Pulmonary Hypertension and the Right Ventricular Rollercoaster in Noncardiac Surgery

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I have no financial disclosures

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Learning Objectives

- Understand the definition of pulmonary hypertension
- Describe the adaptations of the right ventricle in the setting of pulmonary hypertension
- Explain anesthetic considerations and management strategies for patients with pulmonary hypertension

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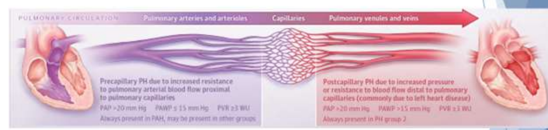

Ruopp NF, Cockrill BA. "Diagnosis and Treatment of Pulmonary Arterial Hypertension: A Review" *JAMA*2022;327(14):1379-91

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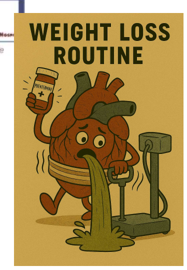

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TABLE 1 Haemodynamic criteria of pulmonary hypertension (PH)

	Haemodynamic characteristics
PH	mPAP >20 mmHg
Pre-capillary PH	mPAP >20 mmHg PAWP ≤15 mmHg PVR >2 WU
Isolated post-capillary PH (ipcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR ≤2 WU
Combined post- and pre-capillary PH (cpcPH)	mPAP >20 mmHg PAWP >15 mmHg PVR >2 WU
Exercise PH	mPAP/CO slope >3 mmHg/L/min between rest and exercise

mPAP: mean pulmonary arterial pressure; PAWP: pulmonary arterial wedge pressure; PVR: pulmonary vascular resistance; WU: Wood Units; CO: cardiac output.

Kovacs G, Bartolome J, Denton CP, Gatzoulis MA, G S, *et al*. "Definition, classification and diagnosis ofpulmonary hypertension" *Eur Respir J* 2024;64:2101324

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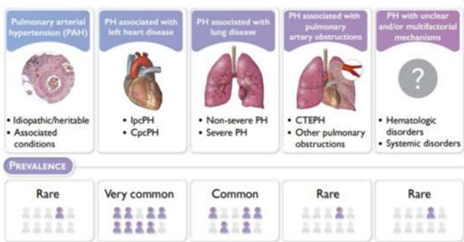

Pulmonary Hypertension Clinical Classification

Maron BA. "Revised Definition of Pulmonary Hypertension and Approach to Management: A Clinical Primer" *J Am Heart Assoc.* 2023;12:e029024. DOI: 10.111/JAHA.122.029024

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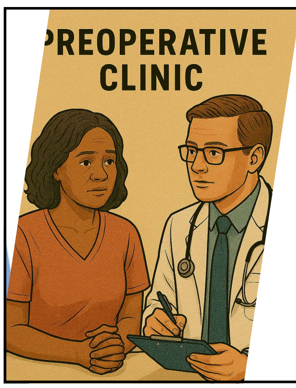

Diagnosis

- History & physical exam
- Echocardiography useful screening tool
- Diagnosis must be made by RHC
  - Vasoreactivity testing
- Identifying associated pathology
  - Echocardiography
  - Chest CT, V/Q scan
  - Functional testing: PFTs, DLCO, overnight pulse oximetry, stress test
  - Cardiac MRI (gold standard for assessment of RV function)

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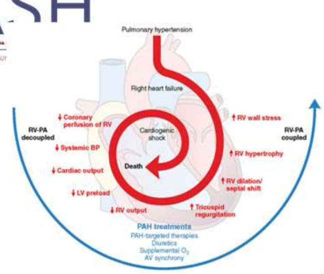

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Rajagopal S, Ruitzler K, Ghadimi K, Horn EM, Kelava M, *et al*. "Evaluation and Management of Pulmonary Hypertension in Noncardiac Surgery: A Scientific Statement from the Americal Heart Association" *Circulation* 2023;147:1317-43

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What are the risks?

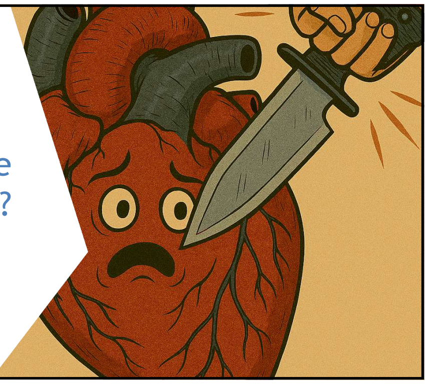

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Table 11 Studies of PH in Non-Cardiac Surgery

	Ramakrishna (2005) (*n* = 145)	Minai (2006) (*n* = 21)	Lai (2007) (*n* = 62)	Price (2010) (*n* = 28)	Memtshoudis (2010) (*n* = 3543)	Kaw (2011) (*n* = 96)	Meyer (2013) (*n* = 114)	Kim (2014) (*n* = 115)	Bennett (2014) (*n* = 33)	Smilowitz (2019) (*n* = 143,846)	Deljou (2020) (*n* = 196)
Mortality	7%	18%	9.7%	7%	2.4% all 5% PPH	1%	3.5%	0%	3.8%	4.4% all 8.3% PAH	3%
Morbidity	42%	14%	24%	29%	–	28%	6.1%	34.7%	–	8.3% MACE	27%
Major surgery	79%	86%	58%	57%	THA/TKA	100%	100%	THA	30%	100%	
GA	100%	79%	58%	50%	–	100%	82%	1%	68%	–	
PH due to LHD included	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No
Study type/ limitations	RS No control Echo	RS No control Severe PAH	RS Control Echo	RS No control RHC	RS NIS Dx codes Matched	RS Control RHC	PS No control RHC	RS Control Ortho Echo	RS No control ES	RS NIS Dx codes Matched	RS No control

Dx, diagnosis; ES, Eisenmenger syndrome; MACE, major adverse cardiac events; NIS, US based national inpatient study; PPH, primary pulmonary hypertension; PS, prospective study; RS, retrospective study; THA, total hip arthroplasty; TKA, total knee arthroplasty.

McGlothlin DP, Granton J, Klepetko W, Beghetti M, Rosenzweig EB, *et al*. "ISHLT consensus statement: Perioperative management of patients with pulmonary hypertension and right heart failure undergoing surgery" *J Heart Lung Transpl* 2022;41(9):1135-94

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Table 2. Incidence and Type of Early (≤30 Days) Morbidity in Patients With Pulmonary Hypertension (n = 145) After Noncardiac Surgery

Morbidity	Patients* (n)	Frequency (%)
Respiratory failure	41	28
Cardiac dysrhythmia	17	12
Congestive heart failure	16	11
Renal insufficiency	10	7
Sepsis/hemodynamic instability	10	7
Hepatic dysfunction	6	4
Ischemia/myocardial infarction	5	4
Stroke	1	1

*Patients may have had one or more morbid event(s).

Table 4. Univariate Association of Operative Characteristics With Perioperative Morbidity and Length of Hospital Stay* (Days) After Noncardiac Surgery

Characteristic	Patients n (%)†	Morbidity n (%)	p Value	LOS Median (IQR)	p Value‡
Type of surgery			<0.01		<0.01
Low risk	31 (21)	6 (19)		2 (0, 4)	
Intermediate/high risk	114 (79)	54 (47)		6 (3, 8)	
Duration of anesthesia			0.02§		<0.01
≤3 h	94 (65)	32 (34)		3 (1, 6)	
>3 h	50 (34)	27 (54)		7 (4, 15)	
Intraoperative nitrous oxide			0.09		0.04
No	66 (46)	32 (49)		6 (2, 8.25)	
Yes	78 (54)	27 (35)		4 (2, 6.25)	
Intraoperative acute beta-blockade			0.18		0.09
No	126 (88)	49 (39)		4.5 (2, 7)	
Yes	18 (13)	10 (56)		7 (3.75, 12)	
Intraoperative dopamine			<0.01		<0.01
No	132 (92)	48 (36)		4 (2, 7)	
Yes	12 (8)	11 (92)		12 (7, 21)	
Intraoperative epinephrine			<0.01		0.03
No	133 (92)	49 (37)		4 (2, 7)	
Yes	11 (8)	10 (91)		9 (6, 16)	

*From surgery to discharge. †Values may be <145, because data variables were not available for all patients. ‡p values calculated using log LOS as the dependent variable. §p < 0.01, duration of anesthesia analyzed as a continuous variable.
Abbreviations as in Table 3.

Impact of Pulmonary Hypertension on the Outcomes of Noncardiac Surgery
Predictors of Perioperative Morbidity and Mortality

Gautam Ramakrishna, MD,* Juraj Sprung, MD, PhD,† Barugur S. Ravi, MD,* Krishnaswamy Chandrasekaran, MD, FACC,* Michael D. McGoon, MD, FACC*
Rochester, Minnesota

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Perioperative Management

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PH Clinical Classification	Preoperative Risk Assessment	Optimization of PH Prior to Surgery	Intraoperative Management of PH	Postoperative Management of PH

Group 1 includes
- Idiopathic PAH
- PAH associated with:
  - Connective tissue disease
  - Congenital heart disease
  - Portal hypertension
Group 2 includes
- Chronic systolic heart failure
- Chronic diastolic heart failure
- Valvular disease
Group 3 includes
- COPD
- Intersitial lung disease
- Obstructive Sleep Apnea
- Obesity Hypoventilation Syndrome
- Other diseases with chronic hypoxemia
Group 4 includes
- CTEPH
- Other PA obstructions
Group 5 includes
- Hemolytic anemias
- Sarcoidosis
- Other multifactorial mechanisms
	PAH Risk Assessment
	- Functional class
	- Exercise capacity
	- Signs and symptoms
	- Labs
	- Imaging/Studies
	Pulmonary Risk Assessment
	- General health
	- Comorbidities
	- Surgical Risk Factors
	Cardiac Risk Assessment
	- Functional capacity
	- Comorbidities
	- Surgical Risk Factors
	Other systemic disorders that contribute to PH
	ASA Physical Status Classification
		Elective Surgery
		Medication optimization
		- PAH-targeted therapies
		- Diuretics
		Pulmonary optimization
		- Pulmonary rehab
		Cardiac optimization
		- Absence of arrhythmias, concern for low cardiac output
		Emergent Surgery
		Preload Optimization
		RV afterload reduction
		- Avoid acidosis
		- Normalize oxygenation
		- Inhaled nitric oxide
		- Prostanoids
		RV coronary perfusion
		- Consider PAC monitoring
		- Vasoactives for MAP
			Choice of Anesthesia
			- General
			- Neuroaxial
			- Peripheral nerve block
			Intraoperative monitoring
			- ECG
			- Defibrillator pads prior to induction
			- Pulse oximetry
			- End-tidal CO2
			- (Invasive) BP monitoring
			- Central venous catheter
			- Transesophageal echocardiogram
			Ensure stable RV function and End-organ perfusion
			Maintain normal sinus rhythm / baseline rhythm
			Maintain end-organ perfusion
			- CI ≥2.2 L/kg/m²
			- MAP ≥60 mmHg
			- RAP <8 mmHg
			Avoid hypoxia and hypercarbia
			- Tidal volume 6-8 mL/kg IBW
			- PEEP 5-10 mmHg
			Medical Therapies
			- PAH-targeted therapies
			- Selective pulmonary vasodilators
			- Inotropes and vasoactives
				PACU
				- Pulse oximetry
				- End-tidal CO2 monitoring
				- Pain control
				Critical Care Management
				- Invasive BP monitoring
				- Central venous catheter
				- Echocardiogram
				- Laboratory monitoring
				- Fluid balance
				Medical management
				- PAH-targeted therapies
				- Selective pulmonary vasodilators
				- Inotropes and vasoactives
				Avoid hypoxia / hypercarbia
				- Supplemental oxygen
				- Noninvasive Ventilation
				- Mechanical Ventilation
				  - Tidal volume 6-8 mL/kg IBW
				  - PEEP 5-10 mmHg
				- VV ECMO
				Mechanical circulatory support (multidisciplinary approach)
				- VA ECMO
				- RVAD

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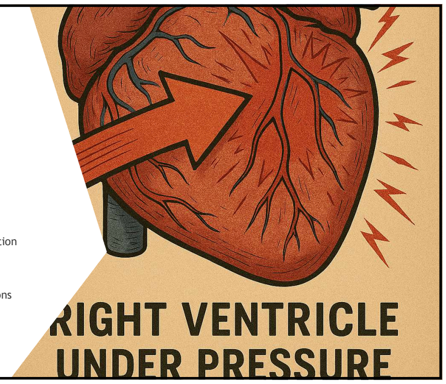
Pre-Operative Evaluation & Optimization

- H&P
  - PH Classification
  - Signs & Symptoms
  - Outpatient workup & management
- Optimized?
  - Underlying cardiac or pulmonary disease optimization
  - Volume status
  - Medication management
  - Anticoagulation considerations
  - Adequate resources for OR?



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- **History:**
- Determine Functional Classification
  - Exertional SOB, CP, syncope to determine FC
- **Physical Exam:**
- Look for signs of RHF
  - Elevated JVP, RV gallop, TR mumur, ascites, edema, cool periphery, reduced capillary refill
- **Tests:**
- BNP, basic chemistry, CBC, coagulation panel
- CXR, ECG
- 6 min walk test/CPET
- Echo within 2 weeks
- RHC in selected patients

WHO Functional Classification

Class	Description
I	No limitation of physical activity; ordinary physical activity does not cause undue dyspnea or fatigue, chest pain, or near syncope
II	Slight limitation of physical activity; no discomfort at rest; ordinary physical activity causes undue dyspnea or fatigue, chest pain, or near syncope
III	Marked limitation of physical activity; no discomfort at rest; less than ordinary activity causes undue dyspnea or fatigue, chest pain, or near syncope
IV	Unable to carry out any physical activity without symptoms; signs of right-heart failure; dyspnea and/or fatigue may be present at rest; discomfort is increased by any physical activity

Table 1 Surgery Specific Risks

Lowest Risk Procedures
Procedures with local anesthesia for minor procedures
Dermatologic surgeries
Low Risk Surgeries
Dermatologic surgeries
Endoscopic procedures
Cataract surgery
Breast surgery
Intermediate Risk Surgeries
Carotid endarterectomy
Head and neck surgery
Gynecologic surgery
GI/abdominal surgery
Orthopedic surgery
Prostate surgery
High Risk Surgeries
Emergent major surgery
Cardiovascular surgery
Liver transplantation
Any operation with anticipated large fluid shifts and/or blood loss

Pre-operative Evaluation

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Table 2 PH Specific Risk Assessment Tools

	Low risk	High risk
Clinical symptoms/signs		
RHF	None	Present
Functional class	I/II	III/IV
Exercise capacity		
6 mwd	> 400 meters	< 165 meters
CPET	Peak VO2 > 15 ml/min/kg^{-1} VE/VCO2 slope < 36.0	Peak VO2 < 11 ml/min/kg^{-1} VE/VCO2 slope > 45.0
Imaging (echo, MRI)	Normal RV size & function Normal RA size	Markedly dilated RV, RV dysfunction Severe RAE, pericardial effusion
Hemodynamics	RAP < 8, CI > 2.5, SvO2 > 65%, RVSP/SBP < 0.33	RAP > 14, CI < 2.0, SvO2 < 60%, mPAP > 35 mm Hg, RVSP/SBP > 0.66
Biomarkers (ng/liter)	BNP < 50, NT-pro BNP < 300	BNP > 300, NT-pro BNP > 400
PAH risk score	Low risk	High risk

BNP, brain type natriuretic peptide; CI, cardiac index; mPAP, mean pulmonary artery pressure; RA, right atrium; RAE, right atrial enlargement; RAP, right atrial pressure; RV, right ventricle; RVSP, right ventricular systolic pressure; SBP, systolic blood pressure; SvO2, systemic venous O2 saturation; VE/VCO2, minute ventilation/carbon dioxide production; VO2, maximal oxygen consumption; .

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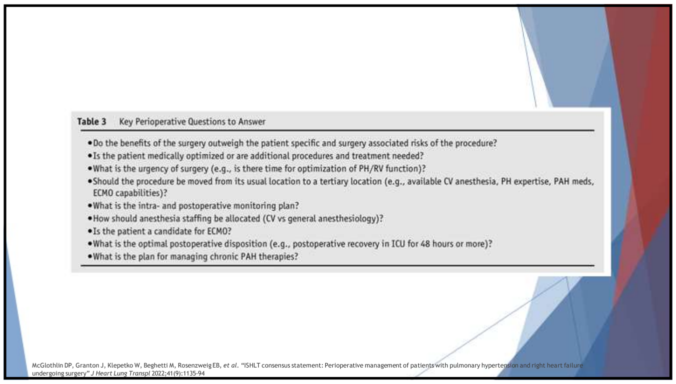

Table 3 Key Perioperative Questions to Answer

- Do the benefits of the surgery outweigh the patient specific and surgery associated risks of the procedure?
- Is the patient medically optimized or are additional procedures and treatment needed?
- What is the urgency of surgery (e.g., is there time for optimization of PH/RV function)?
- Should the procedure be moved from its usual location to a tertiary location (e.g., available CV anesthesia, PH expertise, PAH meds, ECMO capabilities)?
- What is the intra- and postoperative monitoring plan?
- How should anesthesia staffing be allocated (CV vs general anesthesiology)?
- Is the patient a candidate for ECMO?
- What is the optimal postoperative disposition (e.g., postoperative recovery in ICU for 48 hours or more)?
- What is the plan for managing chronic PAH therapies?

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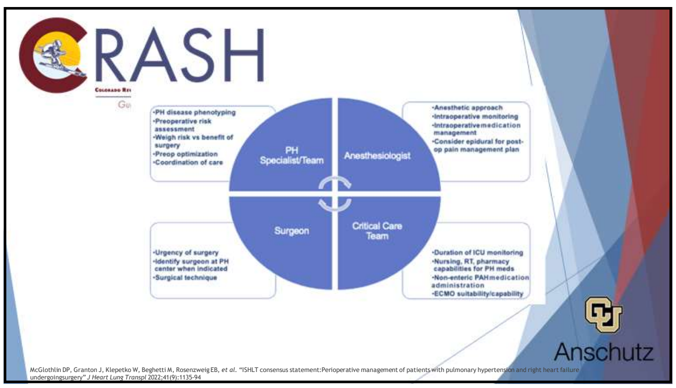

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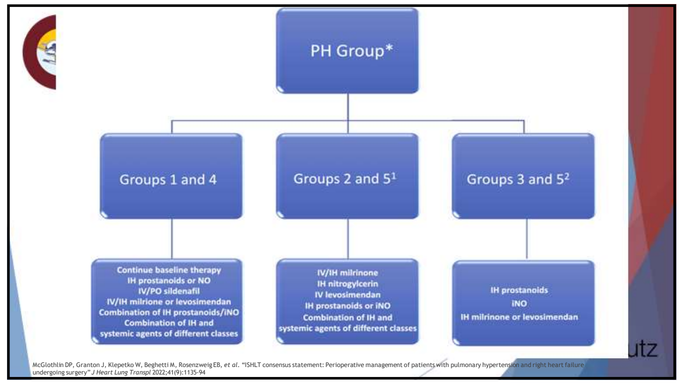

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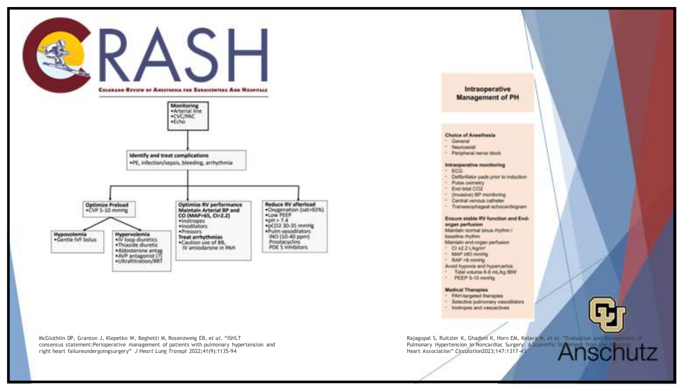

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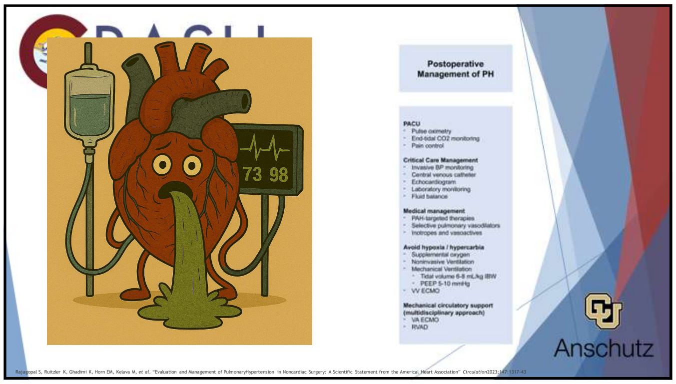

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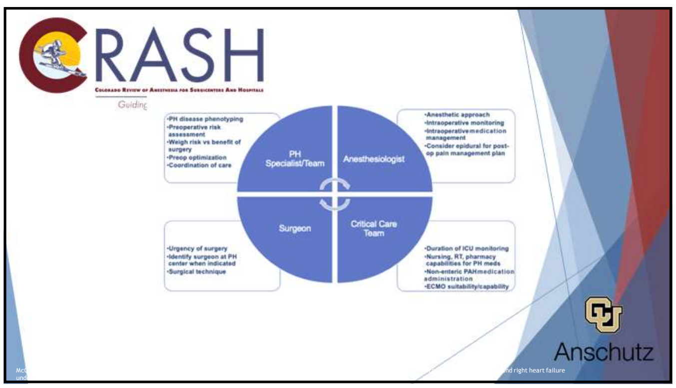

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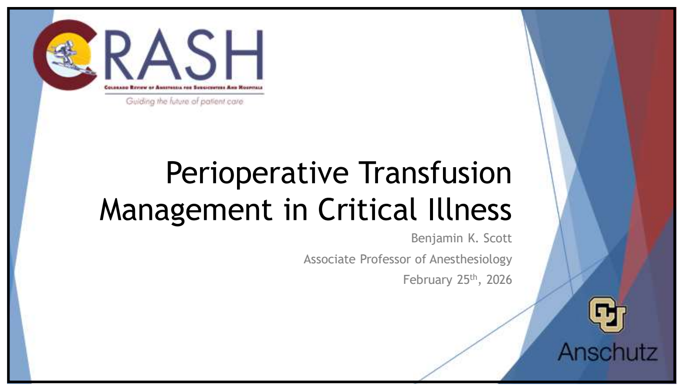

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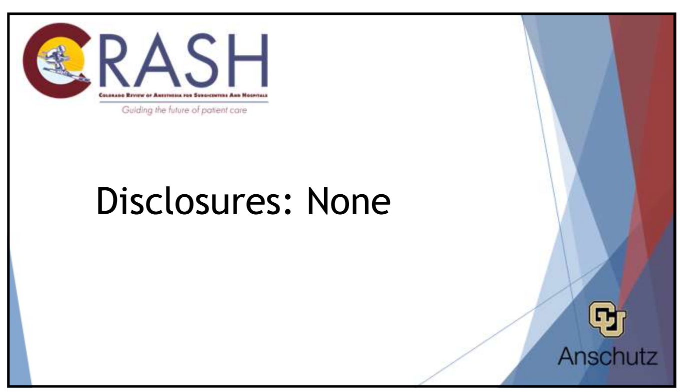

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Learning Objectives

1. Evaluate recent developments in evidence-based transfusion management
2. Describe practical and effective transfusion strategies in the perioperative period
3. Explore future directions in transfusion medicine including the role of AI, personalized medicine, and predictive analytics

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Transfusion strategies: recent history

- Blood banking and component therapy
- Damage control and goal-directed strategies
- "Simulated whole blood" 1:1:1 Transfusion Strategy
- Protocolization of Massive Transfusion Strategies

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Why Transfusion Strategy Matters

- Transfusion is one of most common intraoperative interventions
- Associated with increased perioperative morbidity and mortality
- Substantial variation in practice patterns across institutions
- *Most* Evidence supports restrictive over liberal strategies

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Transfusion Targets

- Current State
  - More Blood → More O2 Delivery, Less Ischemia
  - Less Blood → Less Complications (Infxn., TRALI), Less Cost, Less Use of Valuable Resource
  - Current Standard → HGB > 7 for Most (Periop and ICU)
    - ICU TBI > 9-10, AMI > 10
    - Cardiac Surgery > 7.5
  - ? Large Volume EBL

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Transfusion Targets (Periop)

- Clinical Question - Does a Liberal or Restrictive Periop Transfusion Target Improve Patient Outcomes?

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Transfusions Targets (Periop)

- FOCUS Trail (NEJM 2011, n=2016)
  - RCT in Hip Fracture + CV Disease of HGB >10 vs. > 8 → No Difference in Mortality (5.2% vs. 4.3%) or Ischemic Complications (4.3% vs. 5.2%)
- TITRe2 (NEJM 2015, n=2003)
  - RCT in CT Surgery of HGB > 9 vs. HGB > 7.5 → ? Difference in Mortality (2.6% vs. 4.2%) or Composite Complications (33% vs. 35%)
- TRICS III (NEJM 2017, n=4860)
  - RCT in CT Surgery of HGB > 9.5 vs. > 7.5 → No Difference in Mortality (3.6% vs. 3.0%) or Composite Complications (12.5% vs. 11.4%)

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Trial	Population	Transfusion thresholds	Primary outcome	Key secondary outcomes
Clinical trials				
FOCUS,[12] 2011	Older patients undergoing hip fracture surgery with cardiovascular disease or risk and Hgb <10 g/dL	Restrictive, symptoms or Hgb <8 g/dL; liberal, Hgb <10 g/dL	Death or inability to walk independently at 60 d: 35.2% in liberal group vs 34.7% in restrictive group (OR, 1.01; 95% CI, 0.84-1.22)	Death at 30 d: 5.2% in liberal group vs 4.3% in restrictive group (OR, 1.23; 95% CI, 0.71-2.21) Death at 60 d: 7.6% in liberal group vs 6.6% in restrictive group (OR, 1.17; 95% CI, 0.75-1.83) In-hospital acute MI, unstable angina, or death: 4.3% in liberal group vs 5.2% in restrictive group (OR, 0.82; 95% CI, 0.48-1.42)
TITRe2,[13] 2015	Patients after cardiac surgery with Hgb <9 g/dL	Restrictive: Hgb <7.5 g/dL; Liberal: Hgb <9 g/dL	Composite of a serious infection (sepsis or wound infection) or an ischemic event (permanent stroke, MI, infarction of the gut, or acute kidney injury) within 3 mo: 35.1% in restrictive group vs 33.0% in liberal group (OR, 1.11; 95% CI, 0.91-1.34)	Infection: 25.4% in restrictive group vs 25.2% in liberal group (OR, 1.02; 95% CI, 0.83-1.26) Ischemic event: 15.7% in restrictive group vs 14.0% in liberal group (OR, 1.16; 95% CI, 0.90-1.49) All-cause mortality: 4.2% in restrictive group vs 2.6% in liberal group (HR, 1.64; 95% CI, 1.00-2.67)
TRICS III,[14] 2017	Moderate-to-high risk cardiac surgery (EuroSCORE ≥6)	Restrictive: <7.5 g/dL (operating room, ICU, ward per protocol); liberal: <9.5 g/dL (operating room or ICU) or <8.5 g/dL (ward)	Composite of death, MI, stroke, or new dialysis by discharge or 28 d: 11.4% in restrictive group vs 12.5% in liberal group (OR, 0.90; 95% CI, 0.76-1.07)	Death: 3.0% in restrictive group vs 3.6% in liberal group (OR, 0.85; 95% CI, 0.62-1.16) Stroke: 1.9% in restrictive group vs 2.0% in liberal group (OR, 0.92; 95% CI, 0.61-1.38) MI: 5.9% in restrictive group vs 5.9% in liberal group (OR, 1.00; 95% CI, 0.79-1.27) New-onset kidney failure with dialysis: 2.5% in restrictive group vs 3.0% in liberal group (OR, 0.84; 95% CI, 0.60-1.19)
REALITY,[15] 2021	Acute MI with Hgb, 7-10 g/dL	Restrictive: Hgb ≤8 g/dL; Liberal: Hgb ≤10 g/dL	MACE (composite of all-cause death, stroke, recurrent MI, or emergency revascularization prompted by ischemia) at 30 d: 11.0% in restrictive group vs 14.0% in liberal group (RR, 0.79; 1-sided 97.5% CI, 0.00-1.19)	All-cause death at 30 d: 5.6% in restrictive group vs 7.7% in liberal group Recurrent MI at 30 d: 2.1% in restrictive group vs 3.1% in liberal group Emergency revascularization at 30 d: 1.5% in restrictive group vs 1.9% in liberal group Stroke at 30 d: 0.6% in restrictive group vs 0.6% in liberal group
MINT,[16] 2023	Acute MI with Hgb <10 g/dL	Restrictive: Hgb 7-8 g/dL; Liberal: Hgb <10 g/dL	Composite of MI or death at 30 d: 16.9% in restrictive group vs 14.5% in liberal group (RR, 1.15; 95% CI, 0.99-1.34)	Death at 30 d: 9.9% in restrictive group vs 8.3% in liberal group (RR, 1.19; 95% CI, 0.96-1.47) MI at 30 d: 8.5% in restrictive group vs 7.2% in liberal group (RR, 1.19; 95% CI, 0.94-1.49) Composite outcome of death, MI, ischemia-driven unscheduled coronary revascularization, or readmission to the hospital for an ischemic cardiac condition within 30 d: 19.6% in restrictive group vs 17.4% in liberal group (RR, 1.13; 95% CI, 0.98-1.29)

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Transfusion Targets (Periop)

- New Evidence in 2025 →TOP

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Transfusion Targets (TOP, JAMA 2025)

JAMA | Original Investigation

Liberal or Restrictive Postoperative Transfusion in Patients at High Cardiac Risk

The TOP Randomized Clinical Trial

Panos Kougias, MD, MSc; Sherene E. Sharath, PhD, MPH; Min Zhan, PhD; Jeffrey L. Carson, MD; L. Erin Norman, MSW; Zhibao Mi, PhD; Rupsi Pal, PhD, MS; Hasan Dosluoglu, MD; J. Gregory Modrall, MD; George A. Sarosi Jr, MD; Peter Nelson, MD, MS; Shipra Arya, MD, SM; Alexandra Scrymgeour, MS, PharmD; Jade Ollison, MLA; Lawrence A. Calais, RN, CCRC; Vijay Nambi, MD; L. Parker Gregg, MD, MSCS; Shuaib M. Abdullah, MD; Shirling Tsai, MD; Natasha Becker, MD, MPH; Justin C. Choi, MD; Louisa Chiu, MD; Salvatore Scali, MD; Neal R. Barshes, MD, MPH; Samir Awad, MD; Mohammed Moursi, MD; Matthew C. Koopmann, MD; Mitchell Sally, MD; Daniel Ihnat, MD; Archana Ramaswamy, MD; Warren Gasper, MD; Edith Tzeng, MD; Mark A. Wilson, MD; Gale Tang, MD; Grant Huang, PhD; Kousick Biswas, PhD; for the TOP Trial Investigators

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Transfusion Targets (TOP, JAMA 2025)

- Prospective RCT of Post-Operative Liberal (HGB < 10) vs. Restrictive (HBG < 7) Transfusion Trigger
- Primary Outcome → Composite Death or Major Ischemic Complications at 90-days

(AMI, Cardiac Cath, Acute Kidney Failure, Ischemic Stroke)

- 16 VA Hospitals in US, n=1428
- Ischemic Disease (Cardiac/Vascular/Neuro), Major Vascular or General Surgery, Post-Op HGB < 10

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Transfusion Targets (TOP, JAMA 2025)

- Prospective RCT of Post-Operative Liberal (HGB < 10) vs. Restrictive (HBG < 7) Transfusion Trigger
- Primary Outcome → Composite Death or Major Ischemic Complications at 90-days

(AMI, Cardiac Cath, Acute Kidney Failure, Ischemic Stroke)

- 16 VA Hospitals in US
- Calculated Sample Size 1520 Patients → Based on 7.5% Reduction (30% → 22.5%)
- 3022 Screened → 1428 Randomized → 1428 Included in ITT

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Transfusion Targets (TOP, JAMA 2025)

- Patient Population
  - PMH Ischemic Disease (Cardiac/Vascular/Neuro)
  - Major Vascular or General Surgery
  - Post-Op HGB < 10

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Variable	Liberal transfusion (n = 712)	Restrictive transfusion (n = 712)
Transfusions before index surgery, units		
Median (IQR)	0	0
No./total (%)	35/711 (4.9)	54/712 (7.6)
Transfusions intraoperatively during index surgery, units		
Median (IQR)	0 (0-1)	0 (0-1)
No./total (%)	194/711 (27.3)	215/712 (30.2)
Transfusions after index surgery before randomization, units		
Median (IQR)	0	0
No./total (%)	54/711 (7.6)	33/712 (4.6)
Transfusions after randomization, median (IQR), units[a]	2 (1-3)	0 (0-0)
Total	1878	307
Due to rapid bleeding	0	0
Total	25	21
Intraoperatively for other surgeries	0	0
Total	70	42
Transfusions after randomization, No./total No. (%)		
0 units	46/712 (6.5)	548/712 (77.0)
1 unit	198/712 (27.8)	91/712 (12.8)
2 units	174/712 (24.4)	44/712 (6.2)
≥3 units	294/712 (41.3)	29/712 (4.1)
Major protocol violation, No./total No. (%)		
Participants assigned to restrictive group who were transfused when hemoglobin >7 g/dL		27/712 (3.8) Total incidents, 39
Participants assigned to liberal group who were not transfused when hemoglobin <10 g/dL	62/712 (8.7) Total incidents, 114	

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Transfusion Targets (TOP, JAMA 2025)

- Primary Outcome – Composite Death or Major Ischemic Complications at 90-days → No Difference
  - Liberal (HGB < 10) 9.1% vs. Restrictive (HGB < 7) 10.1% (CI 0.65-1.24)
  - No Difference In Any Individual Component
- Secondary Outcomes
  - Primary Outcome at 30-days → No Difference (4.9% vs. 6.4%)
  - Cardiac Complications (Arrythmia/Heart Failure/Cardiac Arrest) → 5.9% vs. 9.9% (CI 0.36-0.98)
    - Arrhythmia 4.3% vs. 2.6%, HF 5.8% vs. 4.0%

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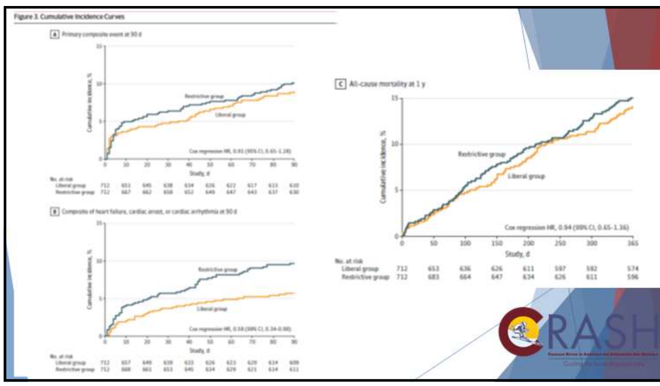

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Transfusion Targets (TOP, JAMA 2025)

- Strengths
  - Multisite Prospective RCT w/ ~Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol (HGB Difference 2.0 on Day 5)
  - High-Risk Patients
- Weaknesses
  - Substantially Underpowered (20x) For Primary Outcome → ? False Negative
  - 98% Male, 91% Vascular Surgery

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Transfusion Targets (Periop)

- Clinical Question – Does a Liberal or Restrictive Periop Transfusion Target Improve Patient Outcomes?
- Best Evidence To Date → TOP
  - Primary Outcome → No Difference
  - Cardiac Complications → 5.9% vs. 9.9%
- My Practice (OR) → High-Risk Patients (PMH Ischemic Disease) HGB > 8
  - Especially w/ Larger Volume EBL or Signs Malperfusion
- Future Directions → Additional Trials in Selected Populations

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Transfusion Targets (ICU)

- Clinical Question – Does a Liberal or Restrictive ICU Transfusion Target Improve Patient Outcomes?

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Transfusions Targets (ICU)

- TRICC Trail (NEJM 1999, n=838)
  - RCT of HGB > 10 vs. HGB > 7 → No Difference in Mortality (23.3% vs. 18.7%)
- TRISS (NEJM 2014, n=998)
  - RCT in Septic Shock of HGB > 9 vs. HBG > 7 → No Difference in Mortality (45% vs. 43%)
- MINT (NEJM 2023, n=3504)
  - RCT in AMI and Anemia of HGB > 10 vs. 7-8 → No Difference in Mortality (8.3% vs. 9.9%), Composite Infarction + Mortality (14.5% vs. 16.9%, p=0.07)
  - Bayesian Analysis - 90.8-99.8% Chance of Harm

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Transfusion Targets (ICU TBI)

- TRAIN Trial (JAMA 2024, n=820)
  - RCT of HGB > 9 vs. HGB > 7 in ICU TBI Patients → Unfavorable Neurologic Outcome (62.6% vs. 72.6%)
- HEMOTION (NEJM 2024, n=736)
  - RCT of HGB > 10 vs. HGB > 7 in ICU TBI Patients → Unfavorable Neurologic Outcome (68.4% vs. 73.5%)
  - Non-Significant 2/2 Underpowering (10% Reduction)

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Transfusion Targets (Periop)

- New Evidence in 2025 → None
  - Cochrane Meta-Analysis Update (from 2021)

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Transfusion Target (Cochrane 2025)

Cochrane Library

Cochrane Database of Systematic Reviews

Transfusion thresholds and other strategies for guiding red blood cell transfusion (Review)

Carson JL, Stanworth SJ, Dennis JA, Fergusson DA, Pagano MB, Roubinian NH, Turgeon AF, Valentine S, Trivella M, Dorée C, Hébert PC

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Transfusion Target (Cochrane 2025)

- Liberal (> 9-10+) vs. Restrictive (HGB > 7-8)
- Reported as RR of 30-day Mortality with Restrictive Transfusion Target
- ICU (9 Trials, n=2,958)
  - 30-day Mortality RR 1.05 (CI 0.85-1.29)
  - GI Bleed – RR 0.63 (CI 0.24-0.95)
  - TBI (Poor Neurologic Outcome) – RR 1.14 (CI 1.05-1.22)
  - AMI – RR 1.1 (CI 0.7-1.73)

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Transfusion Target (Cochrane 2025)

- Liberal (> 9-10+) vs. Restrictive (HGB > 7-8)
- Reported as RR of 30-day Mortality with Restrictive Transfusion Target
- Cardiac Surgery (5 Trials, n=4,079)
  - 30-day Mortality RR 0.99 (CI 0.73-1.35)
- Ortho Surgery (9 Trials, n=1,598)
  - 30-day Mortality RR 1.16 (CI 0.75-1.79)
- No Difference for Trauma or Vascular Surgery

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Transfusion Targets (ICU)

- Clinical Question – Does a Liberal or Restrictive ICU Transfusion Target Improve Patient Outcomes?
- Best Evidence To Date → TRICC, TRISS, MINT, 2025 Cochrane
  - No Difference in Mortality
  - Exceptions – GI Bleed and TBI
- My Practice (ICU)→ HGB > 7
  - Exceptions TBI > 9-10, AMI > 10
- Future Directions → Trials for HGB > 6-6.5

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Ottawa 2023: Key Recommendations

- Restrictive Hgb trigger of 70 g/L (7 g/dL) for non-cardiac patients
- Use point-of-care hemoglobin testing devices
- Employ algorithmic transfusion protocols
- Preoperative discussion between surgeon and anesthesiologist

Ottawa Intraoperative Transfusion Consensus (2023). JAMA Network Open, 7(1)

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Factors Beyond Hemoglobin

- Ongoing surgical bleeding and hemorrhage potential
- Hemodynamic stability and vital signs
- Signs of end-organ ischemia (EKG, urine output, O_2 sat)
- Comorbidities: cardiac disease, age, cerebrovascular disease

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Implementation Strategy

- Transfuse one unit at a time in most cases
- Decision should involve both surgeon and anesthesiologist
- Document indication in EMR (except extreme urgency)
- Post-op audit: review appropriateness with surgical team

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Evidence Summary

Restrictive strategies demonstrate:

- Reduced RBC transfusion (65% fewer units)
- No increase in mortality or ischemic complications
- Lower rates of infection
- Shorter length of stay in some populations

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Consider Higher Triggers in:

- Neurological injury
- Significant cardiac disease or ischemia risk
- Acute myocardial infarction history (particularly with recent symptoms)
- Unstable angina or uncontrolled hypertension
- Signs of perioperative organ ischemia

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Complementary Blood Conservation

- Optimize preoperative hemoglobin (iron therapy, hold anticoagulants)
- Minimize intraoperative bleeding (hemostasis, positioning)
- Cell salvage and neuraxial anesthesia when appropriate
- Maintain normothermia and avoid dilutional coagulopathy

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Preoperative Informed Consent

- Discuss risks of anemia vs. risks of transfusion
- Disclose possibility of intraoperative transfusion
- Identify patient preferences and cultural/religious considerations
- Document discussion in medical record

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Transfusion Management in Disaster and Mass Casualty

Simulated Whole Blood on a per patient basis

Vs.

Tranfusion triage in a population

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An All-Hazards Approach

Mass Casualty Events may be "rare or recurrent" depending on local context

In addition to MCE, blood bank shortages with similar implications have accompanied

- Weather events
- Supply chain vulnerabilities
  - Power disruptions
  - Cyberattack
- Pandemics

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- A review of 1645 mass casualty events in Israel over five years suggests an average of 1.3 RBC units per patient
- Moderate and severe traumatic injuries in this cohort received an average of 4.5 and 6.7 units per patient, respectively
- Other countries report similar numbers: approximately 2-4 units per injured patient

How much blood will we need?

- Shinar E, Yahalom V, Silverman BG. Meeting blood re- quirements following terrorist attacks: the Israeli experi- ence. Curr Opin Hematol 2006; 13: 452e6
- Glasgow S, Davenport R, Perkins Z, Tai N, Brohi K. A comprehensive review of blood product use in civilian mass casualty events. J Trauma Acute Care Surg 2013; 75: 468e74
- Lozada MJ, Cai S, Li M, Davidson SL, Nix J, Ramsey G. The Las Vegas mass shooting: an analysis of blood component administration and blood bank donations. J Trauma Acute Care Surg 2019; 86: 128e33

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Significant Risk of Over-ordering

- Anticipated demand may far exceed the actual need
- September 11th Terrorist Attacks
  - Approx 4000 injured patients
  - 475,000 blood units collected nationwide
  - 258 units transfused

- Compernolle V, Najdovski T, Bouyalski D, Vandekerckhove P. Lessons for blood services following the Brussels terrorist attacks in March 2016. ISBT Sci Ser 2018; 13: 47e50
- Schmidt PJ. Blood and disaster—supply and demand. N Engl J Med 2002; 346: 617e20

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High risk of psychological stress for lab staff

- The risks of cognitive overload, moral distress, and burnout are well-described in first responders and medical teams exposed to MCE and disaster
- Less well reported are the strains on labarotory and blood bank teams
- Even when actual transfusion volumes are low, there may be significant stress on lab and blood bank teams

- Naumann DN, Boulton AJ, Sandhu A, et al. Fresh whole blood from walking blood banks for patients with trau- matic hemorrhagic shock: a systematic review and meta- analysis. J Trauma Acute Care Surg 2020; 89: 792e800
- Chowdhury F, Doughty H, Batrick N. London 2017: lessons learned in transfusion emergency planning. Transfus Med 2021; 31: 81e7

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Maintaining Safety, Minimizing Waste

- Standardization and coordination (health system, state, country)
- Maintenance of transfusion safety using sequential record systems for patients and units
- Triage systems for product allocation
- Modified transfusion protocols rather than fixed ratios
- Simulation and annual system testing
- Transfusion Coordinators

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Future Directions: AI and Predictive Analytics

Transfusion Risk
Avital G, Gelikas S, Radomislensky I, et al. A prehospital scoring system for predicting the need for emergent blood product transfusion. *Transfusion*. 2021; 61: S195-S205
Lou SS, Liu H, Lu C, Wildes TS, Hall BL, Kannampallil T. Personalized Surgical Transfusion Risk Prediction Using Machine Learning to Guide Preoperative Type and Screen Orders. Anesthesiology. 2022 Jul 1;137(1):55-66)

Blood antigen quantification/prediction
Hyvärinen K, Haimila K, Moslemi C, Biobank BS, Olsson ML, Ostrowski SR, Pedersen OB, Erikstrup C, Partanen J, Ritari J. A machine-learning method for biobank-scale genetic prediction of blood group antigens. PLoS Comput Biol. 2024 Mar 21;20(3):e1011977

Red cell age optimization
Isiksacan Z, D'Alessandro A, Wolf SM, McKenna DH, Tessier SN, Kucukal E, Gokaltun AA, William N, Sandlin RD, Bischof J, Mohandas N, Busch MP, Elbuken C, Gurkan UA, Toner M, Acker JP, Yarmush ML, Usta OB. Assessment of stored red blood cells through lab-on-a-chip technologies for precision transfusion medicine. Proc Natl Acad Sci U S A. 2023 Aug 8;120(32):e2115616120)

Waste minimization
Xiang, R.F., Quinn, J.G., Watson, S., Kumar-Misir, A. and Cheng, C. (2021), Application of unsupervised machine learning to identify areas of blood product wastage in transfusion medicine. Vox Sang, 116: 955-964.

Blood bank supply and demand prediction models
Shih H, Rajendran S. Comparison of Time Series Methods and Machine Learning Algorithms for Forecasting Taiwan Blood Services Foundation's Blood Supply. J Healthc Eng. 2019 Sep 17;2019:6123745

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CRASH

Colorado Review of Anesthesia for Surgicenters And Hospitals

Guiding the future of patient care

2025 Updates in Hemodynamic Management

Jason C. Brainard, MD, FCCM
Associate Professor of Anesthesiology and Critical Care
University of Colorado School of Medicine

Anesthesiology
University of Colorado Anschutz Medical Campus

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Goals and Objectives

- Evaluate recent evidence in anesthesiology and critical care to identify studies with potential to influence clinical practice.
- Incorporate current literature into perioperative and intensive care decision-making to optimize patient outcomes.
- Formulate practice changes based on newly published research relevant to anesthesia and critical care delivery.

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- Zellis Foundation

Conflicts of Interest
- I have no financial relationships with a commercial entity that is relevant to the content of this presentation.

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prag·mat·ic
/praɡˈmadik/

- *adjective*
- dealing with things sensibly and realistically in a way that is based on practical rather than theoretical considerations
- **Clinical Question → Evidence → "My Practice"**

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Topics (OR and ICU)

1) Blood Pressure Targets
2) Goal-Directed Hemodynamic Therapy
3) Vasopressors

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Blood Pressure Targets

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Blood Pressure Targets - Physiology

- **DO2 = CO x (1.34 x HGB x SaO2 + (PaO2 x 0.003))**
- **CO = BP / SVR (↑ BP → ↑ CO)**
- **CO = HR x SV (↑ BP → ↑ Afterload → ↓ SV → ↓ CO)**

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Blood Pressure Targets

- Current State
  - Too Low BP → AKI, Ischemic Injury, Death
  - Too High BP → AKI, Arrhythmias, Death
  - ? Correlation vs. Causation
  - Current Standard → MAP ≥ 60-65 (OR and ICU)
  - Argument for Higher MAP Goal → Improve Perfusion and/or Decrease Risk of Hypoperfusion

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Blood Pressure Targets (OR)

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Blood Pressure Targets (OR)

- Clinical Question – Does Individualizing MAP Goals or Higher vs. Lower MAP Goals Improve Patient Outcomes?

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Blood Pressure Targets (OR)

- INPRESS Trial (JAMA 2017, n=292)
  - RCT of Individualized SBP Goal Within 10% Baseline vs. Routine SBP > 80 → Lower Rate of Post-op Organ Dysfunction (38% vs. 52%)
- POISE-3 (AIM 2023, n=3,742)
  - RCT of Hypotension vs. Hypertension-Avoidance Strategy → No Difference in Cardiovascular Complications

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Blood Pressure Targets (OR)

- New Evidence in 2025 → IMPROVE, PRETREAT, BP-CARES

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Blood Pressure Targets (IMPROVE, JAMA 2025)

JAMA | Original Investigation

Individualized Perioperative Blood Pressure Management in Patients Undergoing Major Abdominal Surgery

The IMPROVE-multi Randomized Clinical Trial

Bernd Saugel, MD; Agnes S. Meidert, MD; Frank M. Brunkhorst, MD; Robert Bischoff, MD; Joseph Esser, MD; Minca Mattis, MD; Pauline Naue; Katharina Vogel, BSc; Alina Bergholz, MD; Moritz Flick, MD; Alina Kröker, MD; Dominik X. Müller, MD; Kristen K. Thomsen, MD; Christina Vokuhl, MD; Mirja Wegge, MD; Sebastian Bratke, MD; Martin Graeßner, MD; Bettina Jungwirth, MD; Sebastian Schmid, MD; Carla D. Grundmann, MD; Jan M. Wischermann, MD; Patrick Kellner, MD; Moritz Steinhaus, MD; Linda Grüßer, MD; Sina M. Coldewey, MD, PhD; Kai Zacharowski, MD, PhD; Patrick Meybohm, MD; Marit Habicher, MD; Alexander Zarbock, MD; Amelie Zitzmann, MD; Svenja Letz, MD; Claudia Neumann, MD; Jan Larmann, MD, PhD; Thomas Renné, MD, PhD; Linda Krause, PhD; Eik Vettorazzi, MSc; Antonia Zapf, PhD; Annemarie Carlstedt, PhD; Daniel I. Sessler, MD; Karim Kouz, MD; for the IMPROVE-multi Trial Group

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Blood Pressure Targets (IMPROVE, JAMA 2025)

- Prospective RCT of Individualized vs. Routine MAP Target
- Primary Outcome → Composite AKI, Myocardial Injury, Cardiac Arrest, Death w/in 7-days
- 15 Hospitals in Germany, n=1134
- Age > 45, High-Risk Intra-Abdominal Surgery (Expected Duration > 90 min), 1 High-Risk Criterion

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Blood Pressure Targets (IMPROVE, JAMA 2025)

- Individualized MAP Target
  - Based on Preoperative Mean Overnight MAP
  - 12am-6am @ 30 min Intervals
  - MAP Target Limits ≥ 65 to ≤ 110
- Routine MAP Target
  - MAP ≥ 65
- Hemodynamic Interventions (Fluids and Vasopressors) Up To Treating Physician (Arterial Line 74%)
- Maintained Target Intraop Through 2hrs Post-Op

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Blood Pressure Targets (IMPROVE, JAMA 2025)

- Primary Outcome – Composite AKI, Myocardial Injury, Cardiac Arrest, Death → No Difference
  - Individualized 33.5% vs. Routine 30.5% (p=0.31)
  - No Difference In Any Individual Component
- Secondary Outcomes → No Differences
  - Primary Outcome at 30-days or 90-days
  - Infection
  - Mortality
  - No Other Differences in Serious Adverse Events

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Blood Pressure Targets (IMPROVE, JAMA 2025)

- Strengths
  - Multisite Prospective RCT w/ ~Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol
- Weaknesses
  - ? Patient-Centered Primary Outcome
  - Intraoperative Hemodynamic Mgmt Not Controlled
  - Post-Operative Management (After 2hrs) Not Controlled

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Blood Pressure Target (PRETREAT, JAMA 2025)

JAMA | Original Investigation

Proactive vs Reactive Treatment of Hypotension During Surgery
The PRETREAT Randomized Clinical Trial

Matthijs Kant, MD; Wilton A. van Klei, MD, PhD; Markus W. Hollmann, MD, PhD; Eline S. de Klerk, MSc; Luuk C. Otterspoor, MD, PhD; Marc G. Besselink, MD, PhD; Teus H. Kappen, MD, PhD; Denise P. Veelo, MD, PhD; for the PRETREAT study group

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Blood Pressure Target (PRETREAT, JAMA 2025)

- Prospective RCT of Proactive Risk Stratified vs. Routine MAP Target
- Primary Outcome → Functional Disability @ 6 Months (WHODAS 2.0, Range 0-100, Higher is Worse)
- 2 Hospitals in Netherlands, n=2306
- Age > 18, Non-Cardiac Surgery, Expected HLOS ≥ 1 Night

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Blood Pressure Target (PRETREAT, JAMA 2025)

- Risk-Stratified MAP Target
  - Preoperative Risk Calculator For Intraoperative Hypotension (Novel, Center-Specific Model)
  - Low-Risk ≥ 70, Intermediate-Risk ≥ 80, High-Risk ≥ 90
- Routine MAP Target
  - MAP ≥ 65
- Hemodynamic Interventions (Fluids and Vasopressors) Up To Treating Physician (Arterial Line 18%)

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Blood Pressure Target (PRETREAT, JAMA 2025)

- Primary Outcome – Mean Functional Disability @ 6 Months → No Difference
  - Risk-Stratified 17.7 vs. Routine 18.2
  - Trial Stopped Early for Futility
  - No Difference in Low-Risk (21% Pts), Intermediate-Risk (56% Pts), or High-Risk (23% Pts) Patients
- Secondary Outcomes → No Differences
  - Mortality, ICU LOS, HLOS, Reoperation

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Blood Pressure Target (PRETREAT, JAMA 2025)

- Strengths
  - Multisite Prospective RCT w/ ~Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol
- Weaknesses
  - Trial Stopped Early for Futility
  - ? Clinical Significance of Median Average Difference of 5.8 mmHg (86.9 vs. 81.1)
  - Intraoperative Hemodynamic Mgmt Not Controlled
  - Post-Operative Management Not Controlled

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Blood Pressure Target (BP-CARES, JACC 2025)

Intensive vs Conventional Intraoperative Blood Pressure Management on Cardiovascular Events After Major Abdominal Surgery

The BP-CARES Randomized Trial

Bingcheng Zhao, MD, Jiaqiang Zhang, MD, PhD, Yishan Xie, MD, Zhuoxi Wu, MD, PhD, Gaofeng Guo, MD, Shaohui Lei, MD, Jiaming Liu, MD, Huamin Liu, PhD, Jian Liu, MD, Weifeng Liu, MD, PhD, Cai Li, MD, PhD, Yangyang Lian, MD, Yuting Tan, MD, Dongxin Wang, MD, PhD, Hong Li, MD, PhD, Daniel I. Sessler, MD, Kexuan Liu, MD, PhD

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Blood Pressure Target (BP-CARES, JACC 2025)

- Prospective RCT of Intensive Intra-Op BP Management (MAP ≥ 80) vs. Routine BP Management (MAP ≥ 65 or 60% Baseline)
- Primary Outcome → Composite Cardiovascular Events (Myocardial Injury/AMI, Arrhythmia, Heart Failure, Stroke, Cardiac Arrest, Death) w/in 30-days
- 3 Hospitals in China, n=1477
- Age > 45, Intra-Abdominal Surgery (Expected Duration > 120 min), Pre-Existing CV Disease or ≥ 2 Risk Factors

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Blood Pressure Target (BP-CARES, JACC 2025)

- Primary Outcome – Composite Myocardial Injury/AMI, Arrhythmia, Heart Failure, Stroke, Cardiac Arrest, Death w/in 30-days → No Difference
  - Intensive 14.5% vs. Routine 13.6% (p=0.61)
  - No Difference In Any Individual Component
- Secondary Outcomes → No Differences
  - Acute Kidney Injury
  - Infection
  - No Other Differences in Serious Adverse Events

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Blood Pressure Target (BP-CARES, JACC 2025)

- Strengths
  - Multisite Prospective RCT w/ Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol
- Weaknesses
  - Modest Difference in Duration of Hypotension Between Groups
  - 75% Male
  - ? Patient-Centered Primary Outcome
  - Intraoperative Hemodynamic Mgmt Not Controlled
  - Post-Operative Management Not Controlled

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Blood Pressure Targets (OR)

- Clinical Question – Does Individualizing MAP Goals or Higher vs. Lower MAP Goals Improve Patient Outcomes?
- Best Evidence To Date → IMPROVE, PRETREAT, BP-CARES
  - IMPROVE (Individual MAP Goal) – No Difference
  - PRETREAT (Risk-Stratified MAP Goal) - No Difference
  - BP-Cares (MAP ≥ 80 vs. MAP ≥ 65) - No Difference
- My Practice → MAP ≥ 65
  - Includes Patients w/ Chronic HTN
- Future Directions → Trials for MAP ≥ 55 or Perfusion Endpoints

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Blood Pressure Targets (ICU)

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Blood Pressure Targets (ICU)

- Clinical Question – Does Individualizing MAP Goals or Higher vs. Lower MAP Goals Improve Patient Outcomes?

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Blood Pressure Targets (ICU)

- SEPSISPAM (NEJM 2014, n=776)
  - RCT of MAP 80-85 vs. 65-70 → No Difference in Mortality, Higher Rate of Afib (6.7% vs. 2.8%), Lower Rate of Dialysis in Subgroup w/ Chronic HTN (32% vs. 42%)
- 65 TRIAL (JAMA 2020, n=2463)
  - RCT of Routine Care (MAP ≥65) vs. MAP 60-65 → No Difference in Mortality, Higher Mortality in Subgroup w/ Chronic HTN (44% vs. 38%)

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Blood Pressure Targets (ICU)

- New Evidence in 2025 → OPTPRESS, Mendes Review

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Blood Pressure Targets (OPTPRESS, ICM 2025)

ORIGINAL

Efficacy of targeting high mean arterial pressure for older patients with septic shock (OPTPRESS): a multicentre, pragmatic, open-label, randomised controlled trial

Akira Endo[1,2,23*], Kazuma Yamakawa[3], Takashi Tagami[4], Yutaka Umemura[5], Takeshi Wada[6], Ryo Yamamoto[7], Hiroki Nagasawa[8], Wataru Takayama[2], Masayuki Yagi[9], Kyosuke Takahashi[10], Mitsuaki Kojima[2,11], Chihiro Narita[12], Satoshi Kazuma[13], Jiro Takahashi[14], Atsushi Shiraishi[15], Masaki Todani[16], Masaki Nakane[17], Toshihiko Nagata[18], Shohei Tanaka[19], Yuta Yokokawa[20], Kunihiko Takahashi[21], Haruka Ishikita[1,2], Ryo Hisamune[3], Junichi Sasaki[7], Ken-ichi Muramatsu[8], Hiroyuki Sonobe[9], Kazunobu Minami[22], Hiromasa Hoshi[1,2] and Yasuhiro Otomo[2,23] on behalf of the OPTPRESS trial investigators

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Blood Pressure Targets (OPTPRESS, ICM 2025)

- Prospective RCT of High MAP (80-85) vs. Low MAP (65-70)
- Primary Outcome → 90-day Mortality
- 29 Hospitals in Japan, n=518
- Age > 65 (70% Chronic HTN), Septic Shock

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Blood Pressure Targets (OPTPRESS, ICM 2025)

- Primary Outcome – 90-day Mortality → High MAP 39.3% vs. Low MAP 28.6% (p=.012)
  - Trial Stopped Early for Mortality Difference
  - Same Outcome in Patients w/ Chronic HTN
- Secondary Outcomes →
  - Dialysis-Free Days – 18 days vs. 20 days (p=0.024)
  - Ventilatory-Free Days – 15 days vs. 18 days (p=0.012)
  - Vasopressor-Free Days – 16 days vs. 19 days (p=0.012)

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Blood Pressure Targets (OPTPRESS, ICM 2025)

- Strengths
  - Multisite Prospective RCT w/ ~Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol
  - Vasopressor Choice Controlled
- Weaknesses
  - Early Termination
  - Resuscitation Not Controlled

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Blood Pressure Targets (Mendes, CC 2026)

REVIEW — Open Access

Mortality effect of higher versus lower blood pressure targets in vasodilatory shock: an updated systematic review and meta-analysis

Henrique Mendes[1*], Jesse King[1], Nikhil Kumar[2], Kush Deshpande[1,3], Rakshit Panwar[2,4] and Frank M. P. van Haren[1,3,5]

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Blood Pressure Targets (Mendes, CC 2026)

- 4 Prospective RCTs Included (n=3,873)
- Higher MAP Target (80±5) vs. Lower MAP Target (65±5)
- Higher MAP Target →
  - 10% Increase in 28-day Mortality (p=0.03)
  - ~1.5 Additional Days of Dialysis (p=0.02)
  - 1.3x Higher Risk of Arrhythmia (p=0.04)
  - No Benefit in Any Secondary Outcome
  - No Benefit from Higher MAP in Any Subgroup (Including Advanced Age and Chronic HTN)

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Blood Pressure Targets (ICU)

- Clinical Question –Clinical Question – Does Individualizing MAP Goals or Higher vs. Lower MAP Goals Improve Patient Outcomes?
- Best Evidence To Date → OPTPRESS, MA
  - OPTPRESS – Higher MAP Increases Mortality
  - MA – Higher MAP Increases Mortality
- My Practice → MAP ≥ 60-65
  - Includes Patients w/ Chronic HTN
- Future Directions → Trials for MAP ≥ 55-60 or Perfusion Endpoints

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Goal-Directed Hemodynamic Therapy

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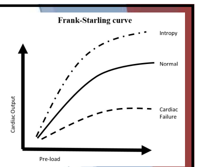
Goal-Directed Hemodynamic Therapy - Physiology



- DO2 = CO x (1.34 x **HGB** x SaO2 + (PaO2 x 0.003))
- CO = SV x HR **(Fluid Resuscitation → Preload → ↑ SV)**
- Improve Care Through "Optimized Tissue Oxygenation"
  - Individualized Therapy
  - Protocolized Targets
  - Real-Time Monitoring

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Goal-Directed Hemodynamic Therapy

- Current State (Fluid Resuscitation)
  - Too Little Fluid → AKI, Ischemia, Death
  - Too Much Fluid → Pulmonary Edema, Pneumonia, Heart Failure, Arrhythmias, Death
  - "Fluid Responsive" – Increase in Stroke Volume in Response to Fluid Bolus (>10%)
  - Current Standard → GDHT Reduces Post-Operative Complications and Mortality

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Goal-Directed Hemodynamic Therapy

- Clinical Question – Does Rigorous GDFT in the OR Improve Patient Outcomes?

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Goal-Directed Hemodynamic Therapy

- OPTIMISE I Trial (JAMA 2014, n=734)
  - RCT of GDHT vs. Routine Care in Major Abd Surgery → ? Reduced Composite of Mortality + Severe Complications (36.6% vs. 43.4%, p=0.07)
- FEDORA (BJA 2018, n=420)
  - RCT of GDHT vs. Routine Care in Major Abd Surgery → Reduction in Severe Complications (8.6% vs. 16.5%, p=0.02)

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Goal-Directed Hemodynamic Therapy

- Diaper (Surgery 2021, n=401)
  - RCT of GDHT vs. Routine Care in Major Abd Surgery → No Difference in Composite Mortality + Severe Complications (58% vs. 53%)
- De Waal (JCA 2021, n=482)
  - RCT of GDHT vs. Routine Care in Major Abd Surgery → No Difference in Severe Complications (0.79 vs. 0.69)

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Goal-Directed Hemodynamic Therapy

- New Evidence in 2025-ish → OPTIMISE II

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GDHT (OPTIMISE II, BMJ 2024)

RESEARCH

OPEN ACCESS

Check for updates

Cardiac output-guided haemodynamic therapy for patients undergoing major gastrointestinal surgery: OPTIMISE II randomised clinical trial

OPTIMISE II Trial Group

CRASH

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GDHT (OPTIMISE II, BMJ 2024)

- Prospective RCT of GDHT vs. Routine Care
- Primary Outcome → Post-Op Infection w/in 30-days
- 55 Hospitals from 11 Countries, n=2498
- Age ≥ 65, ASA ≥ 2, Major Elective GI Surgery (Expected Duration ≥ 90 min)

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GDHT (OPTIMISE II, BMJ 2024)

- GDHT
  - Edwards Monitor w/ ClearSight (Non-Invasive) or FlowTrac (Arterial Line)
  - PRN Fluid Bolus for Stroke Volume Increase > 10% (Primary) and Stroke Volume Variation > 5% (Secondary)
  - Fixed Dose Dobutamine gtt @ 2.5
    - Held for HR > 100
- Both Groups - Vasopressors Up To Treating Physician
- Intervention Extended to 4-hours Post-Op

CRASH

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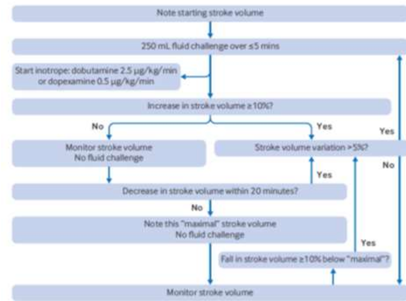

General haemodynamic measures (all patients)
1. Maintenance fluid at 1 mL/kg/h - dextrose 5% recommended
2. Tranfuse blood to maintain haemoglobin >80 g/L
3. Clinician retains discretion to adjust therapy if concerned about risks of hypovolaemia or fluid overload
4. Mean arterial pressure 60-100 mm Hg; SpO_2 ≥94%; temperature 37°C; heart rate <100 beats/min

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GDHT (OPTIMISE II, BMJ 2024)

- Primary Outcome – Post-Op Infection w/in 30-days → No Difference
  - GDHT 23.2% vs. Routine Care 22.7% (p=0.81)
- Secondary Outcomes
  - Cardiac Events w/in 24-hrs → 3.0% vs 1.7% (p=0.03)
    - Primarily 2/2 Arrhythmias (2.6% vs. 1.4%)
  - Cardiac Events w/in 30-days → No Difference
  - No Difference in Mortality or Other Serious Adverse Events

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GDHT (OPTIMISE II, BMJ 2024)

- Strengths
  - Multisite Prospective RCT w/ ~ Adequate Power
  - Patients Well Matched w/ Good Separation and Adherence to Protocol
  - Routine Care Included Some Controls (ex. MAP ≥ 60, HGB > 8) and Similar Vasopressor Mgmt
  - Largest Trial to Date (5x)
- Weaknesses
  - Unclear Contribution of Fixed Inotropic Support
  - Indirect Measure of Stroke Volume
  - Abx. Prophylaxis Not Controlled

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Goal-Directed Hemodynamic Therapy

- Clinical Question – Does Rigorous GDHT in the OR Improve Patient Outcomes?
- Best Evidence To Date → OPTIMISE II
  - No Difference in Primary Outcome
  - Increase in Early Arrhythmias w/ GDHT
- My Practice → No Routine Inotrope Infusions, No Cardiac Output Monitors, Use SVV/PPV In Conjunction w/ Other Data
- Future Directions → Similar Trial w/o Inotrope gtt, Algorithm Targeted to Fluids Responsiveness

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Vasopressors

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Vasopressor - Physiology

- **DO2 = CO x (1.34 x HGB x SaO2 + (PaO2 x 0.003))**
- **CO = BP / SVR (↑ BP → ↑ CO)**
- **CO = HR x SV (↑ BP → ↑ Afterload → ↓ SV → ↓ CO)**

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Vasopressor Choice (Background)

- Septic Shock – Norepinephrine 1st Line, Vasopressin 2nd Line
- OB Anesthesia – Vasodilation During C-Section w/ Spinal Anesthesia – Norepinephrine 1st Line
  - Maintains CO and Decreased Bradycardia vs. Phenylephrine
  - No Effect on Neonatal Outcomes
- Pulmonary Hypertension – Norepinephrine (or Vasopressin) 1st Line

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Vasopressor Choice (OR)

- Clinical Question – Should Norepinephrine vs. Phenylephrine be 1st Line Vasopressor for Intraoperative Hypotension / Vasodilatory Shock? (Non-Septic)

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Vasopressor Choice (OR)

- VEGA-1 Trial (BJA 2023, n=3626)
  - Prospective Crossover Feasibility Trial of Norepi vs. Phenylephrine as 1st Line Vasopressor in OR → No Difference in Any Clinical Outcome
- Chen Trial (CCM 2025, n=156)
  - RCT of Norepi vs. Phenylephrine as 1st Line Vasopressor in OR → No Difference in Any Clinical Outcomes

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Peripheral Vasopressor Safety

- Munroe (JAMA Open, 2025)
  - Peripheral Vasopressor Use in Early Sepsis-Induced Hypotension
  - Prospective Cohort Study of CLOVERS Trial
  - ICU Population w/ Septic Shock
  - n=582 (490 Patients → Peripheral Vasopressors, 95% → Norepinephrine)
  - Peripheral Vasopressor Complication 0.6% vs. Central Line Complications 3.7%

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Vasopressor Choice (OR)

- Clinical Question – Should Norepinephrine vs. Phenylephrine be 1st Line Vasopressor for Intraoperative Hypotension / Vasodilatory Shock? (Non-Septic)
- Best Evidence To Date → Not Much
- My Practice → Norepinephrine as 1st Line

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Summary

- Blood Pressure Targets (MAP)
  - OR and ICU – MAP ≥ 60-65
  - No Change for Chronic Hypertension
- Goal-Directed Hemodynamic Therapy
  - No Routine Inotrope Infusions
  - No Cardiac Output Monitors
  - Use SVV/PPV In Conjunction w/ Other Data
- Vasopressors
  - OR – Norepinephrine 1st Line
  - ICU – Norepinephrine 1st Line

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