External validation of a publicly available machine learning model for surgical transfusion risk

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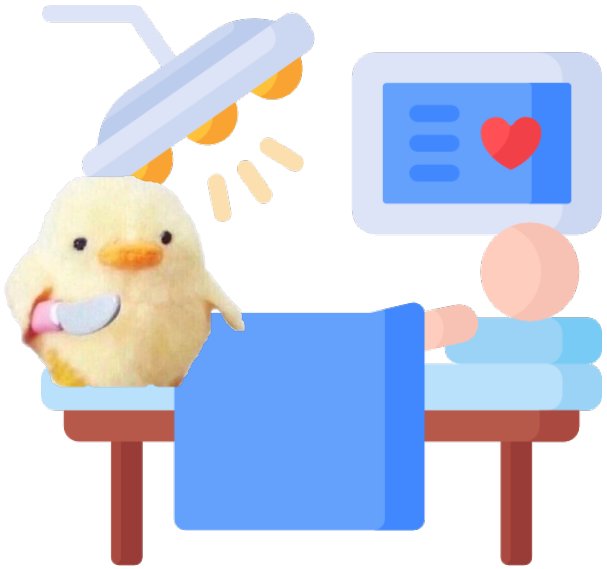
Preoperative preparation for surgical transfusion is…

Important for patient safety



Preparation process:

1. Identify patient's blood type (~1h)
2. Find compatible unit (min-hours)
3. Deliver unit to OR (15-30 min)

Frequently over-utilized

> 50%
have presurgical blood orders

< 5%
require blood during surgery

$10 billion

RBC waste

Which patients should have presurgical blood orders?

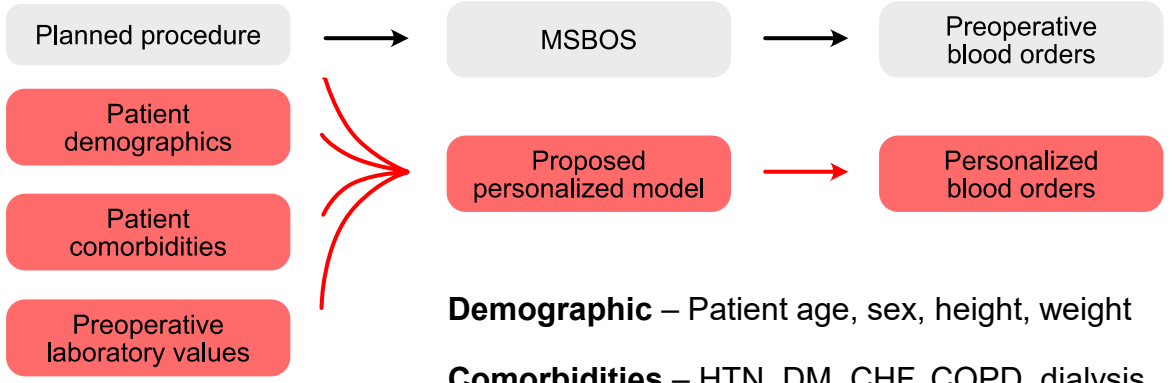
Traditional method: MSBOS

Procedure-specific

Service	Procedure	Routine blood bank order
Cardiac Surgery	Pacemaker/AICD insertion (without extraction)	Type and Screen
	Pacemaker/AICD removal	Type and Cross (2)
	Coronary Bypass and Open Valve Cases	Type and Cross (4)
	Thoracic Aortic Surgery	Type and Cross (4)
	Transcatheter Aortic Valve Surgery (TAVR)	Type and Cross (4)
	ECMO	Type and Cross (6)
	Lung transplant surgery	Type and Cross (6)
	Redo Sternotomy for Heart Surgery	Type and Cross (6)
	Ventricular Assist Device (VAD)	Type and Cross (6)
	Heart transplant surgery	Type and Cross (10)
Cardiology	Transcatheter Mitral Valve Repair	Type and Screen
Electrophysiology	Pacemaker/AICD Insertion or Revision	None (Emergency Release Blood)
	Cardiac Ablation	None (Emergency Release Blood)
	Watchman device/Lariat Procedure (left atrial appendage exclusion	Type and Cross (2)
ENT	Facial Fractures	None (Emergency Release Blood)
	Laryngoscopy with Biopsy	None (Emergency Release Blood)
	Thyroidectomy/Parathyroidectomy	None (Emergency Release Blood)
	Tonsillectomy and/or Adenoidectomy	None (Emergency Release Blood)
	Hemiglossectomy	Type and Screen

Our approach: personalized risk

Patient- and procedure-specific



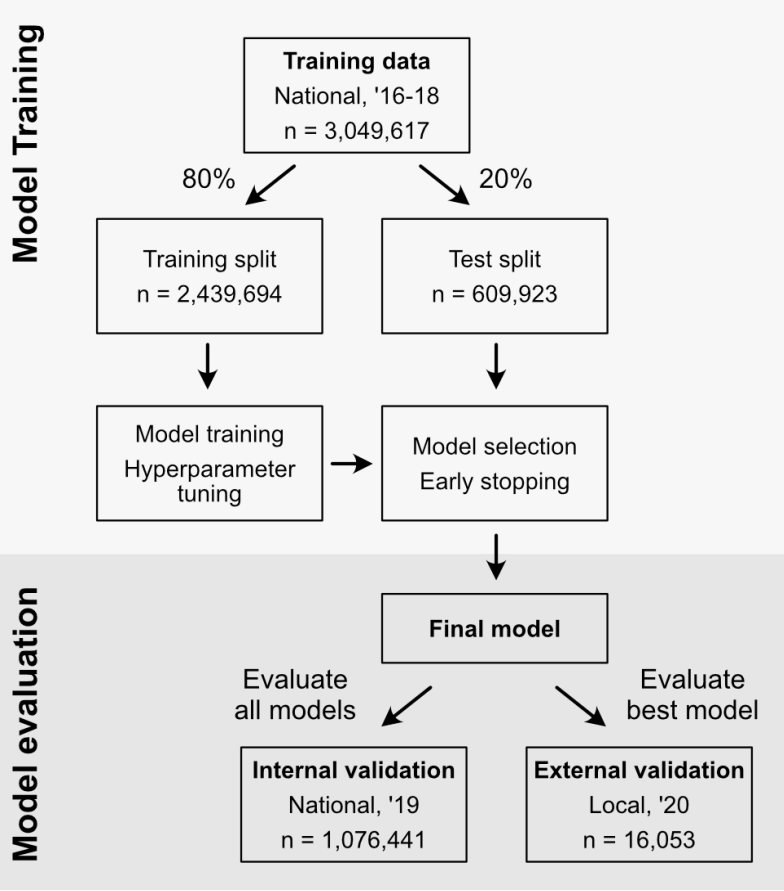
Demographic – Patient age, sex, height, weight

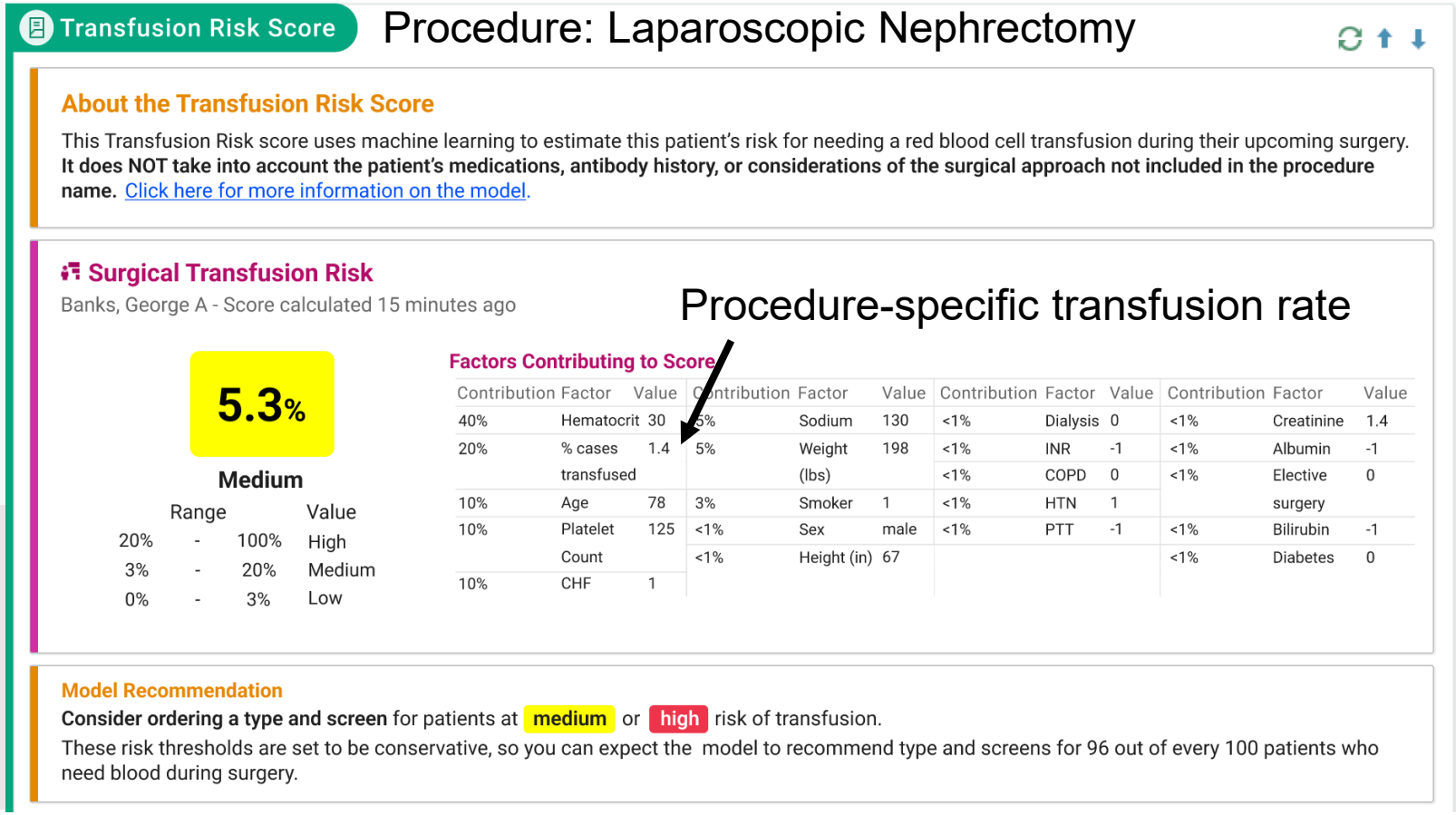
Comorbidities – HTN, DM, CHF, COPD, dialysis, smoking

Preop labs – Hg, Plt, INR, PTT, Na, Cr, albumin, bili

Procedure – procedure-specific risk, elective surgery

Prior work (S-PATH)





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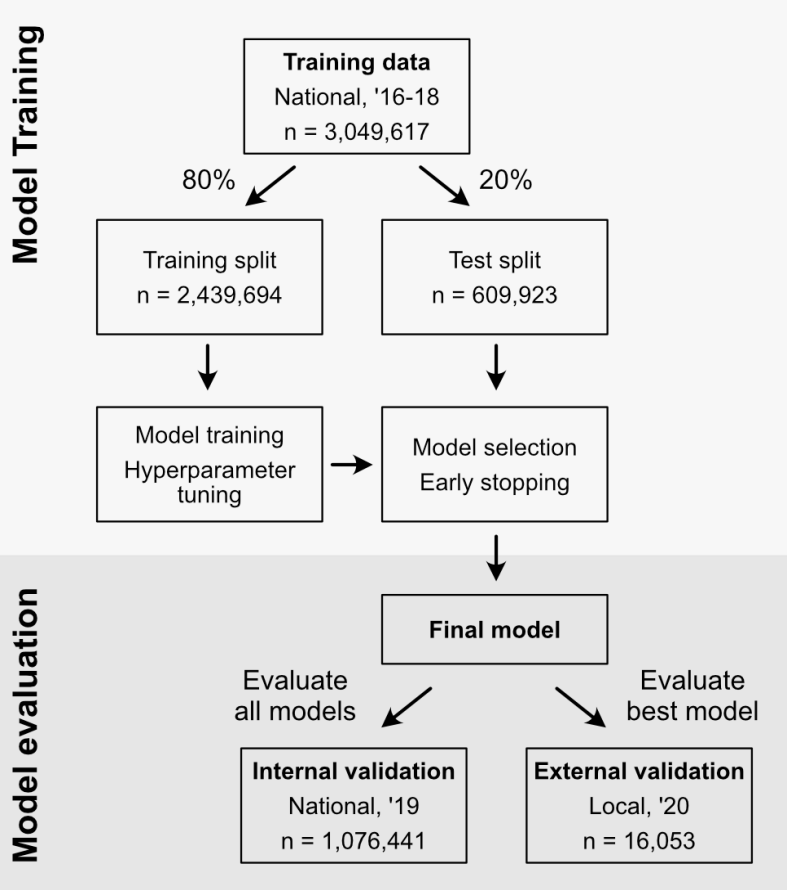


Model	Dataset	AUROC	Sensitivity	# T/S ordered
Baseline MSBOS	NSQIP 2019 (internal val)	0.888	97.0%	613,554 (57%)
S-PATH	NSQIP 2019 (internal val)	0.924	96.3%	389,672 (36%)
Baseline MSBOS	BJH 2020 (external val)	0.908	95.7%	7,336 (46%)
S-PATH	BJH 2020 (external val)	0.939	95.9%	4,976 (31%)

Baseline MSBOS approach has only **84%** sensitivity in internal validation and **91%** sensitivity in external validation using 5% risk threshold

Lou et al. (2022) *Anesthesiology*

MPOG proposal

Aim 1 – External validation of S-PATH across MPOG-participating centers during 2020-2021

Institution-level exclusion criteria

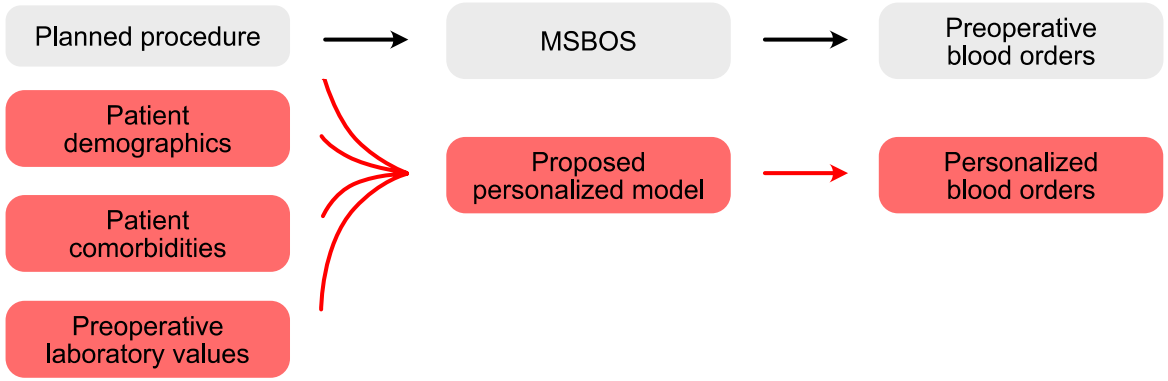
- Data quality issues with Hct (N_i = 1) and Plt (N_i = 3)
- No historical data in MPOG 2016-2019 (N_i = 9)

Case-level exclusion criteria

- ASA = 6
- Obstetric / MRI / Non-operative procedures
- No reliable procedure-specific risk available

Aim 2 - Explore hospital-level predictors of S-PATH performance

Input variables for the model



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Procedure – **procedure-specific risk**, elective surgery

Requirements

- Grouping variable for procedure
  - Anes or Surg CPT
  - Structured text
- Historical transfusion data

Example

To make a prediction for a patient having an esophagectomy at Institution #43 in 2020:

Hct = 39, Plt = 139, Age = 63 …

CPT 00500: Anesth for esophageal procedures

Transfusion rate 2016-2019 at Institution #43: 6/60

Procedure-specific risk = 10%

Calculating a procedure-specific risk

48 institutions in MPOG 2019-2020

Median missingness in Actual Anesthesia CPT Code: **2.5% (IQR 0.5-6.2%)**

Median missingness in Predicted Anesthesia CPT Code: **0.01% (IQR 0.0-0.12%)**

If **fewer than 50 examples** are present in historical data (2016-2019), the procedure-specific risk was considered to be **unreliable** and was set to **missing -> these cases were excluded from the analysis**

Median missingness in hospital-specific procedure-specific risk (using Predicted CPT code): **1.2% (IQR 0.5-2.3%)**

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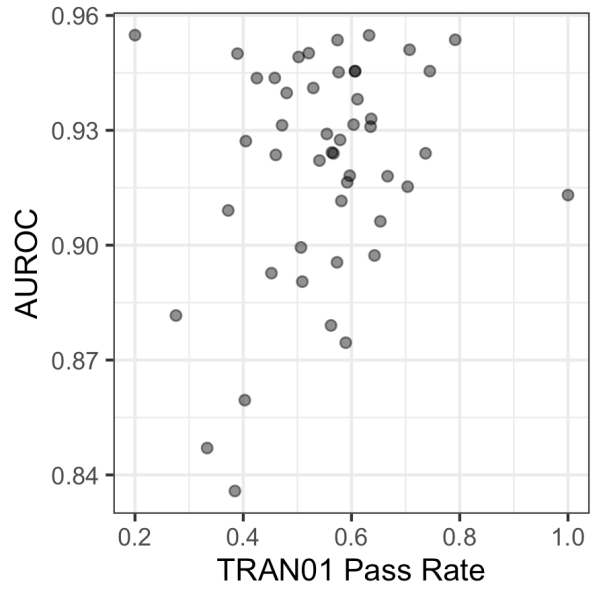
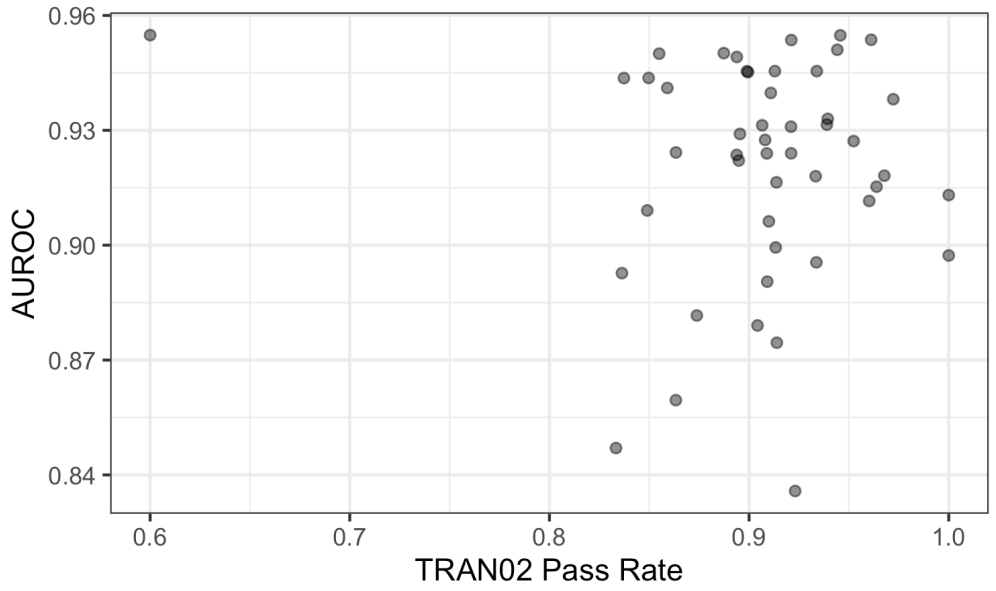
Demographic characteristics of the study sites

Characteristic	Median (IQR) or Count (%)
Annual Surgical Volume	32,014 (14,671 – 54,618)
% cases requiring transfusion	1.6 (0.6 – 3.0)
Med School Affiliation = Yes	31 (65%)
Hospital Bed Size = 100-199	4 (8%)
200-299	2 (4%)
300-399	5 (10%)
400-499	9 (19%)
>= 500	28 (58%)
% cases with ASA PS Score >= 3	52 (47 – 59)
% cases with Base Units >= 7	12 (9 – 15)
% cases with procedure-specific risk > 1%	28 (14 – 39)
TRAN01 pass rate (check Hg prior to transfusing)	57 (47 – 52)
TRAN02 pass rate (posttransfusion Hg < 10)	91 (89 – 93)

S-PATH performance at 48 MPOG sites

Metric	Min	25th %	Median	75th %	Max
AUROC, i.e. c-statistic	0.836	0.908	**0.926**	0.944	0.955
AUPRC, i.e., average positive predictive value	0.005	0.166	**0.279**	0.401	0.527





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AUPRC, i.e., average positive predictive value	0.005	0.166	**0.279**	0.401	0.527
Sensitivity (S-PATH)	0.750	0.957	**0.959**	0.960	0.960
% with type and screen orders (S-PATH)	15.2	26.3	**32.4**	42.4	65.3
% with type and screen orders (MSBOS)	37.5	46.8	**53.4**	61.4	75.7
Difference in type and screen orders	-8.8	14.7	**17.3**	26.7	50.5

Contributors to variation in S-PATH performance (ΔT/S w MSBOS)

β scaled for 25th to 75th percentile change

Positive = greater difference SPATH-MSBOS

i.e. SPATH is better

S-PATH tends to work better at

- Larger hospitals
- More complex cases
- Lower transfusion prevalence
- ? Evidence-based transfusion ?

Measure	Scaled β	P-value
Hospital Bed Size > 500 (N = 28)	Ref	
100-199 (N = 4)	-0.30	**<0.001**
200-299 (N = 2)	-0.12	0.11
300-399 (N = 5)	-0.06	0.21
400-499 (N = 9)	0.02	0.44
Medical School Affiliation = No	0.09	0.07
Surgical Volume	-0.04	0.08
Mortality	-0.03	0.10
% cases with base units >= 7	0.06	**0.005**
% cases with ASA >= 3	0.01	0.57
% cases with historical prior > 1%	-0.10	**0.005**
TRAN01	0.08	**<0.001**
TRAN02	-0.06	**0.003**

Lessons learned

Data quality should be evaluated carefully

Hct, Plt, RBC transfusion, Anesthesia CPT code

TRAN01, TRAN02

High performance compute cluster (Armis2)

OnDemand web interface armis2.arc-ts.umich.edu

- Can launch Rstudio, Jupyter, Matlab, remote desktop

Command line interface $ ssh uniqname@armis2.arc-ts.umich.edu

- Turbo share at /nfs/turbo/umms-sachinhk/PCRC…

S-PATH limitations

Doesn’t account for all factors that influence transfusion risk (i.e., surgeon, anatomy, medications, genetic disorders)

Assumes that average clinician transfusion behavior is reasonable

Timing of preop labs and type and screen is an issue

Past performance is not a guarantee of future success

Significant implementation challenges (political, logistical, technological)

Thanks!

IARS
International Anesthesia Research Society

HEALTHCARE
INNOVATION LAB

(I²)
Institute for Informatics

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For more information
(incl code, calculator)

Univariable associations between institution-level factors and ΔSPATH