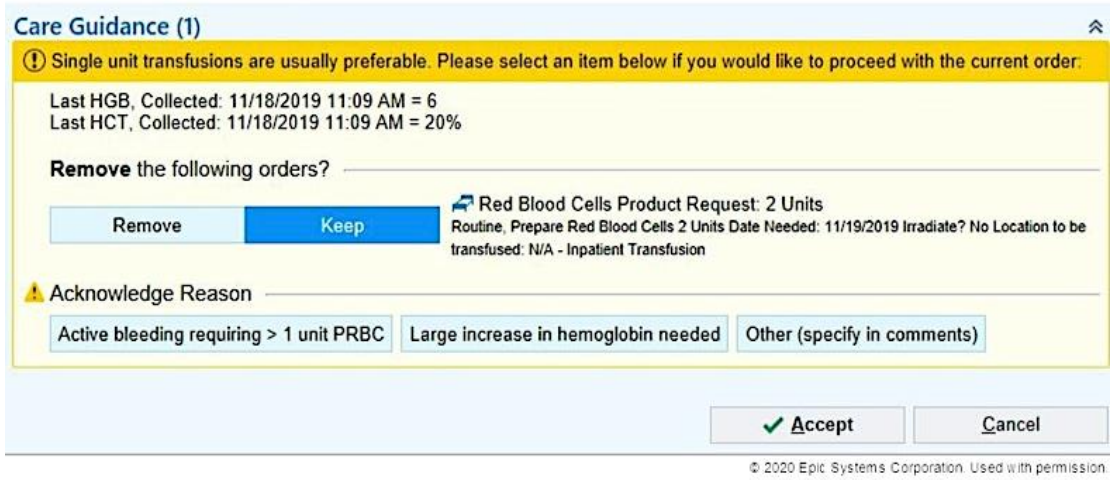
- Randomized trials, Cochrane reviews, and guidelines
  - » Generally support restrictive RBC transfusion strategy
- A variety of individuals make transfusion decisions
- How to support them within their workflows? – smooth/efficient/effective
- Clinical decision support (CDS)
  - » Systematic reviews suggest effective
  - » Mostly before and after study designs
- Should these be standard of care?

Carson et al. Cochrane Database Syst Rev. 2021.
Hibbs et al. Transfus Med Rev. 2015.
Soril et al. BMJ Open. 2018.

CDS Design

- Features: computer-based, recommendations, timing, in normal workflow
  - » In general, less is more
- We implemented two alerts:
  - » Hemoglobin threshold
  - » Single unit policy
- Single unit policy alert initially unsuccessful:
  - » Default action settings influence end user behavior
  - » <1% → 35% effective

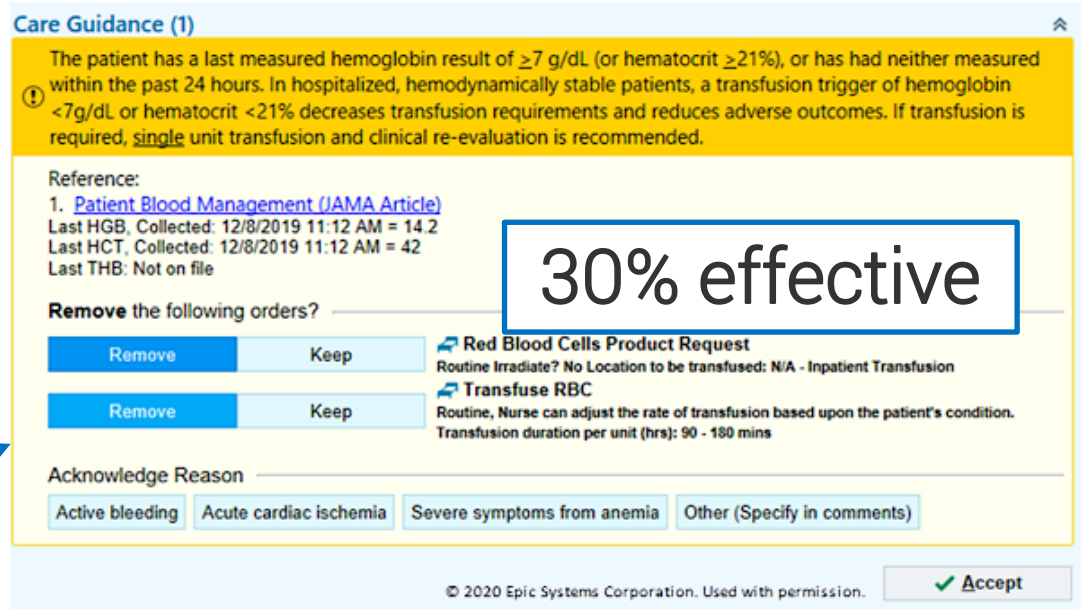


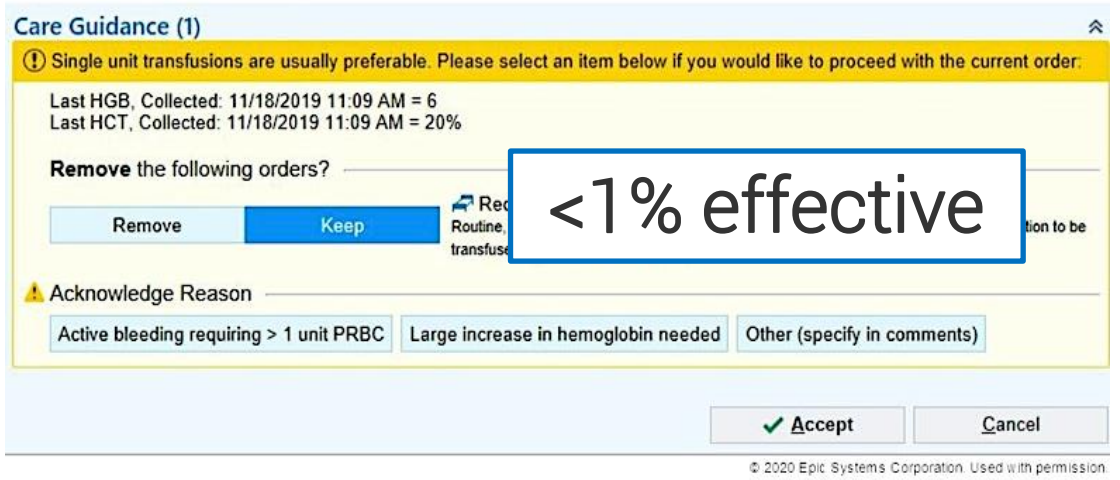


Kawamoto et al. BMJ. 2005.
Metcalf et al. Transfusion. 2021.

CDS Design

- Features: computer-based, recommendations, timing, in normal workflow
  - » In general, less is more
- We implemented two alerts:
  - » Hemoglobin threshold
  - » Single unit policy
- Single unit policy alert initially unsuccessful:
  - » Default action settings influence end user behavior
  - » <1% → 35% effective





Kawamoto et al. BMJ. 2005.
Metcalf et al. Transfusion. 2021.

Best Practice Advisory/CDS Results

- Pre-intervention: 4/2018 to 3/2019
- Post-intervention: 4/2019 to 3/2020

- Systemwide 11% reduction in RBCs transfused
- Acquisition cost savings ~$430k/year

How to make alerts more intelligent?

Blood Product Order	Transfusion Indication Selected (Required)	Test Result to Cause CDS Alert to Fire
RBCs	Severe acute bleeding	NA
	Hb < 7g/dL	Hb ≥ 7g/dL
	Hb < 7.5g/dL CT surgery	Hb ≥ 7.5g/dL
	Hb < 8g/dL ACS	Hb ≥ 8g/dL
	Other	Hb ≥ 7g/dL
Platelets	Severe acute bleeding	NA
	PLT < 10k stable patient	PLT ≥ 10k
	PLT < 20k consumption	PLT ≥ 20k
	PLT < 50k preprocedure/bleeding	PLT ≥ 50k
	Bleeding on anti-PLT med	NA
	Other (provide details)	PLT ≥ 10k

ACS = acute coronary syndrome

How to make alerts more intelligent?

Blood Product Order	Transfusion Indication Selected (Required)	Test Result to Cause CDS Alert to Fire
RBCs	Severe acute bleeding	NA
	Hb < 7g/dL	Hb ≥ 7g/dL
	Hb < 7.5g/dL CT surgery	Hb ≥ 7.5g/dL
	Hb < 8g/dL ACS	Hb ≥ 8g/dL
	Other	Hb ≥ 7g/dL
Platelets	Severe acute bleeding	NA
	PLT < 10k stable patient	PLT ≥ 10k
	PLT < 20k consumption	PLT ≥ 20k
	PLT < 50k preprocedure/bleeding	PLT ≥ 50k
	Bleeding on anti-PLT med	NA
	Other (provide details)	PLT ≥ 10k

ACS = acute coronary syndrome

How to make alerts more intelligent?

Blood Product Order	Transfusion Indication Selected (Required)	Test Result to Cause CDS Alert to Fire
RBCs	Severe acute bleeding	NA
	Hb < 7g/dL	Hb ≥ 7g/dL
	Hb < 7.5g/dL CT surgery	Hb ≥ 7.5g/dL
	[illegible]	Hb ≥ 8g/dL
	[illegible]	Hb ≥ 7g/dL
Platelets	Sev[illegible]g	NA
	PLT <[illegible]ent	PLT ≥ 10k
	PLT < 20k consumption	PLT ≥ 20k
	PLT < 50k preprocedure/bleeding	PLT ≥ 50k
	Bleeding on anti-PLT med	NA
	Other (provide details)	PLT ≥ 10k

ACS = acute coronary syndrome

JAMA | Special Communication

Red Blood Cell Transfusion
2023 AABB International Guidelines

Jeffrey L. Carson, MD; Simon J. Stanworth, MD, DPhil; Gordon Guyatt, MD; Stacey Valentine, MD, MPH; Jane Dennis, PhD; Sara Bakhtary, MD; Claudia S. Cohn, MD, PhD; Allan Dubon, MLS; Brenda J. Grossman, MD, MPH; Gaurav K. Gupta, MD, PhD; Aaron S. Hess, MD, PhD; Jessica L. Jacobson, MD; Lewis J. Kaplan, MD; Yulia Lin, MD; Ryan A. Metcalf, MD; Colin H. Murphy, MD; Katerina Pavenski, MD; Micah T. Prochaska, MD; Jay S. Raval, MD; Eric Salazar, MD, PhD; Nabiha H. Saifee, MD, PhD; Aaron A. R. Tobian, MD, PhD; Cynthia So-Osman, MD, PhD; Jonathan Waters, MD; Erica M. Wood, MD; Nicole D. Zantek, MD, PhD; Monica B. Pagano, MD

Recommendation 1

For hospitalized adult patients who are hemodynamically stable, the international panel recommends a restrictive RBC transfusion strategy in which the transfusion is considered when the hemoglobin concentration is less than 7 g/dL (strong recommendation, moderate certainty evidence).

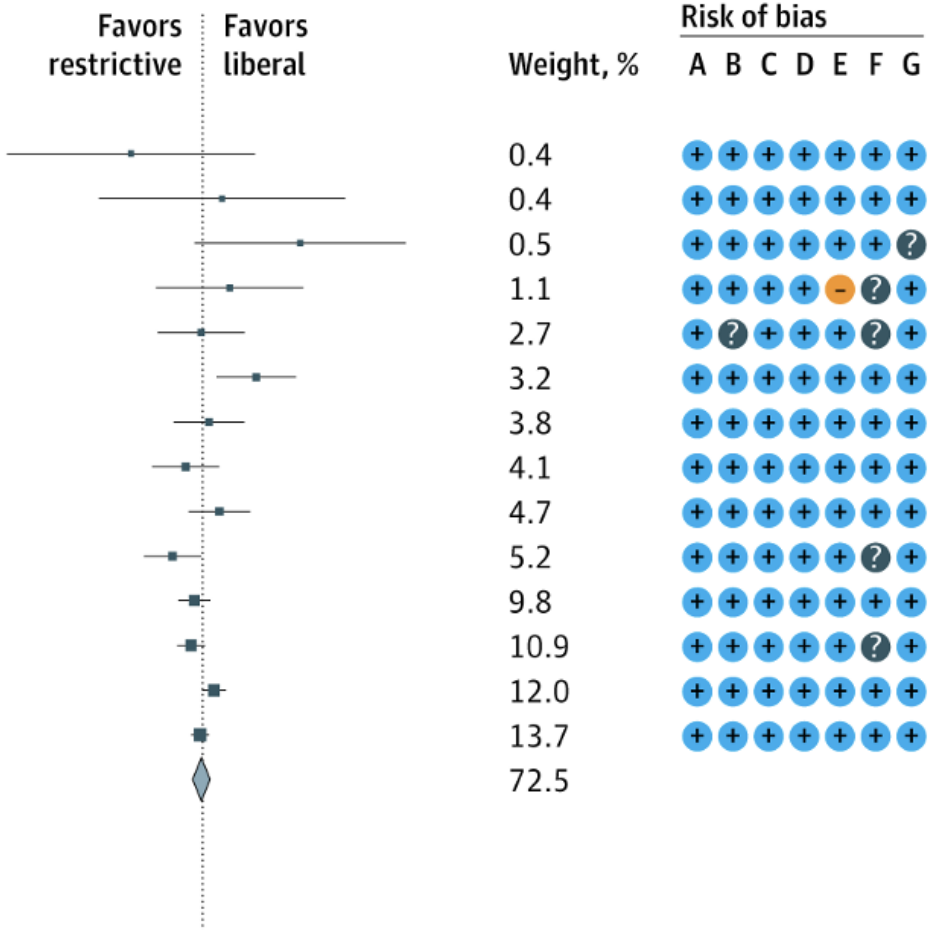
Remark: in accordance with the restrictive strategy threshold used in most of the trials for subgroups of patients, clinicians may choose a threshold of 7.5 g/dL for patients undergoing cardiac surgery and 8 g/dL for patients undergoing orthopedic surgery or those with preexisting cardiovascular disease.

Carson et al. JAMA. 2023

Summary of Major RBC Threshold Trials

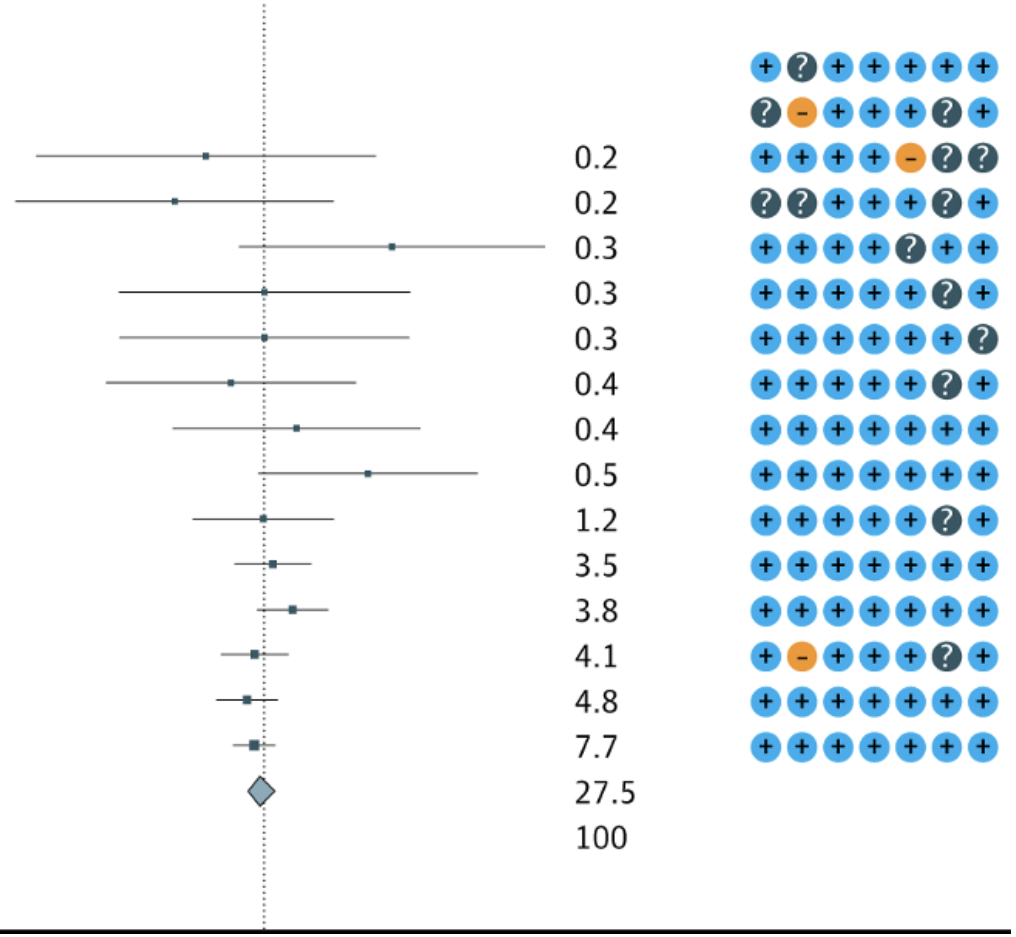
Trial	Population	Participants (n)	Thresholds (hemoglobin)	Primary outcome
TRICC	Critical care	838	7 g/dL vs 10 g/dL	30d mortality 18.7% vs 23.3%, P=0.11
FOCUS	Hip fracture	2016	8 g/dL vs 10 g/dL	Death or inability to walk across room at 60d, 35.2% vs 34.7%, P=0.9
Villanueva et al.	Upper GI Hemorrhage	921	7 g/dL vs 9 g/dL	Mortality at 45d, 5% vs 9% P=0.02
TRISS	Septic Shock	998	7 g/dL vs 9 g/dL	90d mortality, 43% vs 45% P=0.44
TITRE2	Post-cardiac surgery	2003	7.5 g/dL vs 9 g/dL	Infection or ischemic event in 3mo, 35.1% vs 33.0% P=0.3
TRICS-III	Cardiac surgery	4860	7.5 g/dL vs 8.5 or 9.5 g/dL	Composite, 11.4% vs 12.5% P<0.001 for noninferiority

Study or subgroup	Restrictive threshold No. of events	Total	Liberal threshold No. of events	Total	Risk ratio (95% CI)
Restrictive, 7.0-7.5 g/dL					
DeZern et al,[33] 2016	1	59	2	30	0.25 (0.02-2.69)
Gillies et al,[36] 2020	2	36	1	26	1.44 (0.14-15.10)
Gobatto et al,[37] 2019	7	23	1	21	6.39 (0.86-47.7)
Parker,[38] 2013	5	100	3	100	1.67 (0.41-6.79)
Hébert et al,[39] 1995	8	33	9	36	0.97 (0.42-2.22)
de Almeida et al,[40] 2015	23	101	8	97	2.76 (1.30-5.87)
Palmieri et al,[41] 2017	16	168	15	177	1.12 (0.57-2.20)
Walsh et al,[42] 2013	12	51	16	49	0.72 (0.38-1.36)
Murphy et al,[43] 2015	26	1000	19	1003	1.37 (0.76-2.46)
Villanueva et al,[44] 2013	19	416	34	417	0.56 (0.32-0.97)
Mazer et al,[45] 2017	74	2427	87	2429	0.85 (0.63-1.15)
Hébert et al,[46] 1999	78	418	98	420	0.80 (0.61-1.04)
Bergamin et al,[47] 2017	84	151	67	149	1.24 (0.99-1.55)
Holst et al,[48] 2014	168	502	175	496	0.95 (0.80-1.13)
Subtotal (95% CI)	5485		5450		1.00 (0.83-1.21)
Total events	523		535		
Heterogeneity: $\tau^2 = 0.05$; $\chi^2 = 26.15$; $df = 13$; $P = .02$; $I^2 = 50\%$					
Test for overall effect: $z = 0.01$; $P = .99$					



Carson et al. JAMA. 2023

Restrictive, <8.0-9.0 g/dL						
Lotke et al,[49] 1999	0	62	0	65	Not estimable	
Laine et al,[50] 2018	0	40	0	40	Not estimable	
Grover et al,[51] 2006	0	109	1	109	0.33 (0.01-8.09)	0.2
Blair et al,[52] 1986	0	26	2	24	0.19 (0.01-3.67)	0.2
Foss et al,[53] 2009	5	60	0	60	11.0 (0.62-194.6)	0.3
Carson et al,[54] 1998	1	42	1	42	1.00 (0.06-15.5)	0.3
Møller et al,[55] 2019	1	29	1	29	1.00 (0.07-15.2)	0.3
Webert et al,[56] 2008	1	29	2	31	0.53 (0.05-5.58)	0.4
Cooper et al,[57] 2011	2	23	1	21	1.83 (0.18-18.7)	0.4
Carson et al,[58] 2013	7	55	1	55	7.00 (0.89-55.0)	0.5
Bush et al,[59] 1997	4	50	4	49	0.98 (0.26-3.70)	1.2
Hajjar et al,[60] 2010	15	249	13	253	1.17 (0.57-2.41)	3.5
Gregersen et al,[61] 2015	21	144	12	140	1.70 (0.87-3.32)	3.8
Jairath et al,[62] 2015	14	257	25	382	0.83 (0.44-1.57)	4.1
Ducrocq et al,[63] 2021	19	342	25	324	0.72 (0.40-1.28)	4.8
Carson et al,[64] 2011	43	1009	52	1007	0.83 (0.56-1.22)	7.7
Subtotal (95% CI)	2526		2631		0.97 (0.75-1.24)	27.5
Total events	133		140			100
Heterogeneity: $\tau^2 = 0.01$; $\chi^2 = 13.35$; $df = 13$; $P = .42$; $I^2 = 3\%$						
Test for overall effect: $z = 0.27$; $P = .78$						



Carson et al. JAMA. 2023

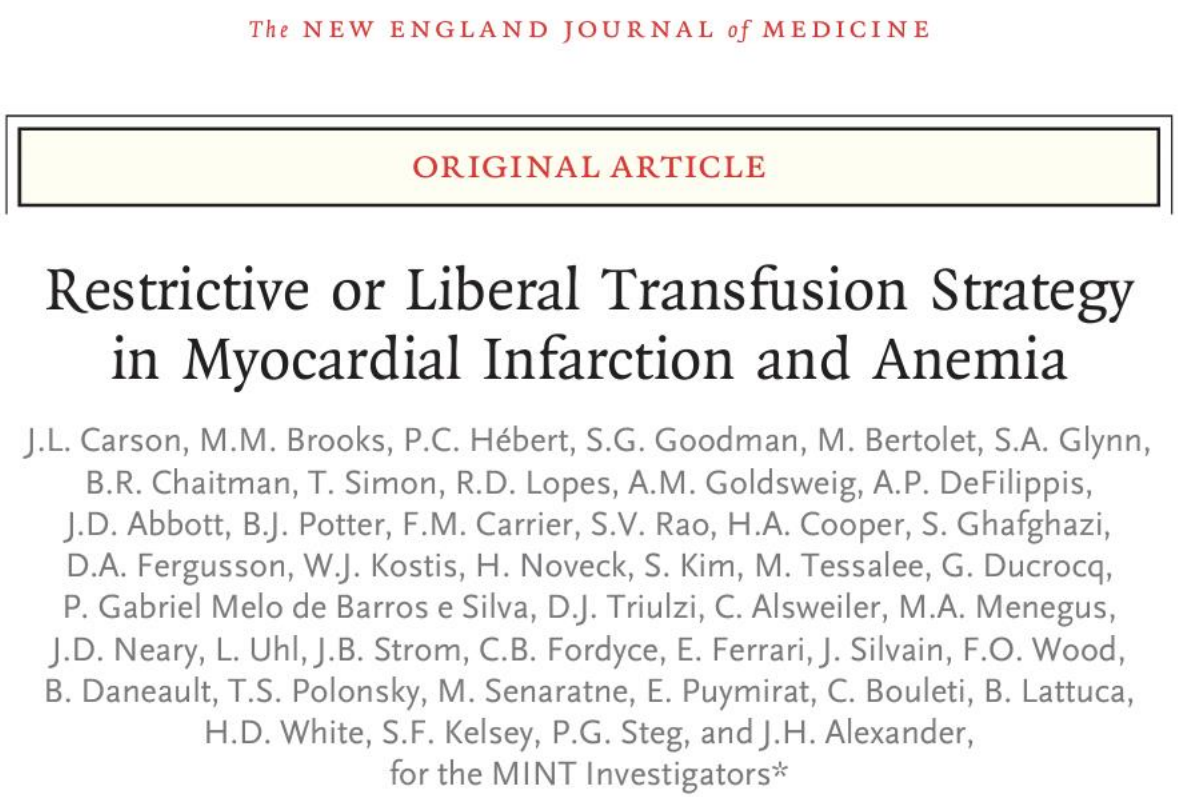
Recommendation 2

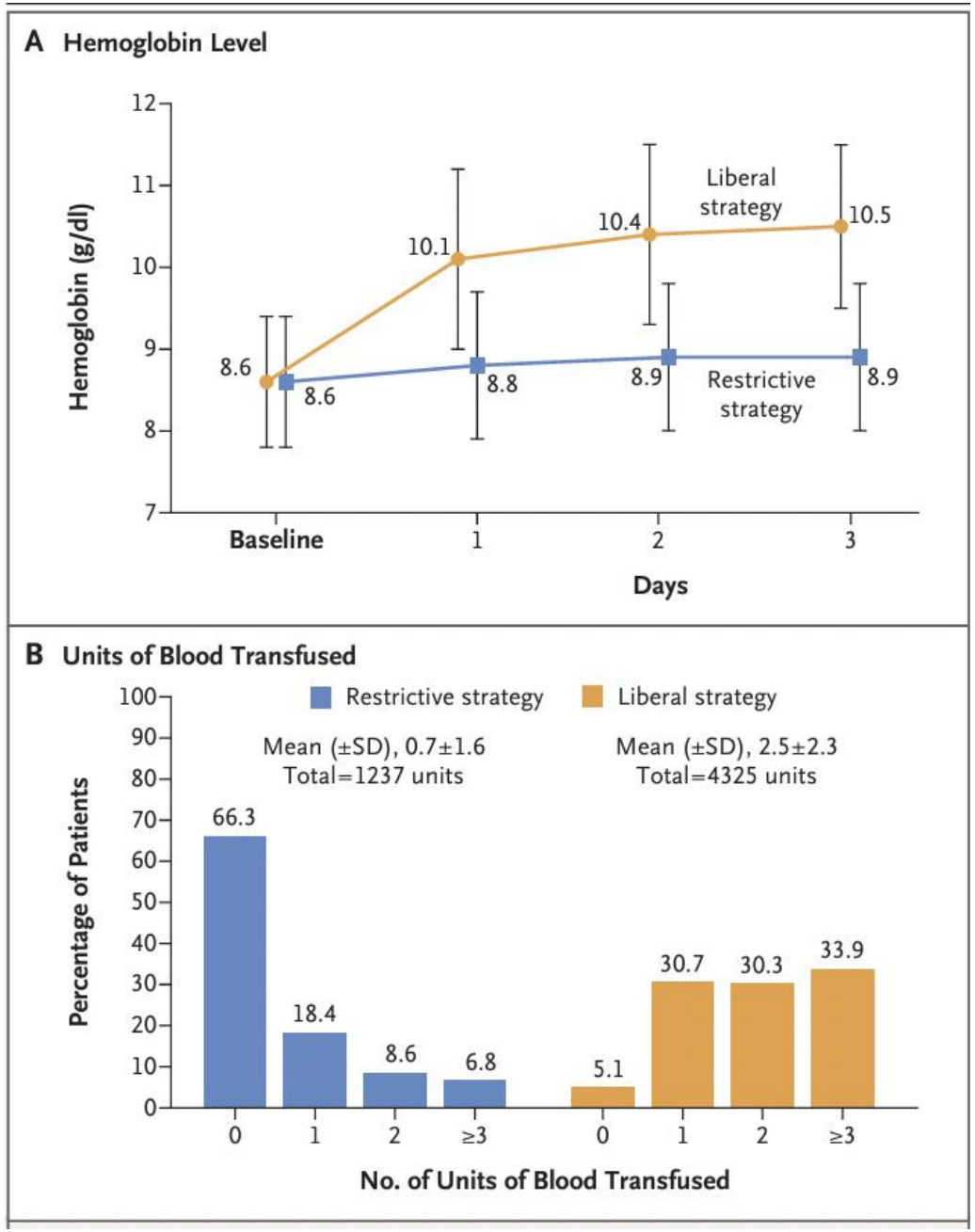
For hospitalized adult patients, the panel suggests a restrictive RBC transfusion strategy in which transfusion is considered when the hemoglobin concentration is less than 7 g/dL in those with hematologic and oncologic disorders (conditional recommendation, low certainty evidence).

Carson et al. JAMA. 2023

MINT Trial

- Population
  - Myocardial infarction (MI)
  - N=3504
- Intervention & Comparison
  - RBC transfusion: restrictive (Hgb<7-8g/dL) vs liberal (Hgb<10g/dL) transfusion strategy
- Outcome
  - Death or MI at 30d
  - Risk ratio 1.15 (95%CI 0.99-1.34)





Note: 14% of subjects in the liberal arm were not transfused liberally due to clinical discretion (e.g. risk of transfusion associated circulatory overload, TACO).

Carson et al. N Engl J Med. 2023.

Outcome	Restrictive Strategy	Liberal Strategy	Risk Ratio (95% CI)
	no. of patients/total no. (%)		
Primary outcome			
Myocardial infarction or death	295/1749 (16.9)	255/1755 (14.5)	1.16 (1.00–1.35)
Secondary outcomes			
Death	173/1749 (9.9)	146/1755 (8.3)	1.19 (0.96–1.47)
Myocardial infarction	149/1749 (8.5)	126/1755 (7.2)	1.19 (0.94–1.49)
Death, myocardial infarction, revascularization, or rehospitalization	342/1749 (19.6)	305/1755 (17.4)	1.13 (0.98–1.29)
Other outcomes			
Heart failure	102/1749 (5.8)	111/1755 (6.3)	0.92 (0.71–1.20)
Death, myocardial infarction, or unstable angina	338/1749 (19.3)	300/1755 (17.1)	1.13 (0.98–1.30)
Unscheduled revascularization	43/1749 (2.5)	39/1755 (2.2)	1.11 (0.72–1.70)
Cardiac death	97/1749 (5.5)	56/1755 (3.2)	1.74 (1.26–2.40)
Stroke	30/1749 (1.7)	26/1755 (1.5)	1.16 (0.69–1.95)
Pulmonary embolism or deep venous thrombosis	26/1749 (1.5)	34/1755 (1.9)	0.77 (0.46–1.27)
Pneumonia or bacteremia	166/1749 (9.5)	153/1755 (8.7)	1.09 (0.88–1.34)

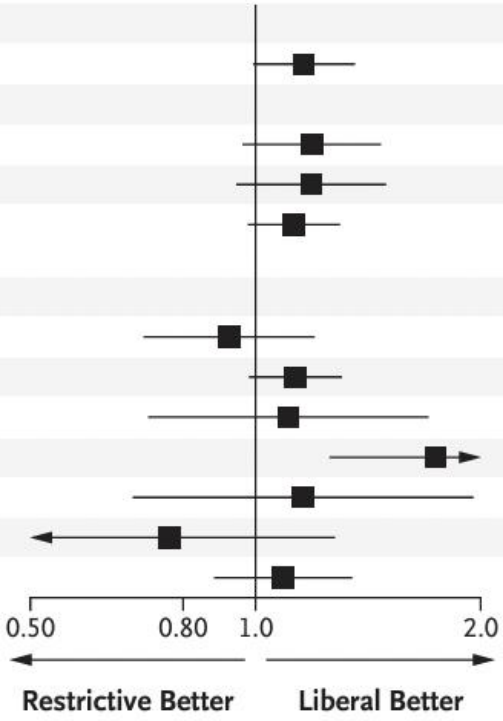


Figure 2. Trial Outcomes at 30 Days.

Shown are the unadjusted risk ratios for the primary, secondary, and other outcomes in patients assigned to a restrictive transfusion strategy as compared with those assigned to a liberal transfusion strategy. The estimate for the primary model with imputed missing data was a risk ratio of 1.15 (95% CI, 0.99 to 1.34; P=0.07).

Carson et al. N Engl J Med. 2023.

Transfusion Related Adverse Events	Restrictive	Liberal	
Transfusion related acute lung injury (TRALI)	0/1748 (0.0%)	6/1754 (0.3%)	- (-.-)
Transfusion associated cardiac overload (TACO)	8/1749 (0.5%)	23/1755 (1.3%)	0.35 (0.16,0.78)
Acute hemolytic transfusion reaction	0/1748 (0.0%)	4/1754 (0.2%)	- (-.-)
Transfusion associated sepsis	0/1748 (0.0%)	1/1754 (0.1%)	- (-.-)
Anaphylactic transfusion reaction	2/1748 (0.1%)	2/1754 (0.1%)	1.00 (0.14,7.12)
Urticarial transfusion reaction	0/1748 (0.0%)	2/1754 (0.1%)	- (-.-)
Febrile non-hemolytic transfusion reaction	1/1748 (0.1%)	14/1754 (0.8%)	0.07 (0.01,0.54)

Carson et al. N Engl J Med. 2023.

Novel Data Science Approaches in Transfusion Medicine

Artificial intelligence (AI) discourse is everywhere

- AI: technologies for functions associated with human intelligence
- Machine Learning (ML): use data to improve with experience
- AI/ML will continue to impact everyday life
  - » More data and computing power
  - » Better algorithms
- Expanding role in Transfusion Medicine (TM)

AI/ML in TM: numerous potential use cases

- Predict transfusions
- Personalized transfusion indications
- *In silico* clinical trials
- Predict bleeding
- Predict laboratory values
- Predict/identify adverse events
- Tasks requiring TM knowledge

- Personalized blood component selection

- Augment supply chain or hospital blood bank operations
  - Transportation efficiency
  - Inventory optimization
  - Document management efficiency
  - Quality control tasks

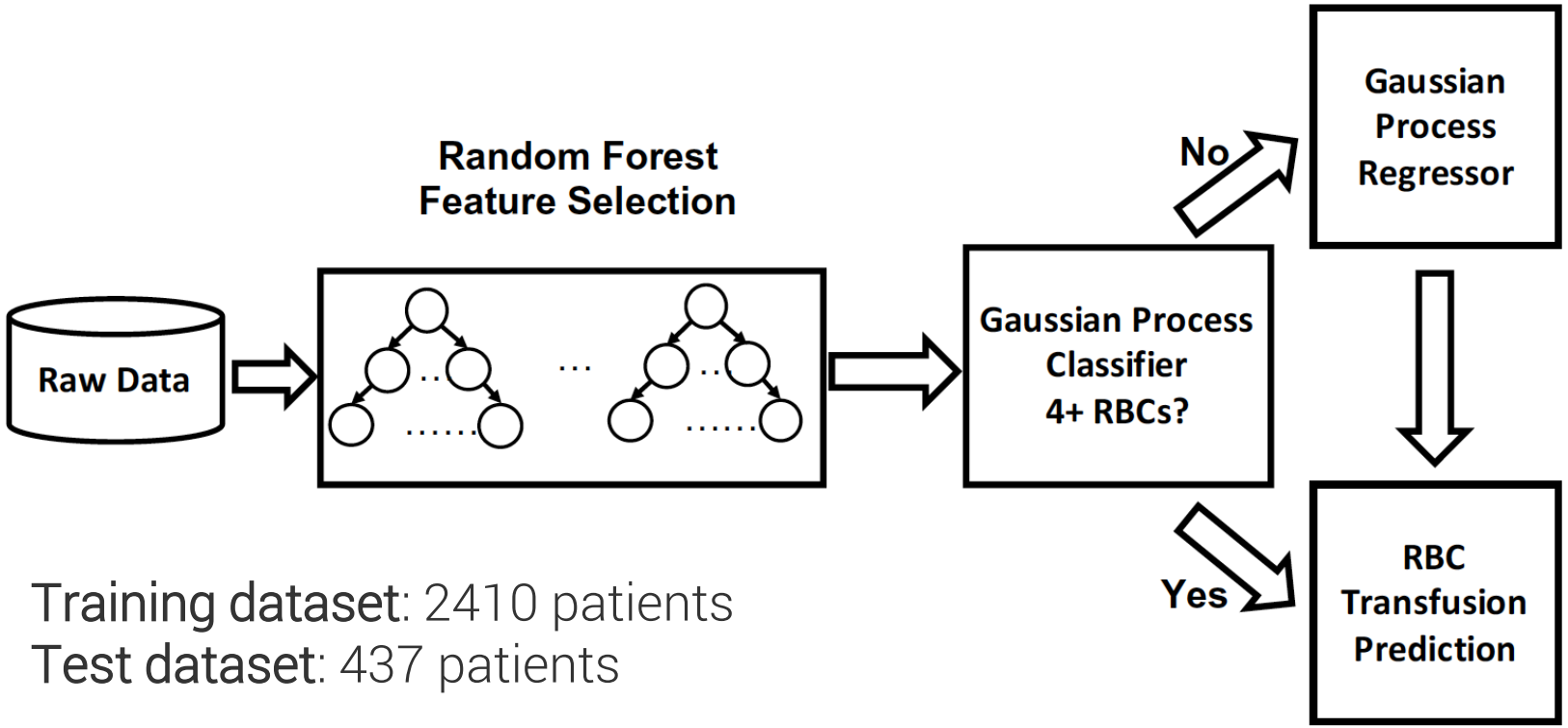
Question: Can we predict transfusion needs in Cardiothoracic Surgery using preoperative variables?

Development and validation of a machine learning method to predict intraoperative red blood cell transfusions in cardiothoracic surgery

Zheng Wang, Shandian Zhe, Joshua Zimmerman, Candice Morrisey, Joseph E. Tonna, Vikas Sharma & Ryan A. Metcalf

Scientific Reports **12**, Article number: 1355 (2022) | Cite this article

Hybrid ML Model:



Training dataset: 2410 patients
Test dataset: 437 patients

Predicting RBC Transfusions in Cardiothoracic Surgery

	All patients (test + training datasets)	0 units transfused	1-3 units transfused	4+ units transfused
Number of cases	2847 (100%)	1962 (69%)	712 (25%)	173 (6%)
RBC transfusions (mean)	1.26	0	1.62	6.34
Most common procedure	CABG[a]	CABG[a]	CABG[a]	Ascending aortic dissection

[a]CABG = coronary artery bypass graft

Wang et al. Sci Rep. 2022.

Predicting RBC Transfusions in Cardiothoracic Surgery

	All patients (test + training datasets)	0 units transfused	1-3 units transfused	4+ units transfused
Number of cases	2847 (100%)	1962 (69%)	712 (25%)	173 (6%)
RBC transfusions (mean)	1.26	0	1.62	6.34
Most common procedure	CABG[a]	CABG[a]	CABG[a]	Ascending aortic dissection

[a]CABG = coronary artery bypass graft

Top Features
Extracorporeal membrane oxygenation (ECMO)
Thoracoabdominal aneurysm repair
Blood gas, barometric pressure
Blood gas, potassium
Ionized calcium
Hemoglobin
Respiratory ventilation >96 hours

Wang et al. Sci Rep. 2022.

Predicting RBC Transfusions in Cardiothoracic Surgery

	All patients (test + training datasets)	0 units transfused	1-3 units transfused	4+ units transfused
Number of cases	2847 (100%)	1962 (69%)	712 (25%)	173 (6%)
RBC transfusions (mean)	1.26	0	1.62	6.34
Most common procedure	CABG[a]	CABG[a]	CABG[a]	Ascending aortic dissection

[a]CABG = coronary artery bypass graft

Model	0-3 units transfused	4+ units transfused
Gaussian Process Regression	0.985[b]	56.941[b]
Gaussian Process Classification	0.826[c] and 0.766[d]	

[b]root mean square error
[c]Area Under Receiver Operator Curve (AUROC)
[d]F1 score

Top Features
Extracorporeal membrane oxygenation (ECMO)
Thoracoabdominal aneurysm repair
Blood gas, barometric pressure
Blood gas, potassium
Ionized calcium
Hemoglobin
Respiratory ventilation >96 hours

Wang et al. Sci Rep. 2022.

Question: Can we predict massive transfusion during surgery in "real time"?

	Development dataset (n=12,535)	Internal validation (n=5451)	External validation (n=494)
Massive transfusion	310 (2.5%)	106 (1.9%)	11 (2.2%)

Lee et al. JAMA Open. 2022.

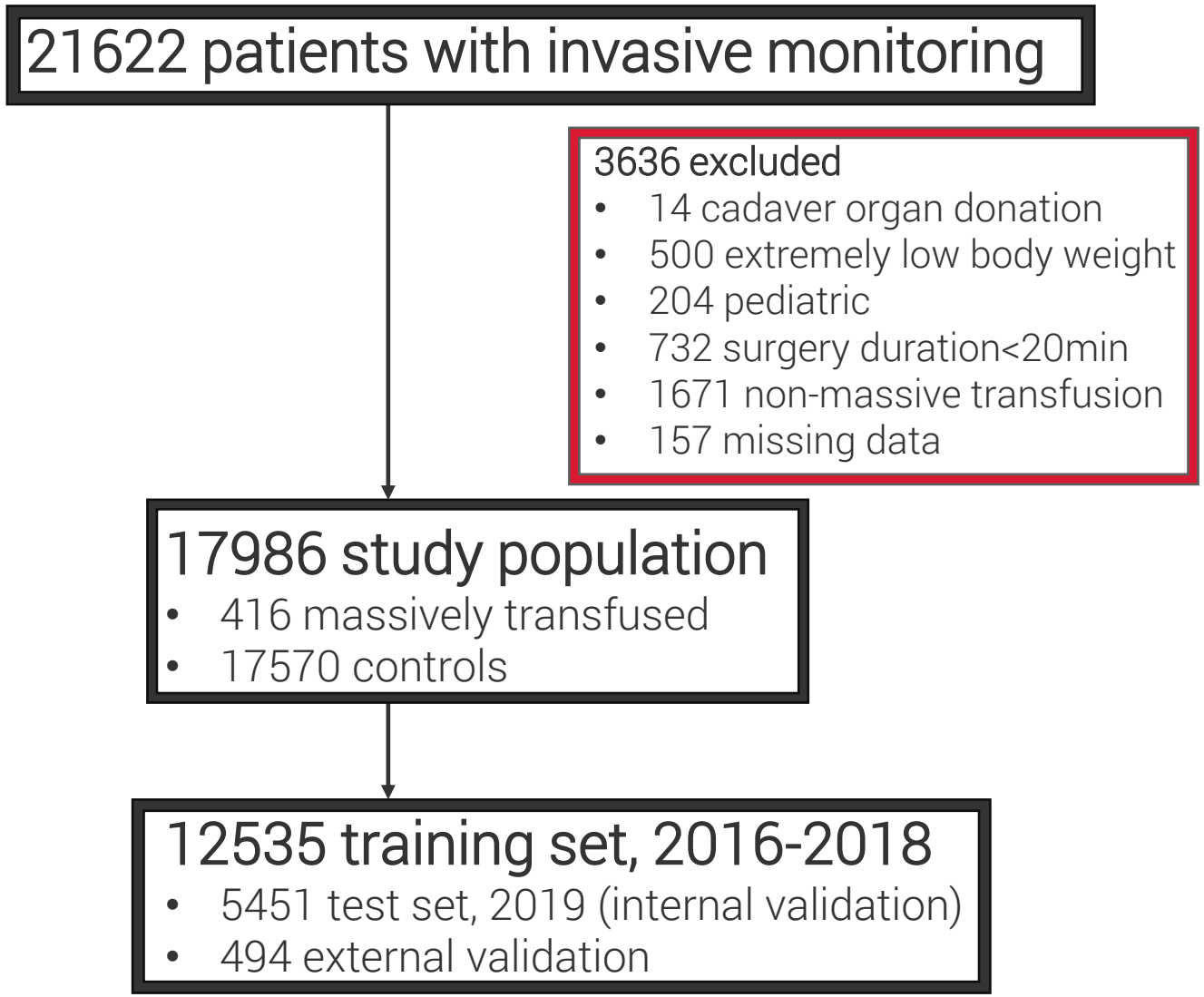
Question: Can we predict massive transfusion during surgery in "real time"?

	Development dataset (n=12,535)	Internal validation (n=5451)	External validation (n=494)
Massive transfusion	310 (2.5%)	106 (1.9%)	11 (2.2%)

	Internal validation	External validation
Preoperative Model (Gradient Boosting)	0.824[a] and 0.193[b]	-
Real-time Model (Preoperative variables and area under arterial waveform each cardiac beat, hematocrit, O2 sat, ST segment elevation)	0.972[a] and 0.571[b]	0.943[a]

[a]Area Under Receiver Operator Curve (AUROC)
[b]Area Under Precision Recall Curve (AUPRC)

Lee et al. JAMA Open. 2022.

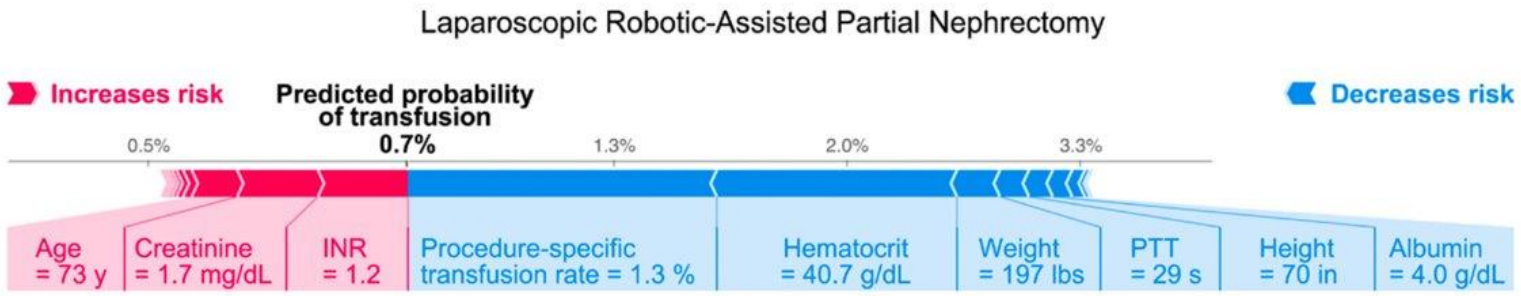


Lee et al. JAMA Open. 2022.

Question: can we predict the need for preoperative type & screen?

- National Surgical Quality Improvement Program (NSQIP) and local databases

- At fixed 96% sensitivity, type & screen recommended:
  - » Gradient boosting: 30-36%
  - » Control (procedure specific transfusion rate): 45-57%



Lou et al. Anesthesiology. 2022.

Foundation Models – example use cases

- Transfusion Medicine knowledge-based tasks

	RBC Transfusion Indications, AUROC	BEST Test[a]
Bard	0.65	55%
GPT 3.5[b]	0.90	40%
GPT 4[b]	0.92	87%

a: BEST = Biomedical Excellence for Safer Transfusion
b: Generative Pre-trained Transformer

Hurley et al. Transfusion. 2023.

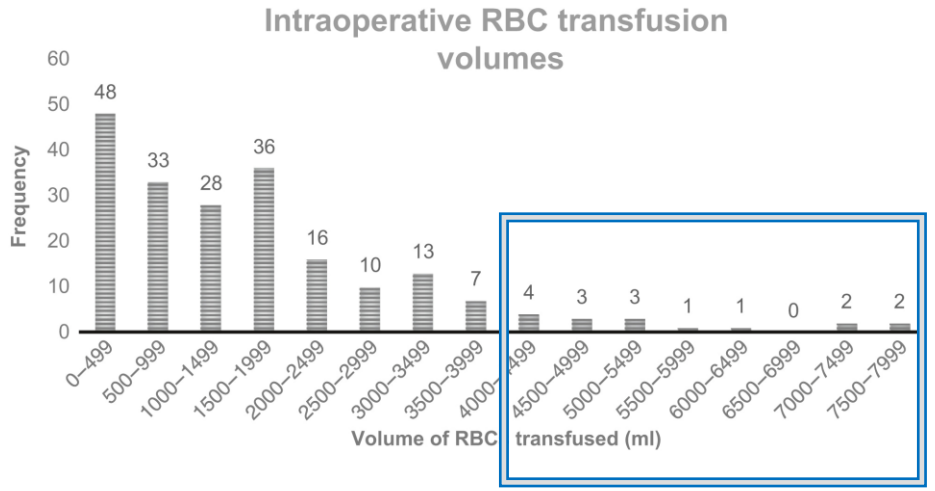
A transformative future?

- Chatbots making diagnoses and treatment recommendations?
  - » Great potential
  - » Also concerns

Haug et al. N Engl J Med. 2023.

AI/ML: Current gaps, challenges, and considerations

- Methodology: TRIPOD reporting guideline, PROBAST risk of bias tool
  - » Handling of missing values, validation, sample size, etc
- Class imbalance – infrequent outcomes
- Biases in datasets
- Local data vs multicenter, data governance
- Implementation gap
  - » Where do the data reside? Accessible?
- Proving benefit



Metcalf et al. Vox Sang. 2018.

Can transfusion medicine take a leading role in responsible use of AI?

- Quality and innovation:
  - » Opposing forces or synergistic partners?
- Co-evolution: quality/safety and data-driven innovations
- Quality management systems (QMS) approach
  - » Development, implementation, monitoring, improvement, optimization
  - » Will rapid acceleration in evolution of AI automate/embed some QMS principles?

Putting the horse before the cart

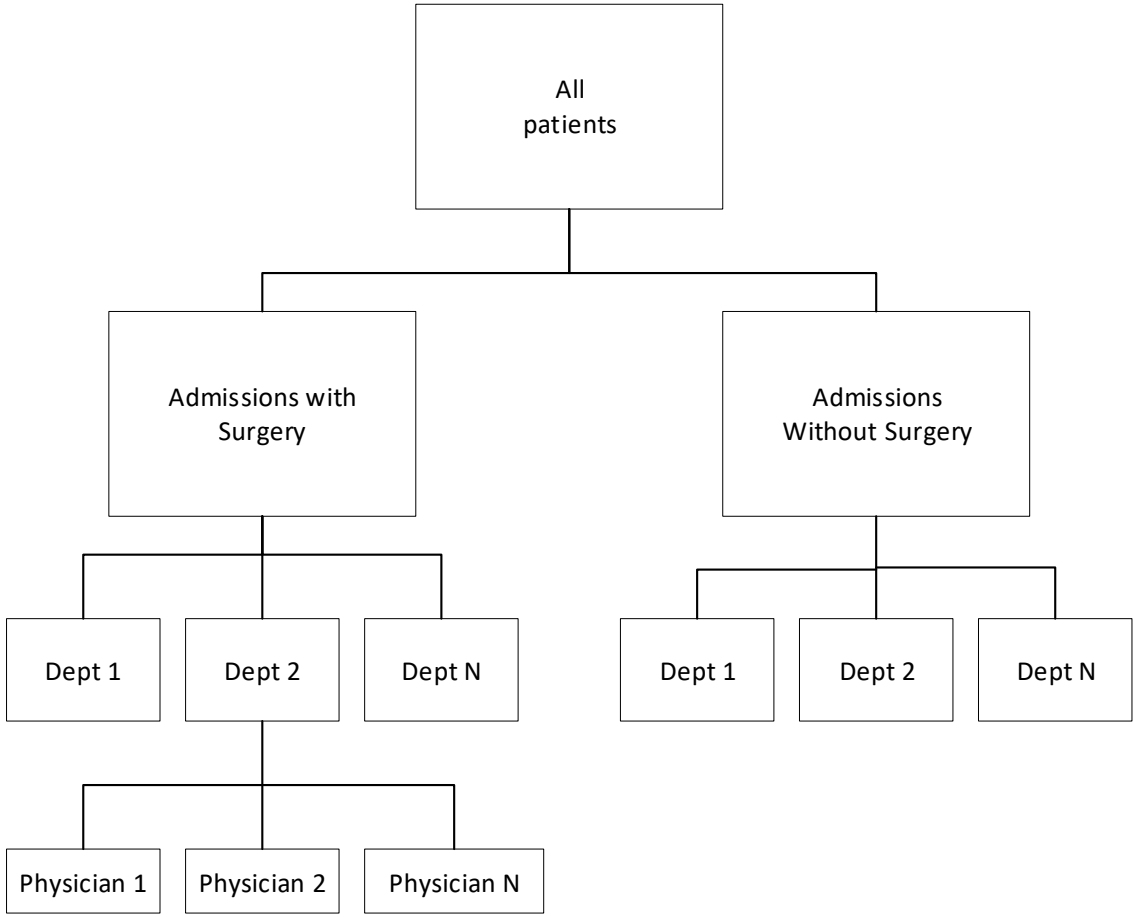
- AI/ML relies on data from the past
  - » Could predictions perpetuate suboptimal practices?
- How are we *really* doing currently with respect to practice quality?

Sanguine: Advanced Data Visualization for Patient Blood Management (PBM)

Going beyond Optimal Blood Use ("OBU")

Risk Adjusted Benchmarking and Hierarchical Levels

- Lab value thresholds: useful, but have limitations
- Complex bleeding patients
  - » Evaluate overall patient blood management (PBM) practice
- Valid question: what if my patients are sicker?
  - » Risk adjusted benchmarking using billing code weights

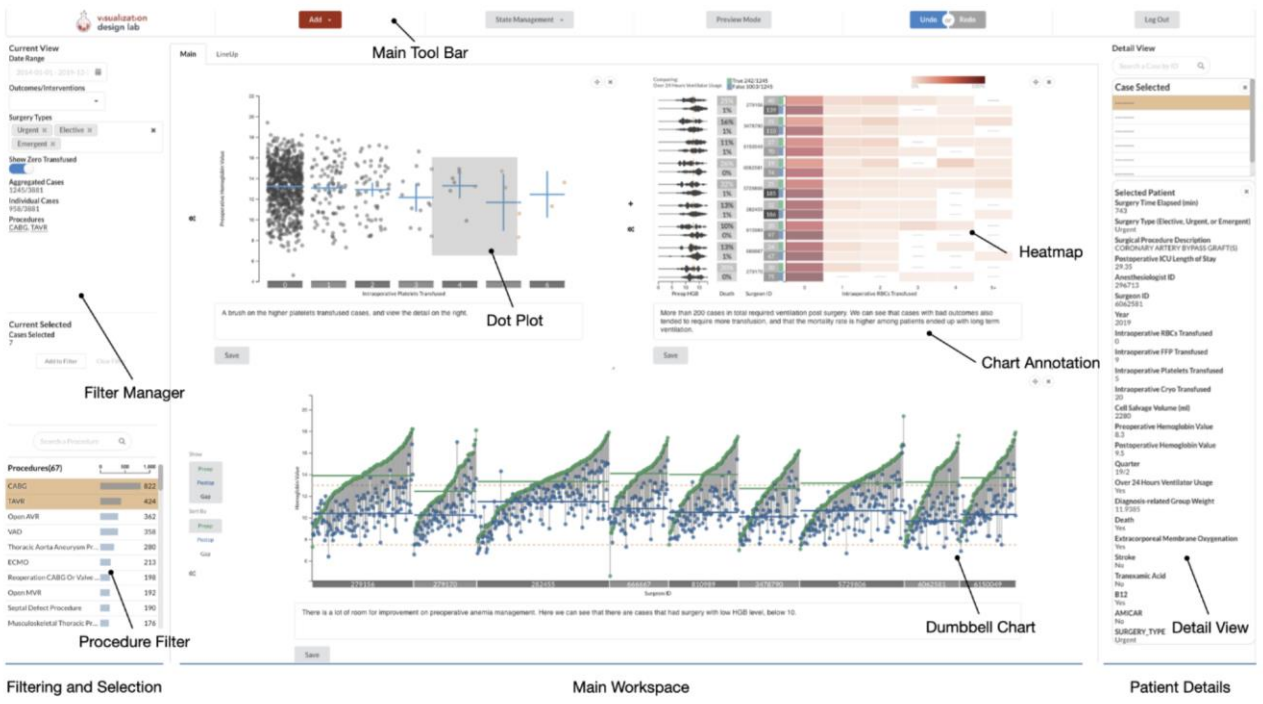


Metcalf et al. Transfusion. 2019.

Application & next steps

- Data visualization: graphical representations of data to facilitate understanding and insights into the data

- *Sanguine*: novel tool with rapid, flexible data visualizations in relevant PBM contexts, all tied to patient outcomes



Lin and Metcalf* et al. Info Vis. 2021.*

Creativity Workshop

- End user stakeholders (participants): CT surgery, CT anesthesiology, IT decision support
- Facilitators: Visualization expert*, PBM expert
- Three hour session
  - » Opening/background, tool demo (20min)
  - » Current workflow (30min)
  - » Wishful thinking (50min)
  - » Visualization analogies (30min)
  - » Barrier removal (40min)
  - » Reflection and next steps (10min)

What would you like to know?
What would you like to do?
What would you like to see?

*Scientific Computing and Imaging (SCI) Institute: sci.utah.edu

vdl.sci.utah.edu/CVOWorkshops

Sanguine: Selected Use Cases

- Preoperative anemia management
- Transfusion appropriateness
- Antifibrinolytic agents
- Cell salvage
- "Patients like mine*"
  - » Learn from prior patients that are similar to your upcoming patient
- General quality
- Financial impact

**Gombar et al. Digital Medicine. 2019.*

Sanguine

bloodvis.chpc.utah.edu

visualization design lab Sanguine

ADD CHART | STATES

CURRENT VIEW | FILTER

MAIN DASHBOARD | SANKEY

Current View

Date Range
Jan 01, 2014 - Oct 13, 2023

Show Zero Transfused

Aggregated Cases
0/4712

Individual Cases
0/4712

Procedure
(Thoracic Aorta Aneurysm Procedure)

Currently Selected

CREATE FILTER

Click "Add" above to start.

Search Procedure

Procedures(69)	0 500 1,000
▶Thoracic Aorta Aneurys...	348
▶CABG	998
▶TAVR	540
▶Open AVR	447
▶VAD	439
▶ECMO	
▶Reoperation CABG Or V...	232
▶Septal Defect Procedure	231
▶Open MVR	231
▶Musculoskeletal Thorac...	230
▶Mediastinal Procedure	206
▶Open Mitral Valvuloplasty	196

Sanguine: status and next steps

- Focused, local deployment
- Ongoing iterative refinement
- Creating simpler hooks to engage all stakeholders
  - » Audit and feedback
- External collaborations

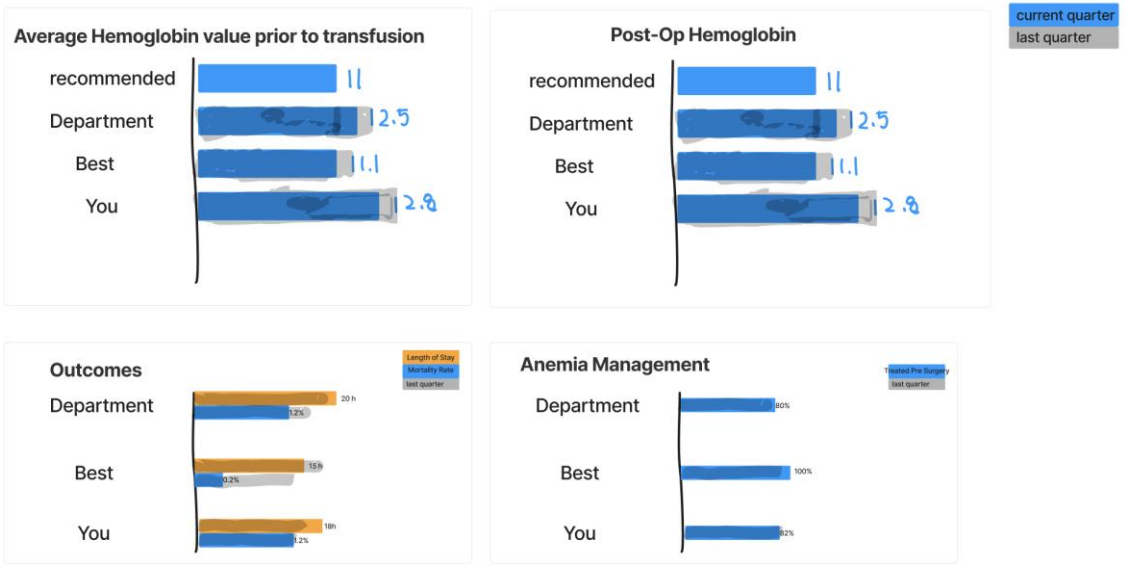
From: Team Sanguine

Title:Your Outcomes and Blood Usage Report for Q3 2022

In the last three month, you have recorded

- 28 caridac surgeries
- used 187 units of blood products.
- the averge complexity of your cases was higher than average
- among the patients you transfused at least 1 red cell unit, the post-operative hemoglobin value was above the recommended threshold 13 percent of the time

Quarterly Charts



Summary and Future Directions

- AI/ML
  - » Dizzying potential
  - » Overcoming methodologic and implementation gaps:
    - QMS approach?
- Advanced data visualization
  - » Novel insights into practice as quality application and “patients like mine”
  - » Advanced multicenter benchmarking

Acknowledgements

- Scientific Computing and Imaging Institute (SCI)
  - » Alex Lex, PhD
  - » Haihan Lin, PhD
  - » Jack Wilburn
- School of Computing
  - » Shandian Zhe, PhD
  - » Zhang Wang
- ARUP Laboratories
  - » Tracy George, MD
  - » Adam Barker, PhD
  - » Kristi Smock, MD
- Data Warehouse
  - » Michael White, MD
  - » Reed Barney
  - » Mike Strong, MD
- Transfusion Medicine
  - » Kelly Cail
  - » Sandy White, MS
- Anesthesiologists and surgeons
  - » Josh Zimmerman, MD
  - » Candice Morrisey, MD
  - » Vikas Sharma, MD

ARUP® LABORATORIES | HEALTH UNIVERSITY OF UTAH

ARUP is a nonprofit enterprise of the University of Utah and its Department of Pathology.