A Roundtable Discussion:
The US Experience in DCD-NRP

TODAY'S PRESENTERS

Yanik Bababekov
MD, MPH
Assistant Professor, Transplant Surgery

uchealth

Shennen Mao
MD
Assistant Professor and Surgical Director of Kidney & Pancreas Transplant

MAYO CLINIC

Phil Paci
MDCM, MSc, FRCSC, FACS
Surgical Director, Kidney & Pancreas Transplantation

Intermountain Health

Anji Wall
MD, PhD
Medical Director, BSW Transplant Center for Innovation, Science, Policy Research, and Ethics

BaylorScott&White HEALTH

THE Alliance | UC San Diego Health | DTI DONATION & TRANSPLANTATION INSTITUTE

Thursday, May 22, 2025, 11:00am – 1:00pm ET

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- Group leaders, please share the follow-up email with all group participants who attended the webinar.

Meet Our Moderators

Deanna Fenton

Senior Manager, Program Development and Operations

THE Alliance

Need Assistance?

Contact Us via Zoom Chat, or info@organdonationalliance.org

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Professor of Surgery

UC San Diego Health

Marty Sellers

MD, MPH

Medical Director

GIFT of LIFE DONOR PROGRAM

Aleah Brubaker

MD, PHD

Assistant Professor of Surgery

UC San Diego Health

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The Baylor Experience with NRP

Anji Wall, MD, PhD, FACS

Baylor University Medical Center in Dallas

Baylor's introduction to NRP

Have you heard of NRP? Is this ethical?

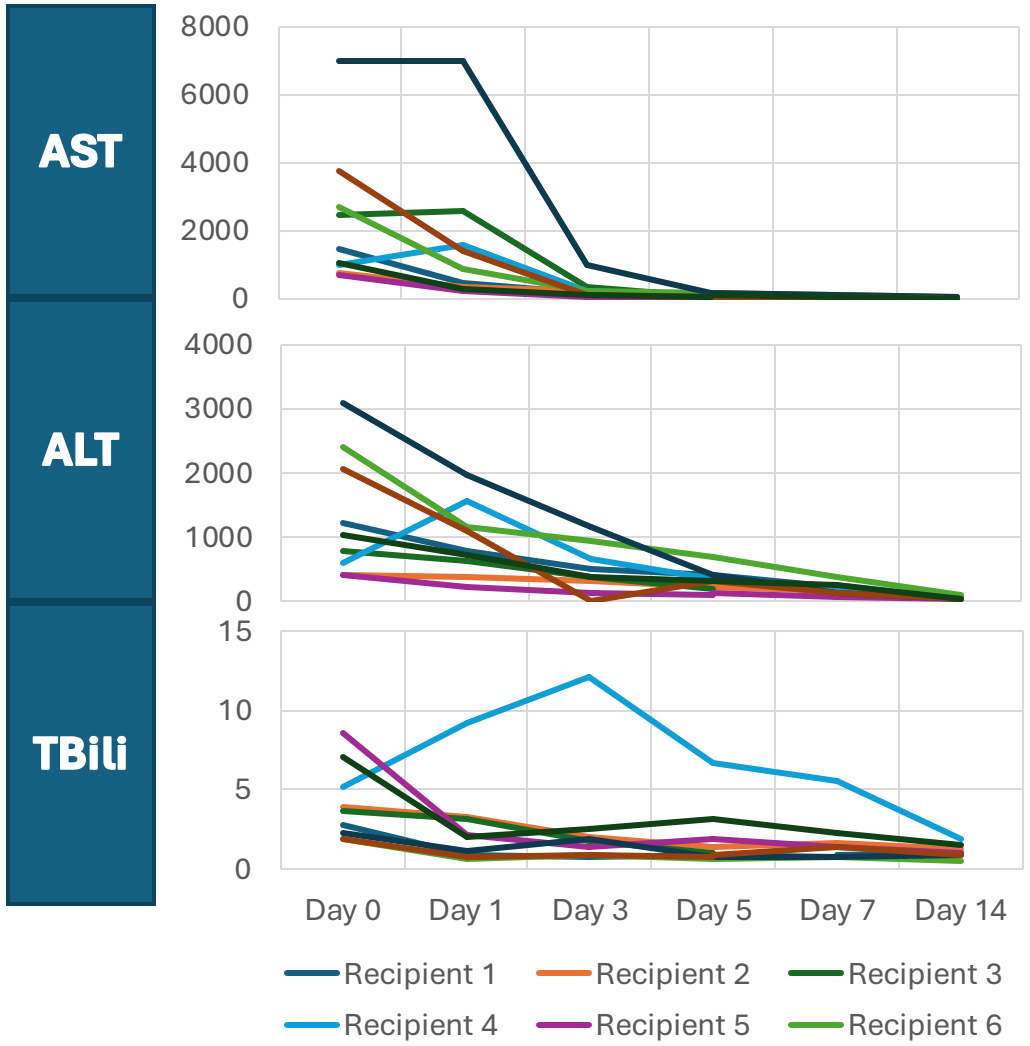
Ethics chair: Is NRP ethical?

Transplant surgeons: have you heard of NRP? Ethics committee supports its ethical acceptability. Are we ok using TA-NRP donors?

First TA-NRP donor

- More controlled donor operation
- Better visual and functional assessment capability
- Excellent recipient outcome (reperfusion, LOS, etc)

First 6 NRP recipients at Baylor



Donor data	
Age, years, mean (SD)	27 (6)
BMI, kg/m2, mean (SD)	26 (6)
Terminal total bilirubin, mg/dL, mean (SD)	0.67 (0.39)
AST, u/L, median (IQR) Range	49 (33-73) (23-753)
ALT, u/L, median (IQR) Range	93 (24.5-131) (21-766)
Functional warm ischemic time, minutes, mean (SD)	22 (3)
Time from incision to flush (on-circuit), minutes, mean (SD)	4.3 (2)
Time on NRP, minutes, median (IQR) Range	60 (55-68.5) (34-120)

Recipient data	
Age, years, mean (SD)	62 (5.6)
BMI, kg/m2, mean (SD)	27 (4.7)
Laboratory MELD-Na score, mean (SD)	19 (7.6)
Cold ischemic time, minutes, mean (SD)	315 (69.5)
Length of stay, days, median (IQR) Range	5 (5-7) (5-9)
Biliary complication (first 6 months post-op) • Anastomotic stricture • No biliary complication	N (%) 1 (14) 7 (86)

If TA-NRP is working…. Why should we limit?

5% of DCD donors have the heart allocated for transplant

NRP increases liver utilization and improves kidney DGF

Can we build a program that applies NRP to non-cardiac donors?

PROGRAM IMPLEMENTATION

Pre-implementation Analysis

Ethics committee review
Financial analysis
Capacity assessment

Pilot testing

Small team
Controlled environment
Low volume
Low risk

Expansion

Mobile team
Increased volume
Increased risk threshold
Creative process improvements

EXPANSION TIMELINE

2021 — 09-08-2021

First in-house A-NRP pathway DCD. 53 M, normal LFTs, BMI 26, head trauma. fWIT 66 minutes. 1 kidney transplanted, IGF

2022 — 06-18-2022

First successful in-house A-NRP DCD pathway liver transplant. 36F, normal LFTs, 18 min fWIT, liver/ kidneys. LTX: 69M, 4d LOS

2022 — 11-20-2022

Local hospital. 51F, normal LFTs, WLST sheath placement in OR. Donor did not expire

2022 — 11-25-2022

First mobile LTX: 42F, BMI 19, normal LFTs, 27 min fWIT;
Recip: 57F, MELD 26, 6 d LOS
Curveball: Tandem lung SRR

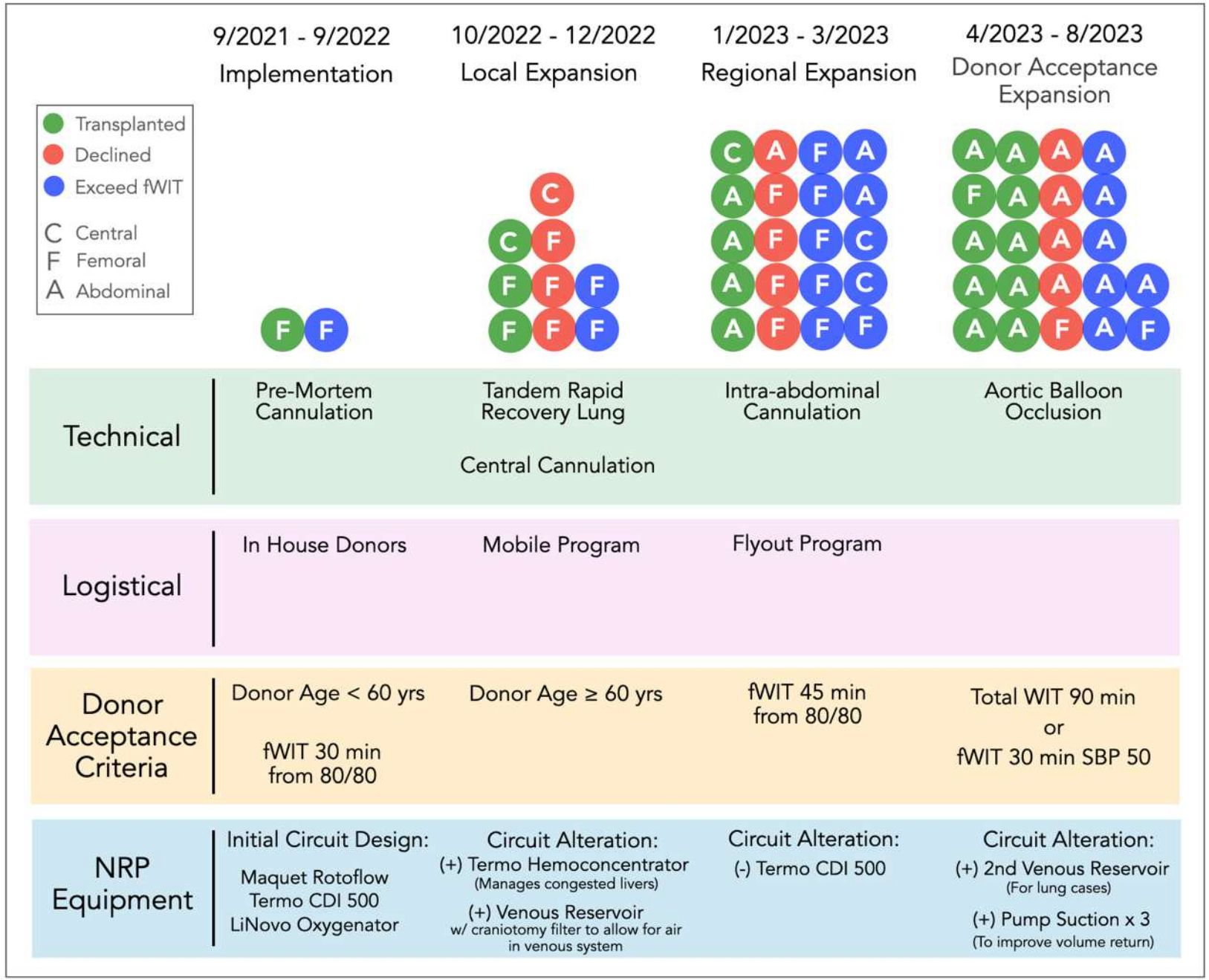
2022 — 12-03-2022

Lifegift donor: central cannulation 12-8-22 second LG donor: 60 M, 22 min fWIT; recip 69M MELD 16, 4 day LOS

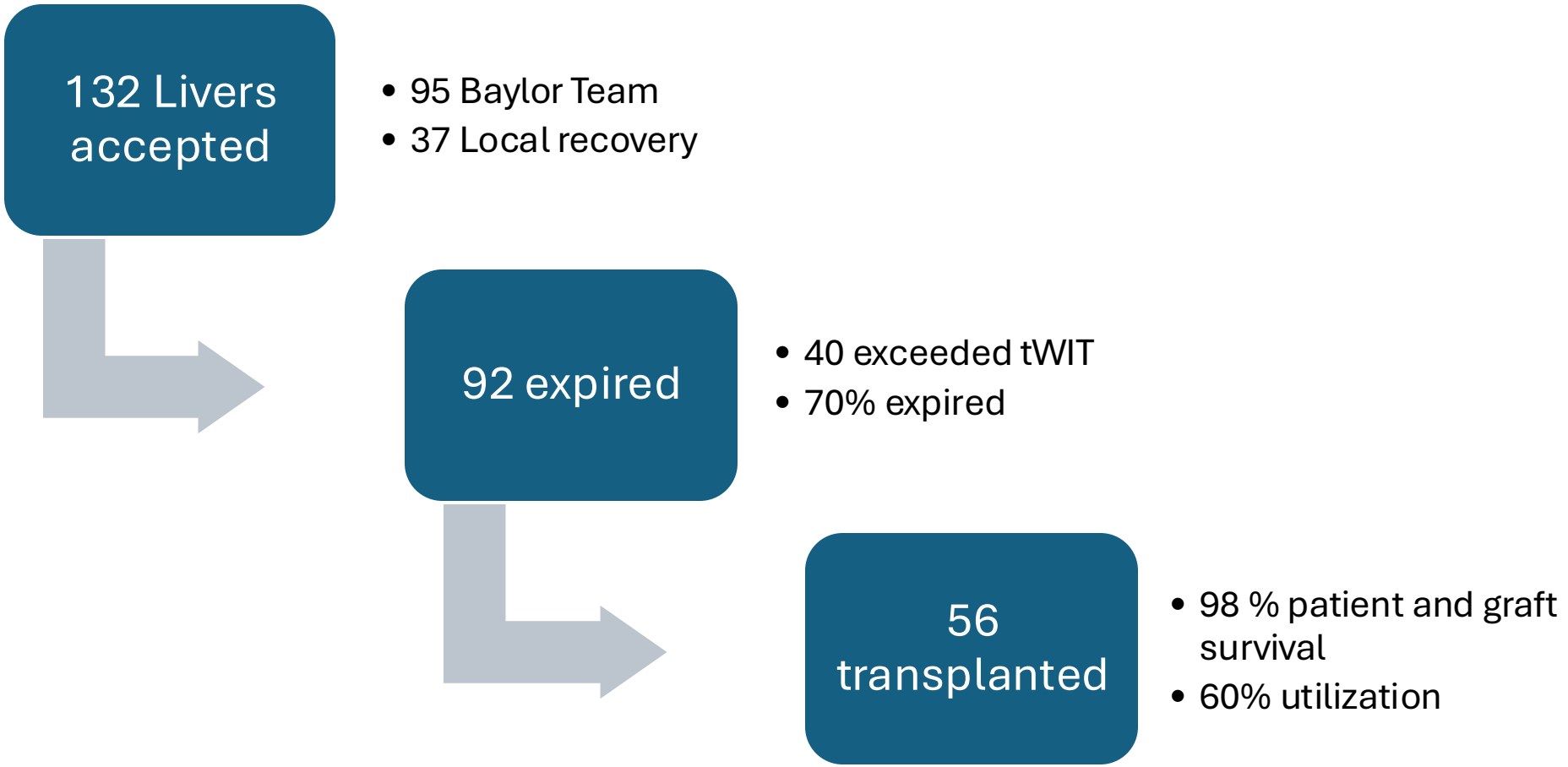
2023 — 02-20-2023

Intra-abdominal cannulation by txp team. 48F, BMI 42, 21 min fWIT. 68M MELD 11, 5 d LOS

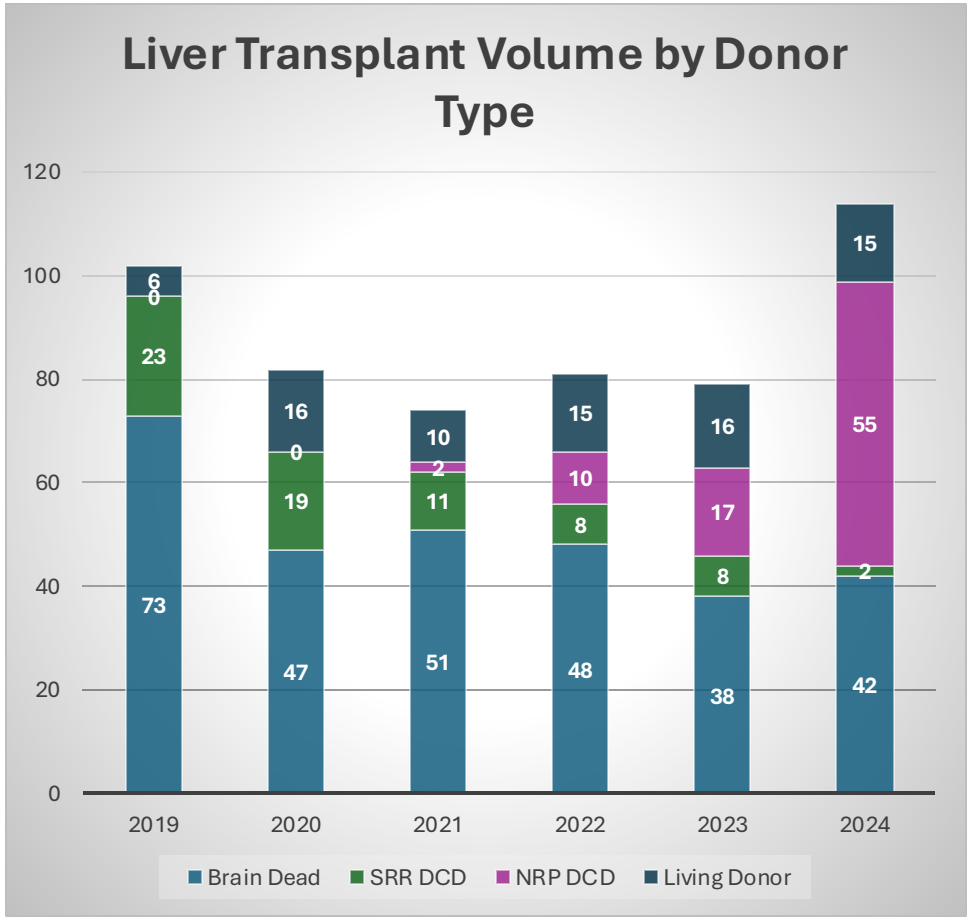
A-NRP ICU → OLTx → Mobile → Lung SRR → New OPO → Abd only

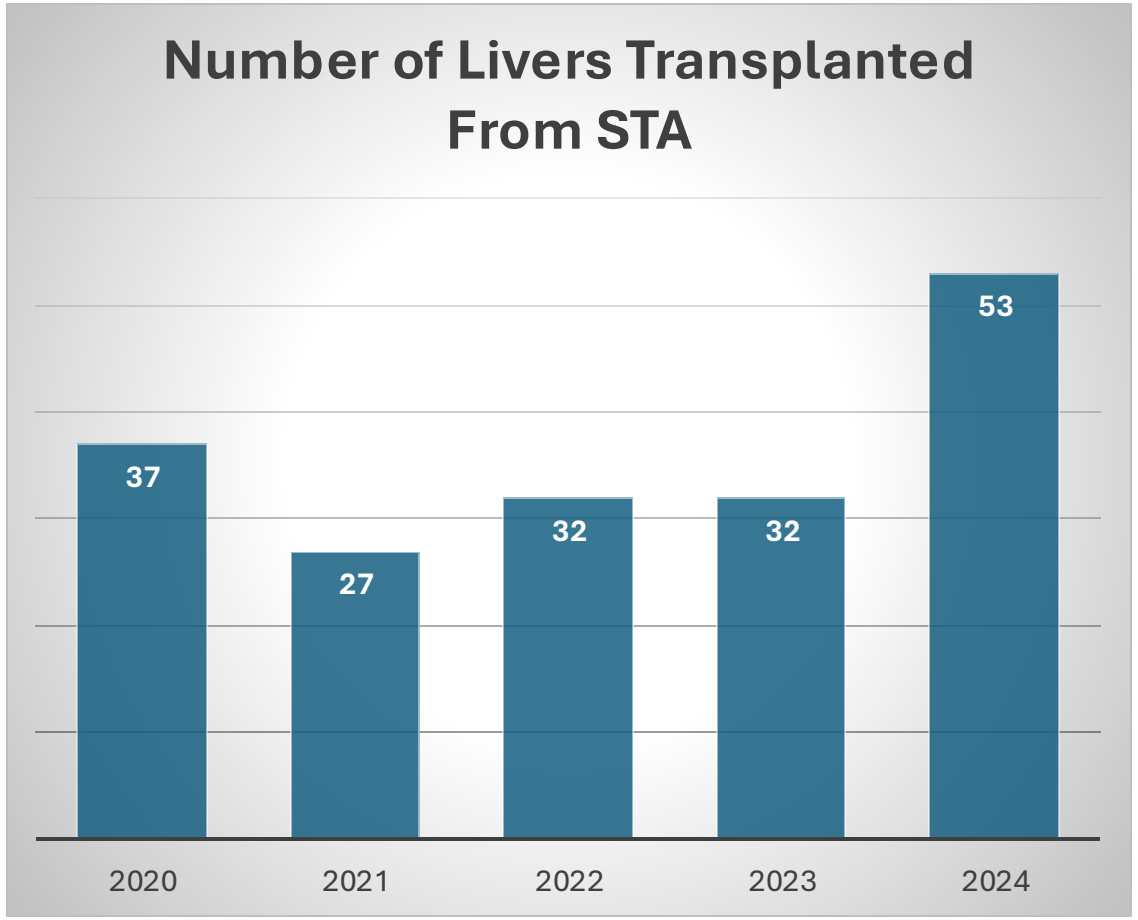

Transplanted
Declined
Exceed fWIT
C Central
F Femoral
A Abdominal
9/2021 - 9/2022
Implementation
10/2022 - 12/2022
Local Expansion
1/2023 - 3/2023
Regional Expansion
4/2023 - 8/2023
Donor Acceptance Expansion
Technical
Pre-Mortem Cannulation
Tandem Rapid Recovery Lung
Central Cannulation
Intra-abdominal Cannulation
Aortic Balloon Occlusion
Logistical
In House Donors
Mobile Program
Flyout Program
Donor Acceptance Criteria
Donor Age < 60 yrs
fWIT 30 min from 80/80
Donor Age ≥ 60 yrs
fWIT 45 min from 80/80
Total WIT 90 min
or
fWIT 30 min SBP 50
NRP Equipment
Initial Circuit Design:
Maquet Rotoflow
Termo CDI 500
LiNovo Oxygenator
Circuit Alteration:
(+) Termo Hemoconcentrator
(Manages congested livers)
(+) Venous Reservoir
w/ craniotomy filter to allow for air in venous system
Circuit Alteration:
(-) Termo CDI 500
Circuit Alteration:
(+) 2nd Venous Reservoir
(For lung cases)
(+) Pump Suction x 3
(To improve volume return)

2024 Clinical NRP program: Liver



The impact of NRP on liver transplant volume BUMC





DCD-NRP for Liver Transplantation: The Colorado Experience

Yanik J. Bababekov, MD, MPH

Assistant Professor of Surgery
Assistant Professor of Public Health
Director of Quality, Department of Surgery
Tufts Medical Center | Tufts University School of Medicine

Adjunct Assistant Professor of Anesthesiology
IC42 Clinical Research and Development Laboratory
University of Colorado- Anschutz Medical Campus

DCD in Action: Advanced Training in Normothermic Regional Perfusion

San Diego, USA

May 22, 2025

I declare I have no conflict of interest

Objectives

- Recognize the local impact of changes to national allocation policy
- Discuss the structure, process, outcomes of NRP for DCD LT at UCH
- Identify additional opportunities to improve DCD NRP

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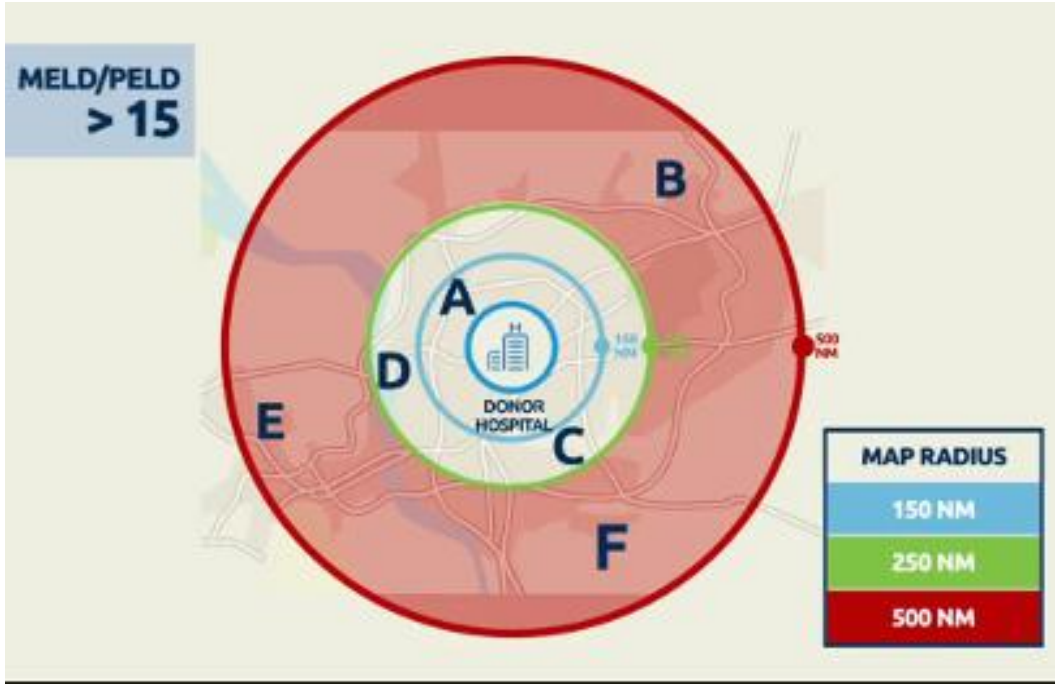
2020: US Policy Prioritizes DCD Liver Allocation

- Variation in Median MELD at Transplant



- Geographic UNOS regions follow State groupings

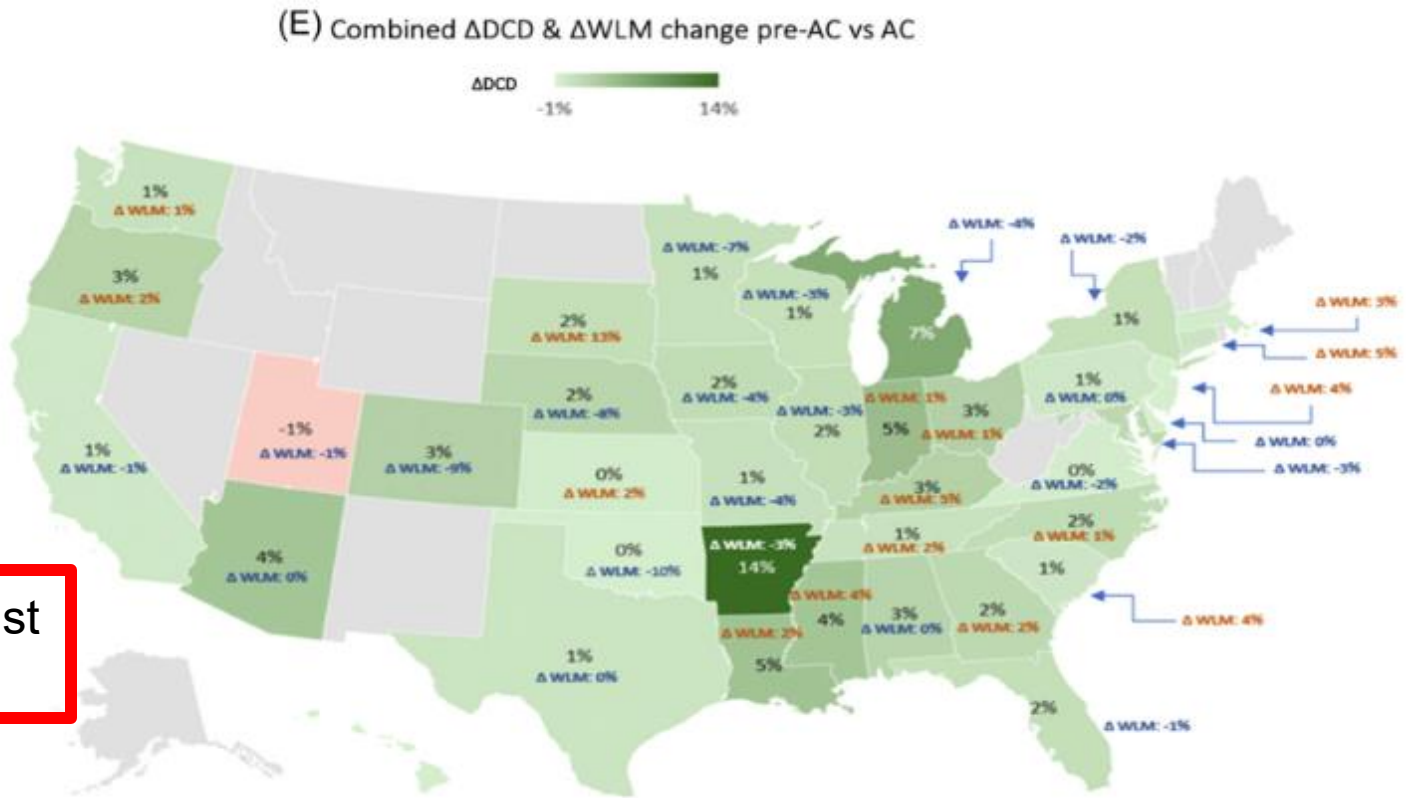
- Geographic circles around donor hospitals
- **Prioritize DCD allocation within 150 NM radius**

RESEARCH LETTER

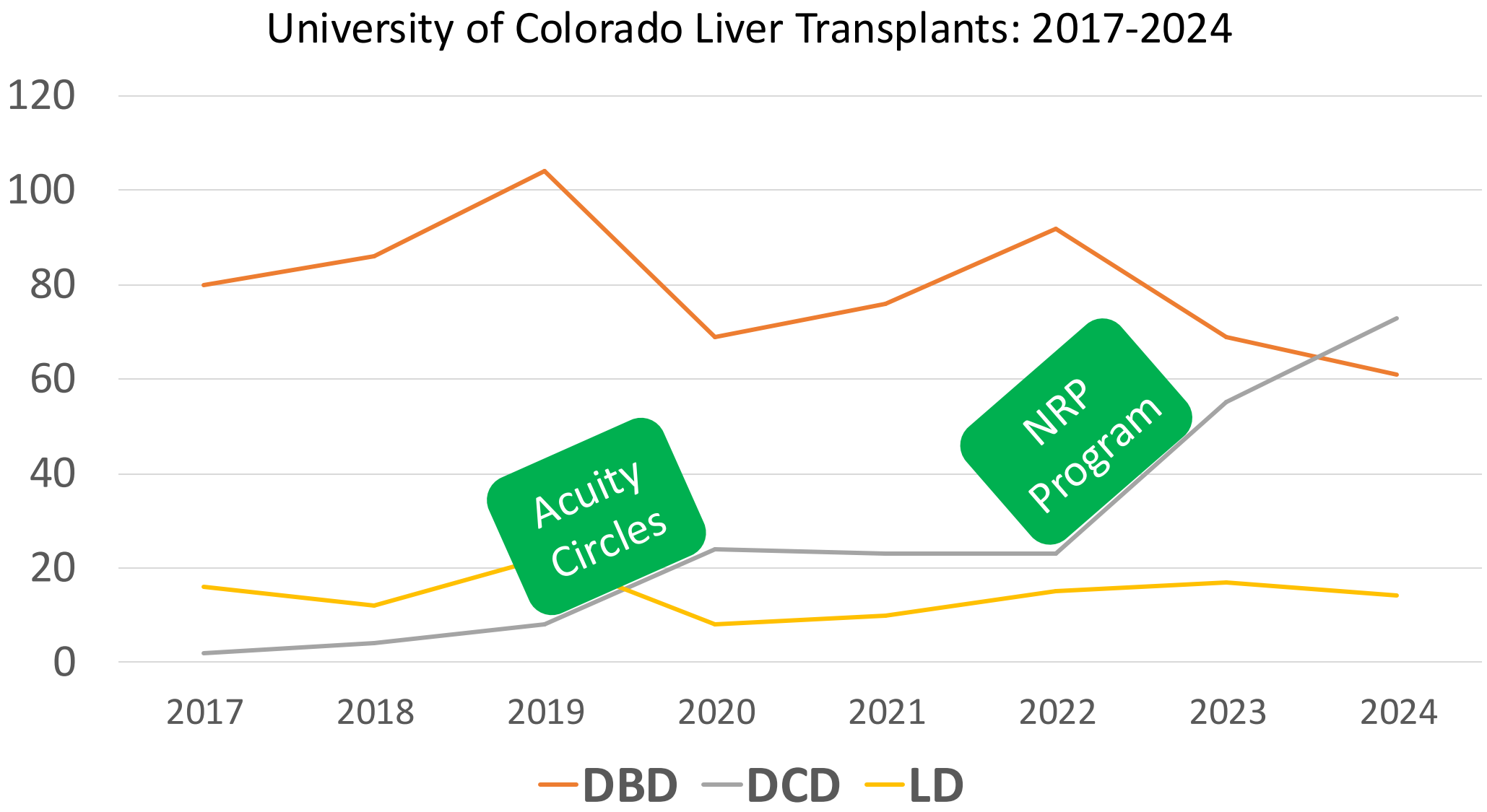
Health Science Reports Open Access WILEY

Acuity circles allocation policy impact on waitlist mortality and donation after circulatory death liver transplantation: A nationwide retrospective analysis

- AC 2/2020 aim to address MMaT variability
- 2016-2019 (*Pre*) vs 2020-2021 (*Post*)
- After AC at State level:
  - Waitlist mortality continue to vary
  - DCD utilization continue to vary
  - Highest DCD rates sustain or reduce waitlist mortality
- **"Evolutionary Pressure"**
  - **Scarcity of local DBDs for some States**



Health Sci Rep. 2023 Feb 1;6(2):e1066



"Necessity is the mother of invention"- Plato

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We learned and continue to learn from Europe

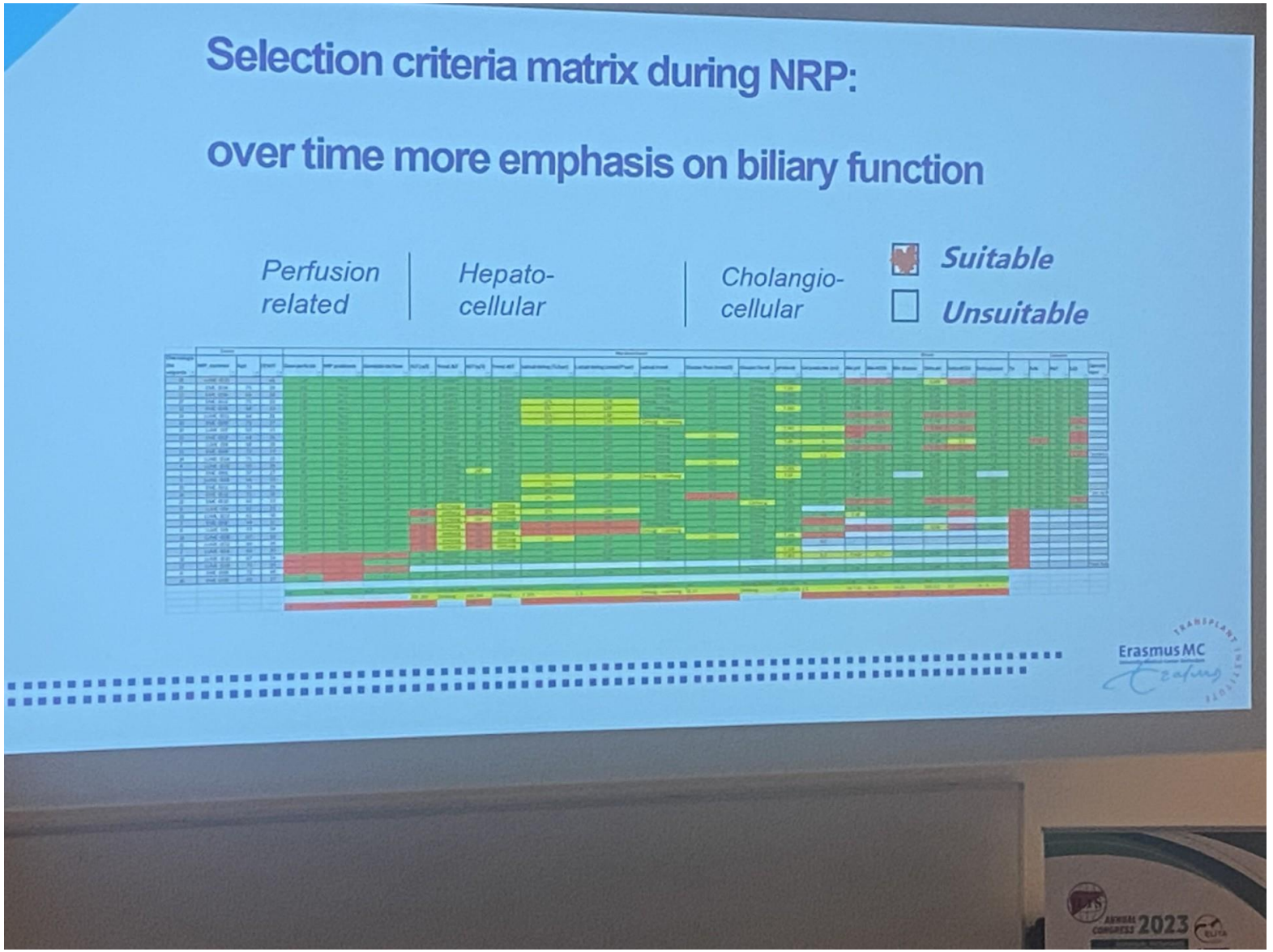
Salvage of Declined Extended-criteria DCD Livers Using In Situ Normothermic Regional Perfusion

Ivo J. Schurink, BSc, Femke H.C. de Goeij, BSc,* Lex J.M. Habets, BSc,†*
Fenna E.M. van de Leemkolk, MD,† Christian A.A. van Dun, BSc,‡
Gabriel C. Oniscu, MD, PhD,§ Ian P.J. Alwayn, MD, PhD,†
Wojciech G. Polak, MD, PhD, Volkert A.L. Huurman, MD, PhD,†*
and Jeroen de Jonge, MD, PhD✉*

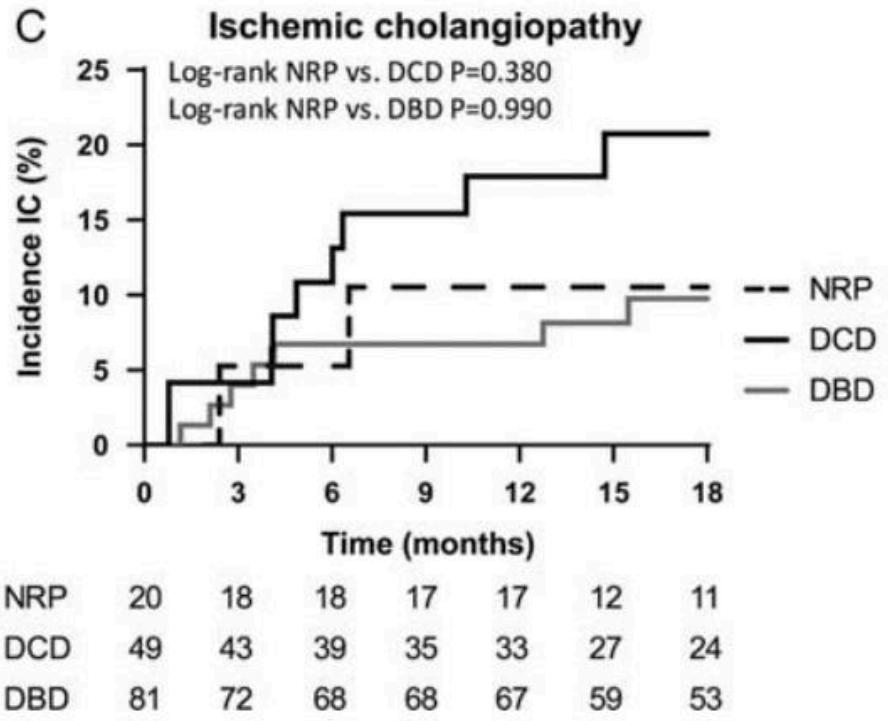
- 45 donor livers rescued by aNRP; 10/2018-3/2021
- 25 donors met final inclusion; **20** livers transplanted
- **Able to rescue livers (*decrease discards*) by evaluating hepatocellular and cholangiocelluar function during aNRP**
- Results comparable to DBD
- Erasmus MC, Rotterdam, Netherlands

Ann Surg 2022;276:e223–e230

Viability Assessment of DCD NRP Liver Allografts: ILTS 2023



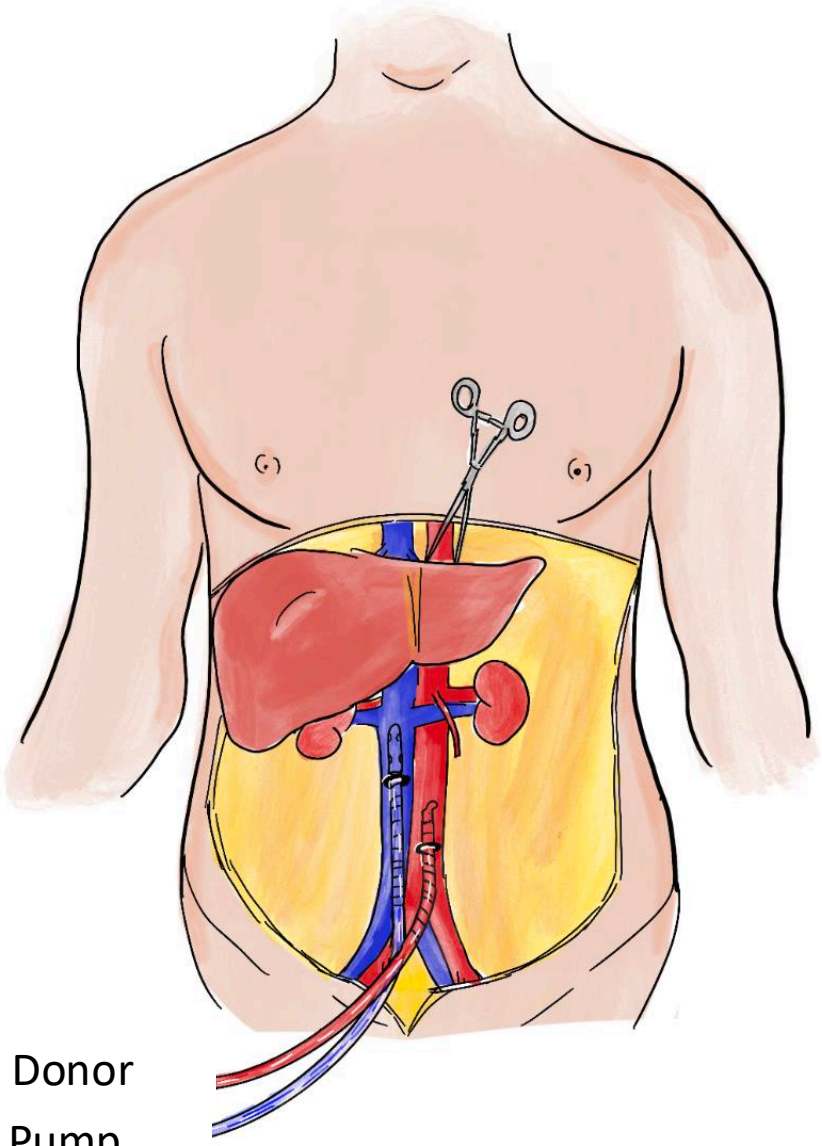
- Able to rescue livers (*decrease discards*) by evaluating hepatocellular and cholangiocelluar function during aNRP



Ann Surg 2022;276:e223–e230

Courtesy of Erasmus Transplant Group; ILTS 2023

NRP: *ABDOMINAL* APPROACH



Blood to Donor

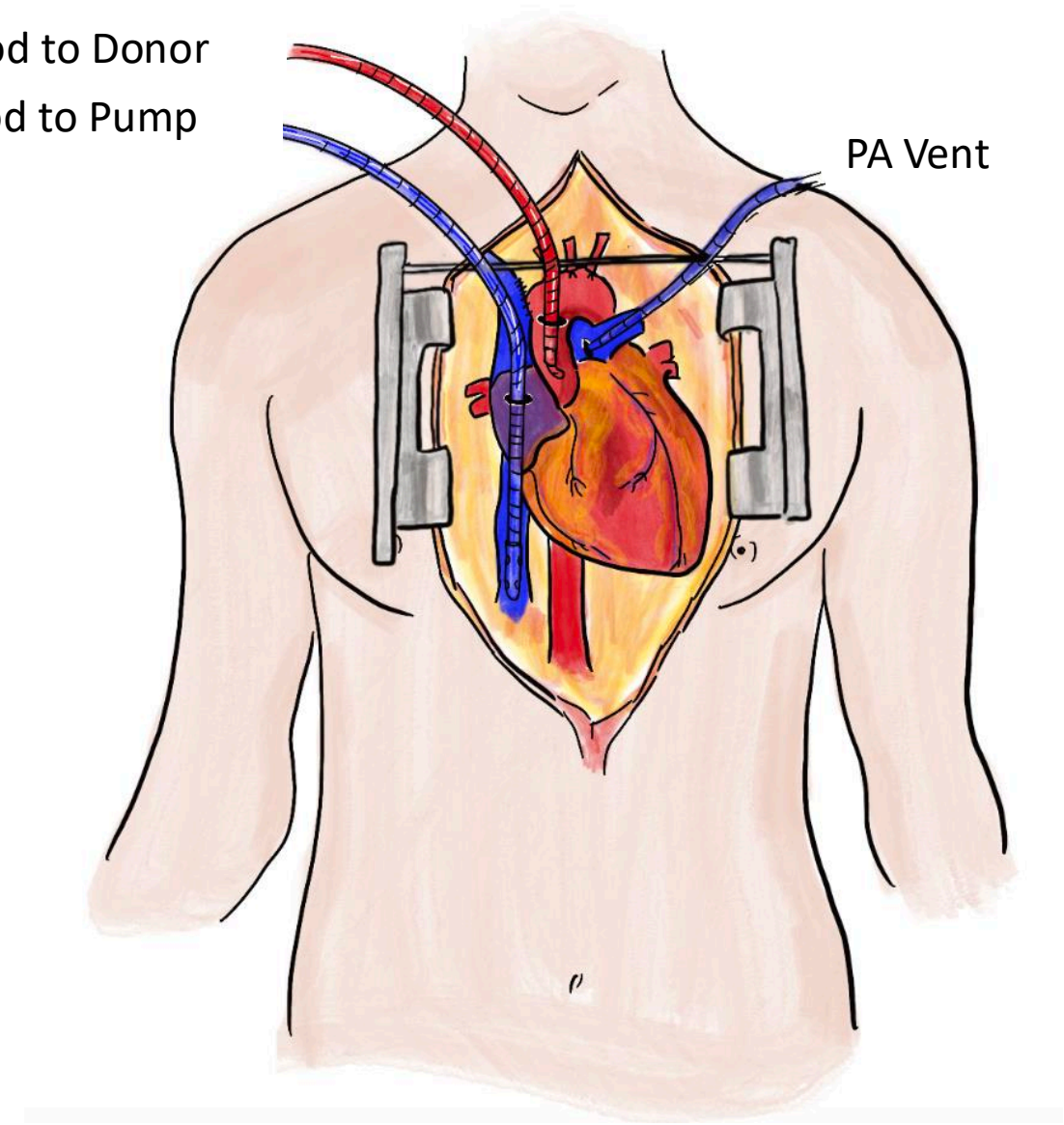
Blood to Pump

NRP: *THORACOABDOMINAL* APPROACH

Blood to Donor

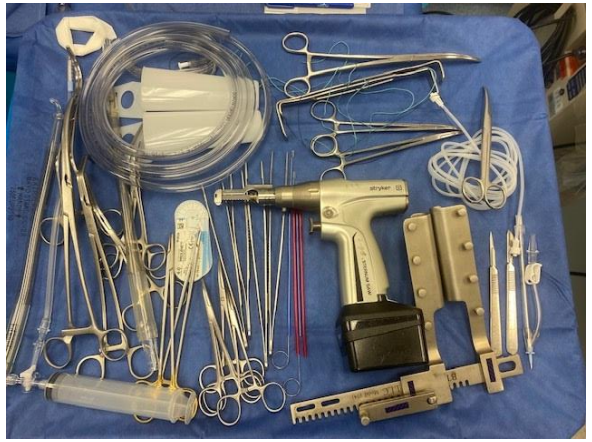
Blood to Pump

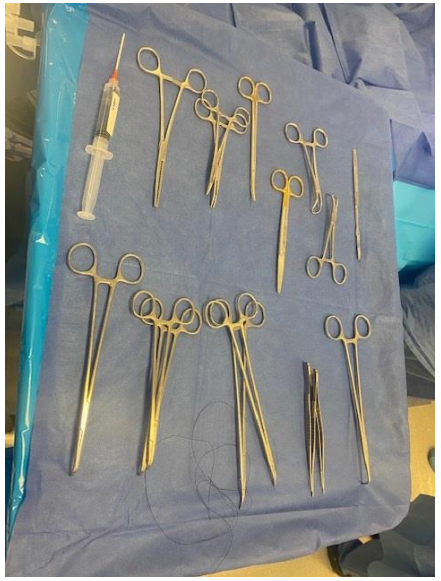
PA Vent



Drawings by Dr. Maria Baimas-George

Thoraco-Abdominal NRP





- Less is more

- LFTs- 15 min
- ABG- 2 min
- Electrolytes- 3 min
- HCT- 3 min

- 10 cartridges
  - $8-12 iStat
  - $12 Piccolo

- Spectrum ECLS
  - Toronto Frame (Carbon Fiber)
  - 20 pounds

UNOS ID: Date of Cold Perfusion X Clamp: OPO:

Procurement Hospital: In Situ Assessment Surgeon: V: 7/14/2023

COLORADO NORMOTHERMIC REGIONAL PERFUSION IN SITU ASSESMENT: ABDOMINAL

Event	Date/Time	Event to on pump (min)
Extubation		
SBP <80		
SBP <50		
MAP <60		
O2 <80		
O2 <70		
1st Declaration		
2nd Declaration		
Incision		
On pump		--
X Clamp		--

Functional Warm Ischemia Guidelines		Minutes
ASTS	SBP<50 or O2<70 to on pump	
ILTS	MAP<60 or O2<80 to on pump	

Liver Visual Assessment	
Estimated Fat %	Soft/ Firm
Procurement Trauma	
Liver Biopsy Y/N	
Micro	
Macro	
Fibrosis	
Necrosis	
Other	

Case Comments

Paremeters to be collected at initiation of NRP and in 15 minute intervals therafter. Record cummulative bile production if possible.

Target Cardiac Index for NRP: ***Target Circuit Flow for NRP:***

NRP Paremeter	***PERFUSION***					***HEPATOCYTE***			***CHOLANGIOCYTE***			
Date/Time	Med/Blood/Fluid/ Circuit Issue	Circuit Flow	Cardiac Index	Serum pH	Base Deficit	Lactate	AST	ALT	Bile pH	Bile Glucose	Bile HCO3-	Bile Production

Kidneys	Accepting Center	Right Kidney:	Left Kidney:	**Pancreas**	Accepting Center:
Quality	Right Kidney Soft/Firm	Left Kidney Soft/Firm		Quality	Soft/Firm
UOP mL on NRP	Hour 1:	Hour 2:	Hour 3: Hour 4:		Pink Y/N
					Fatty Y/N

Case Feedback:

Thoracoabdominal Normothermic Regional Perfusion: Real-World Experience and Outcomes of DCD Liver Transplantation

Background:
DCD LT is underutilized due to historical outcomes associated with ischemic cholangiopathy (IC).

162 DCD LT

(1/2017-8/2024):

97 NRP

79 SCS

Proportion of total LT volume from DCD **increased**.

2% in 2017

53% in 2024

Organ yield for local OPO via NRP was higher than SCS (p <0.001).

NRP	SCS
3.36 organs/donor	**1.91** organs/donor

Long-term outcomes:

	NRP	SCS
6-month IC rate (p=0.03)	**1.2%**	**9.5%**

	NRP	SCS
12-month patient survival (p=0.43)	**97%**	**95%**

Benchmarking Viability Assessment: During NRP Accepted compared to Declined Livers had

Lower peak Lactate and AST

Higher terminal biliary bicarbonate.

Conclusion:
NRP enhances DCD liver utilization and reduces IC compared to SCS. These findings support TA-NRP benchmarking and further protocol development.

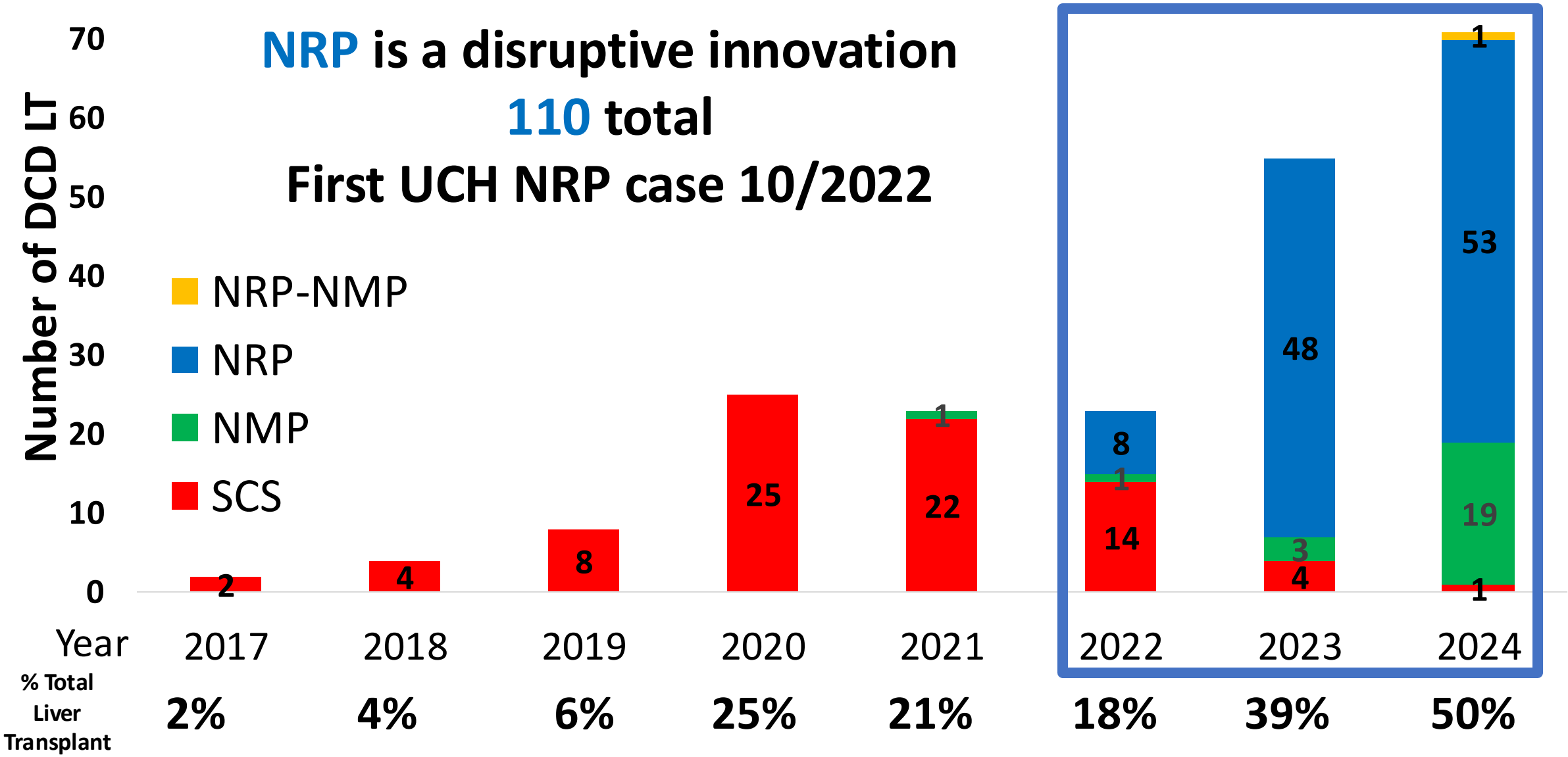
Bababekov et al. 2025 *Transplantation Direct*

University of Colorado Hospital DCD Utilization by Year

NRP is a disruptive innovation

110 total

First UCH NRP case 10/2022



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Proposed Mechanism of NRP

- Warm Ischemia (DCD Progression)
- Adenine nucleotide pool size decrease
- Metabolic breakdown products increase
- Oxygen free radicals released on reperfusion

Viability assessment should be *sensitive* and *specific* to metabolic injury and recovery

- NRP
- Restore energy substrates
- Decrease metabolic breakdown products
- Increase antioxidants

Dr. Amelia Hessheimer, ILTS 2022
Transpl Int. 2015;700-7

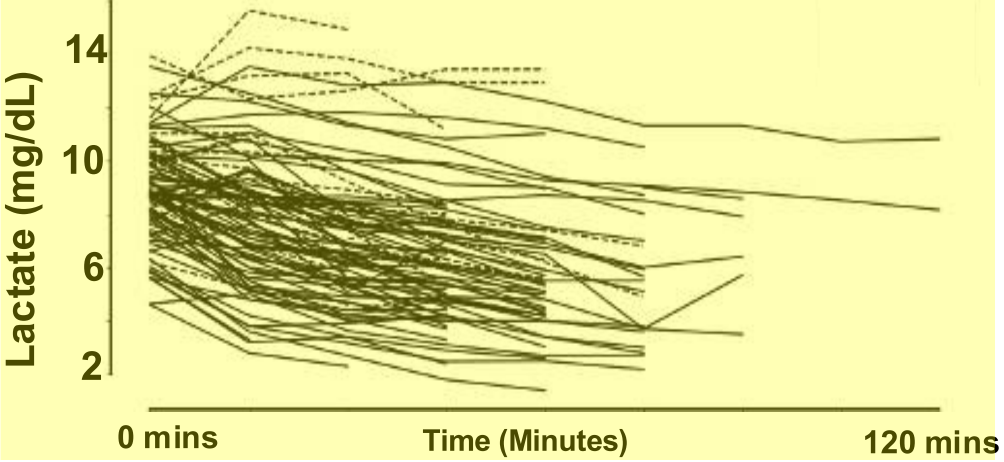
NRP Viability Assessment:
Accepted vs Declined
Hepatocellular Parameters

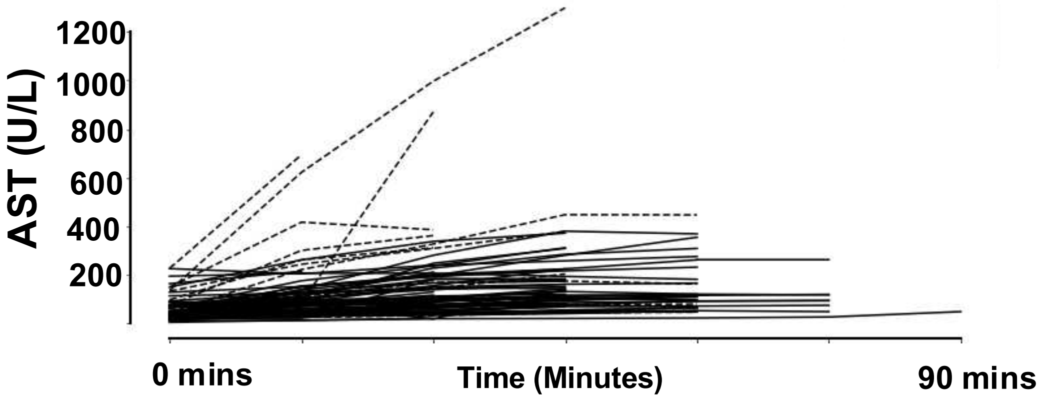
	Accepted (n=97)	Declined (n=40)	p
Lactate, n	77	25	
Peak Lactate (mg/dL)	8.8 (7.6-9.8)	10.1 (8.8-11.0)	0.004
Delta Lactate (mg/dL)	-3.2(-4.0- -1.92)	-2.2 (-4.05- -0.66)	0.04
AST, n	75	22	
Peak AST (U/L)	[illegible]	[illegible]	0.015
Delta AST (U/L)	58 (28-126)	225 (67-450)	0.08
ALT, n	75	21	
Peak ALT (U/L)	85 (55 - 126)	90 (55-453)	0.65
Delta ALT (U/L)	31 (14-76)	125 (15-426)	0.31

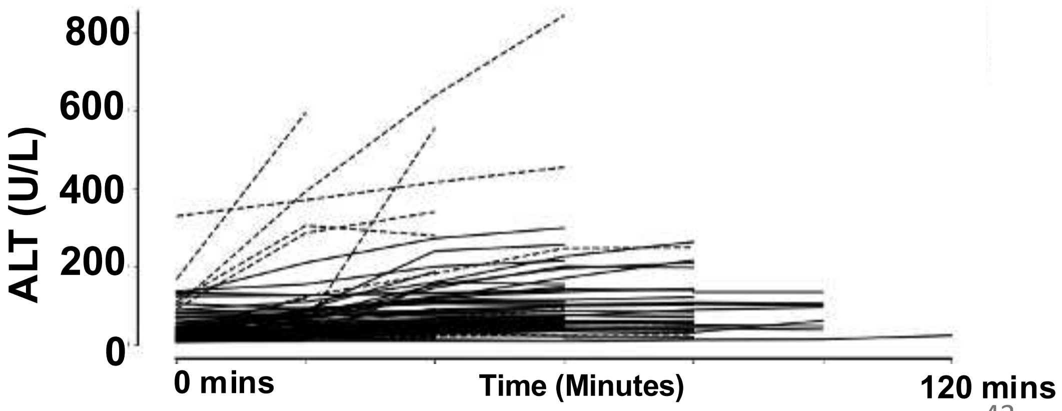
Not clinically meaningful

Lactate Peak of 8.8 vs 10

Lactate Delta of 3 vs 2







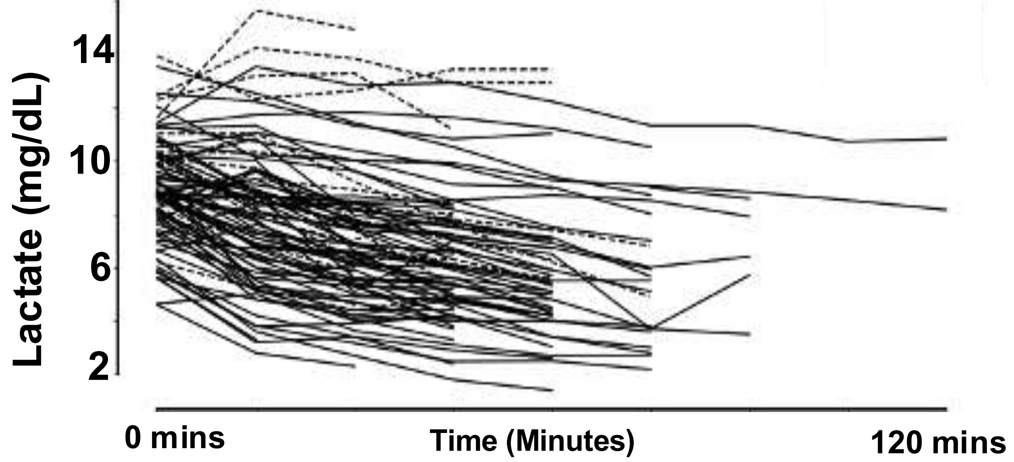
NRP Liver Donors Accepted (solid line)
NRP Liver Donors Declined (dashed line)

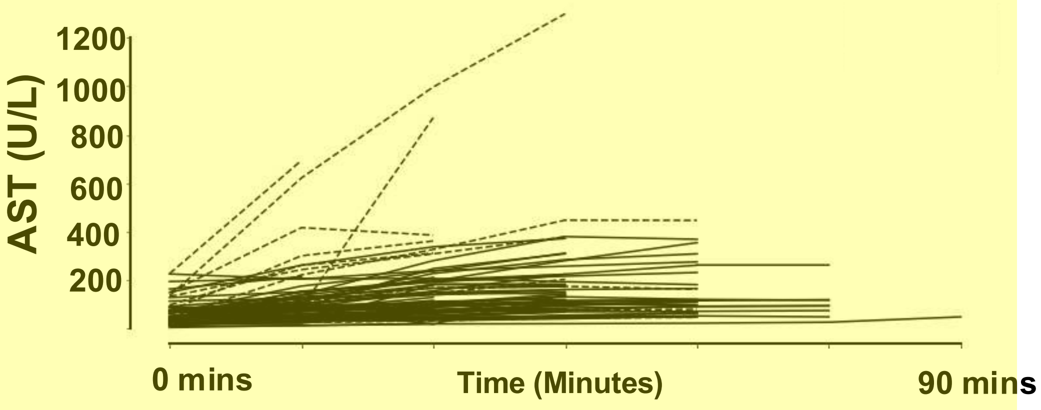
NRP Viability Assessment:
Accepted vs Declined
Hepatocellular Parameters

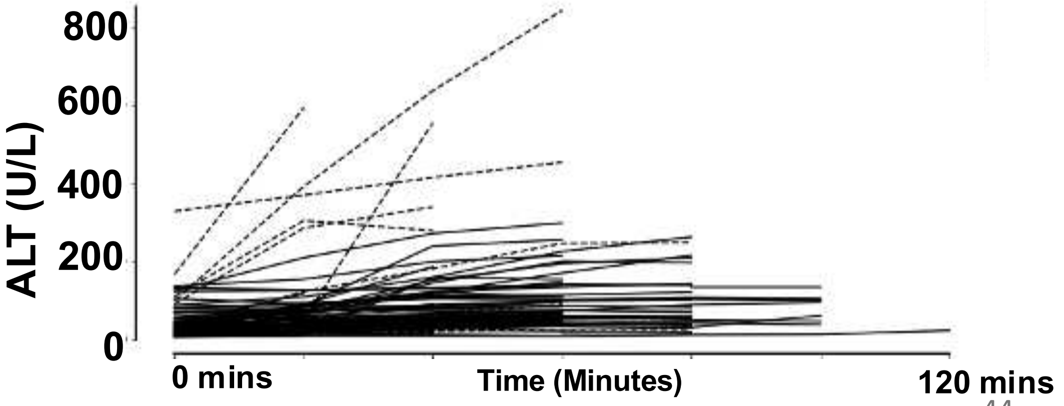
	Accepted (n=97)	Declined (n=40)	p
Lactate, n	77	25	
Peak Lactate (mg/dL)	[illegible]	[illegible]	0.004
Delta Lactate (mg/dL)	[illegible]	[illegible] (-4.05- -0.66)	0.04
AST, n	75	22	
Peak AST (U/L)	132 (86-255)	208 (81-440)	0.015
Delta AST (U/L)	58 (28-126)	225 (67-450)	0.08
ALT, n	75	21	
Peak ALT (U/L)	85 (55 - 126)	90 (55-453)	0.65
Delta ALT (U/L)	31 (14-76)	125 (15-426)	0.31

Not clinically meaningful

Peak AST 132 vs 208



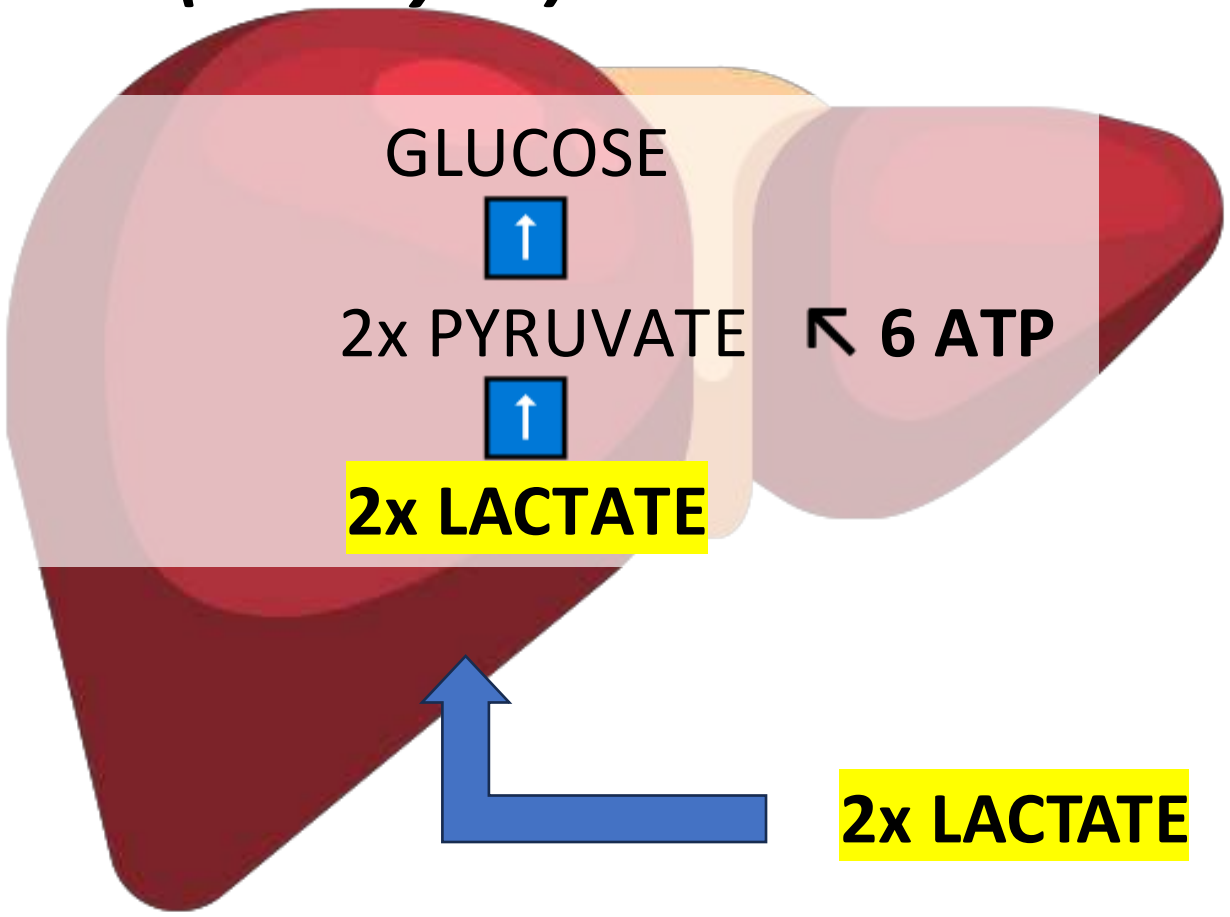




NRP Liver Donors Accepted (solid line)
NRP Liver Donors Declined (dashed line)

Confounders of Lactate: *Metabolism* vs *Production* ?

Lactate Metabolism
(Cori Cycle)



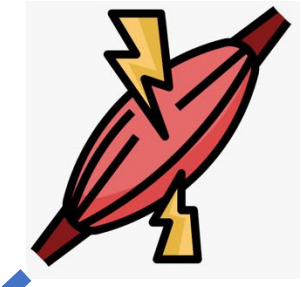
GLUCOSE

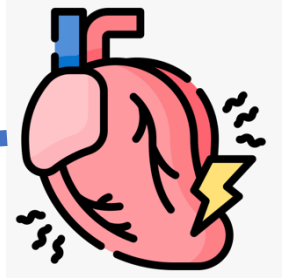
Lactate Production

2x **ATP**

2x PYRUVATE

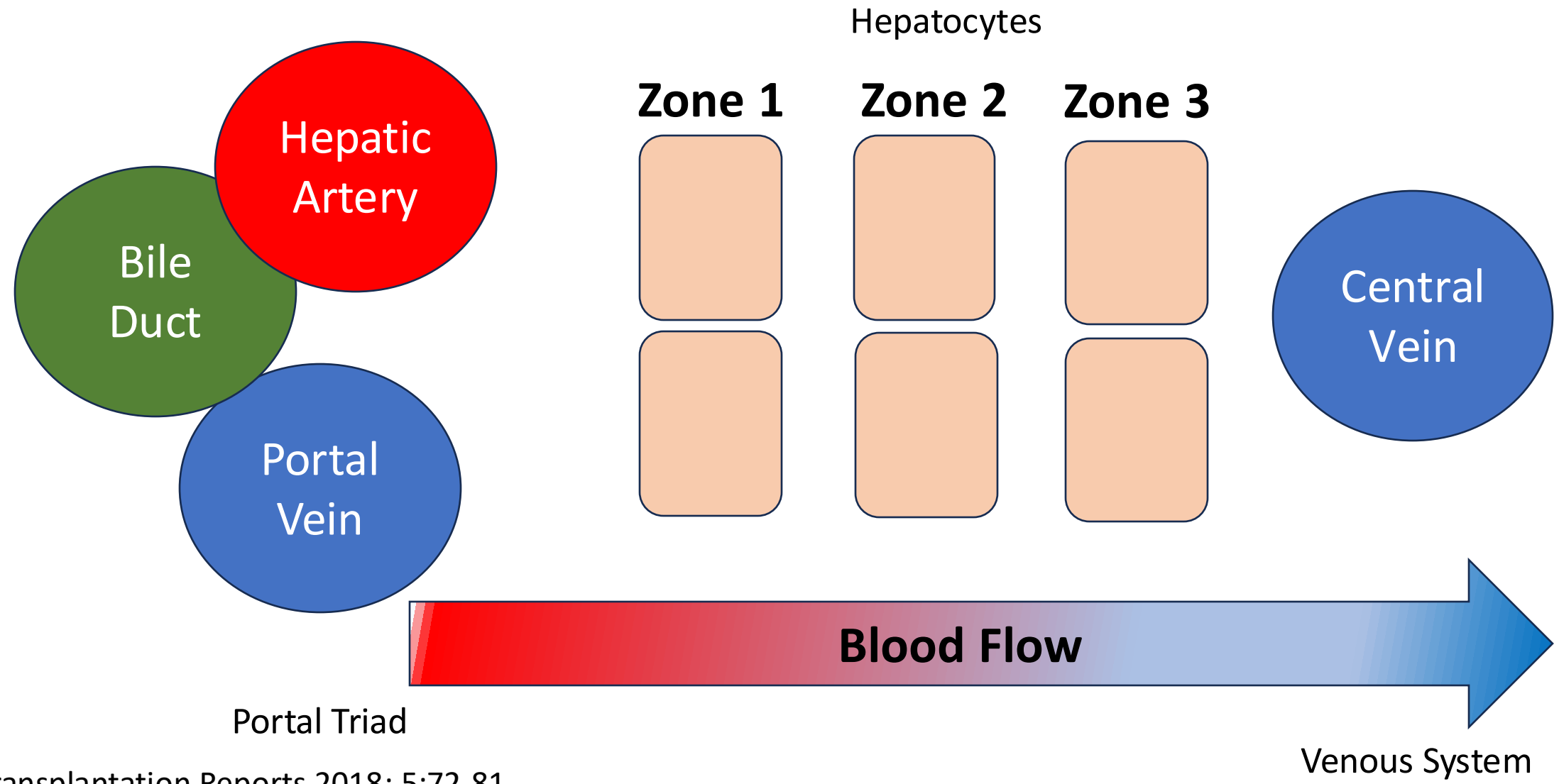
2x LACTATE





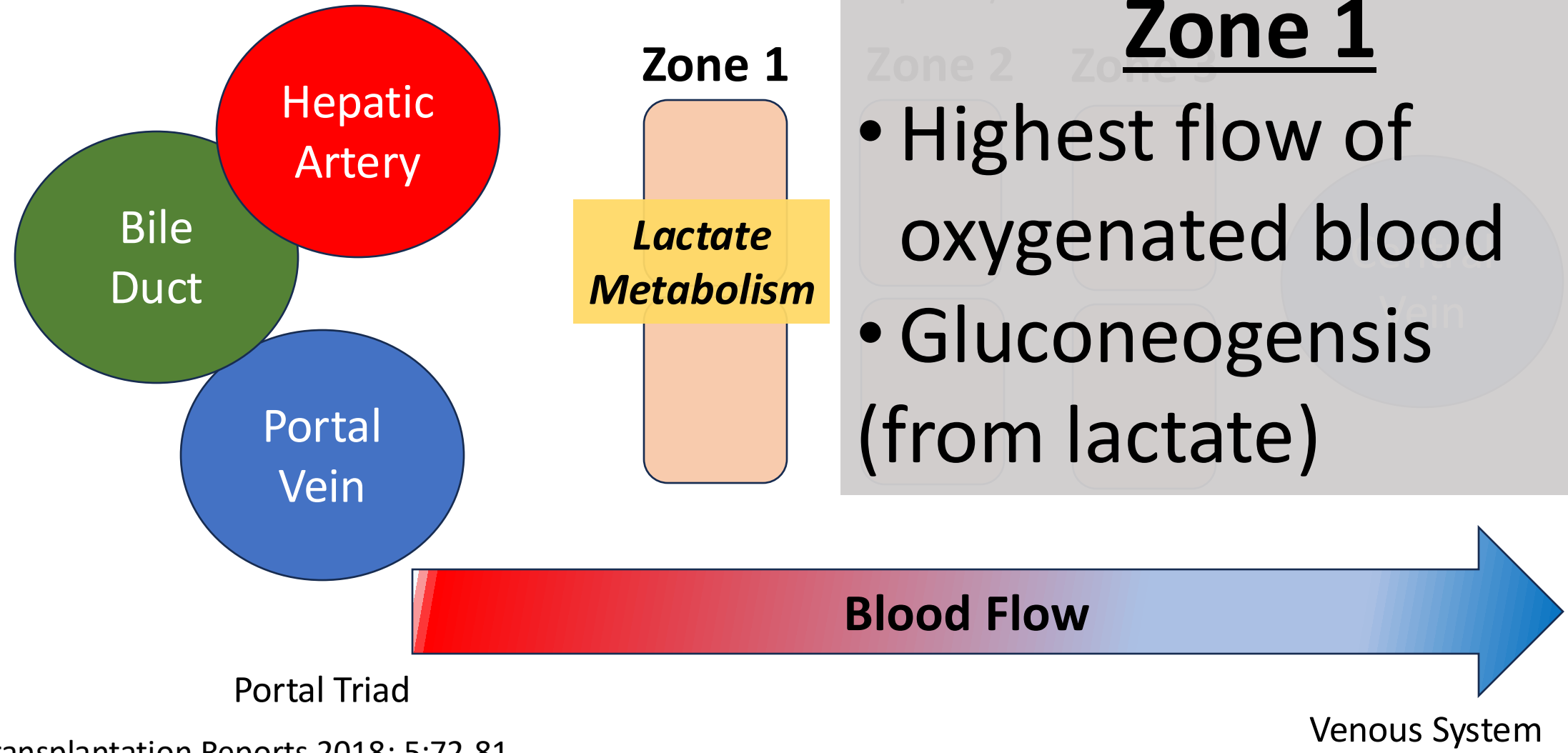
2x LACTATE

Lactate May Not Be Sufficient



Current Transplantation Reports 2018; 5:72-81

Lactate May Not Be Sufficient



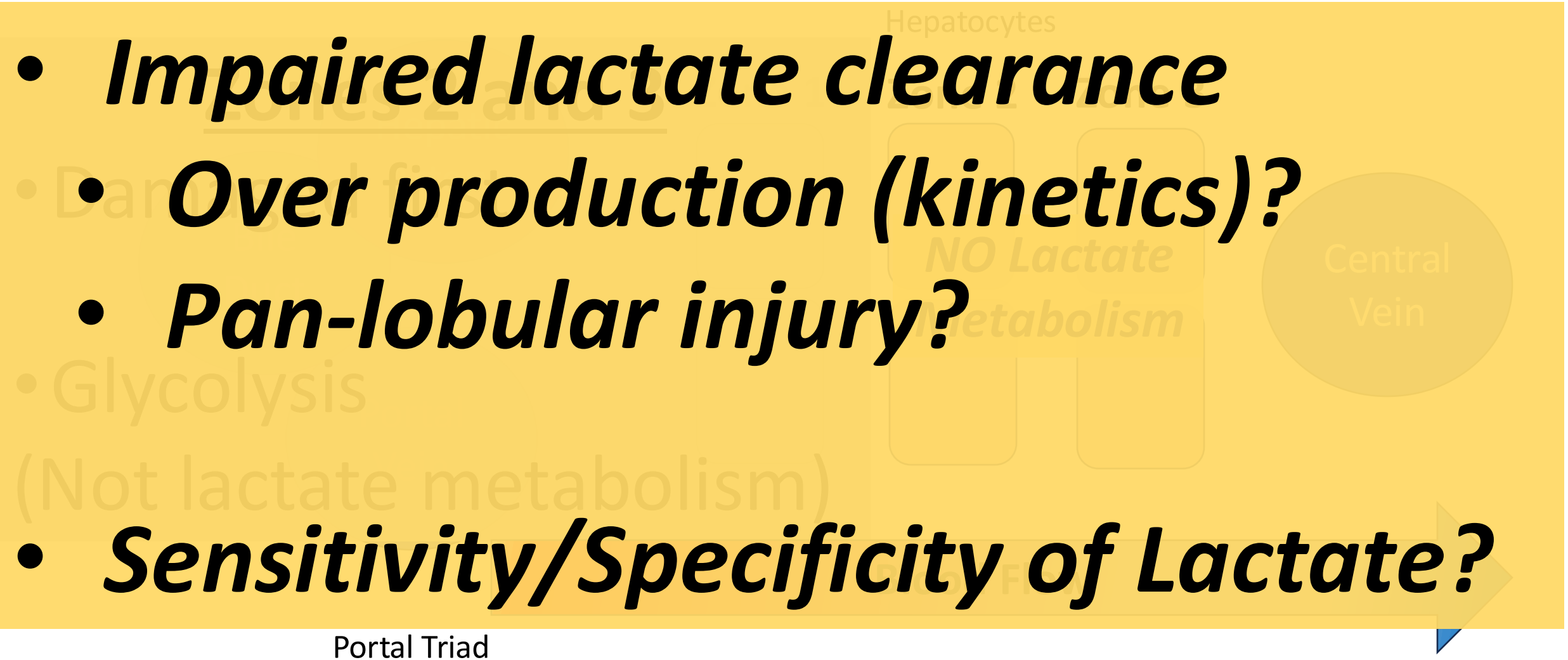
Zone 1

- Highest flow of oxygenated blood
- Gluconeogensis (from lactate)

Current Transplantation Reports 2018; 5:72-81

Lactate May Not Be Sufficient

- ***Impaired lactate clearance***
  - ***Over production (kinetics)?***
  - ***Pan-lobular injury?***
- ***Sensitivity/Specificity of Lactate?***



Current Transplantation Reports 2018; 5:72-81

NRP Viability Assessment: Accepted vs Declined

Cholangiocellular Parameters

	Accepted (n=97)	Declined (n=40)	p
Terminal biliary pH, n	58	13	
Terminal biliary pH	7.70 (7.60-7.70)	7.65 (7.41-7.70)	0.39
Biliary bicarbonate, n	13	5	
Terminal biliary bicarbonate (mEq/L)	**22.5 (20.7-27.2)**	**10.2 (7.41-11.6)**	**0.004**
Peak biliary bicarbonate (mEq/L)	**23 (21.7-29.9)**	**13.3 (7.7-16.7)**	**0.01**
Terminal biliary glucose, n	37	10	
Terminal biliary glucose (mg/dL)	20 (20-20)	20 (20-20)	0.87
Nadir biliary glucose (mg/dL)	20 (20-20)	20 (20-20)	1

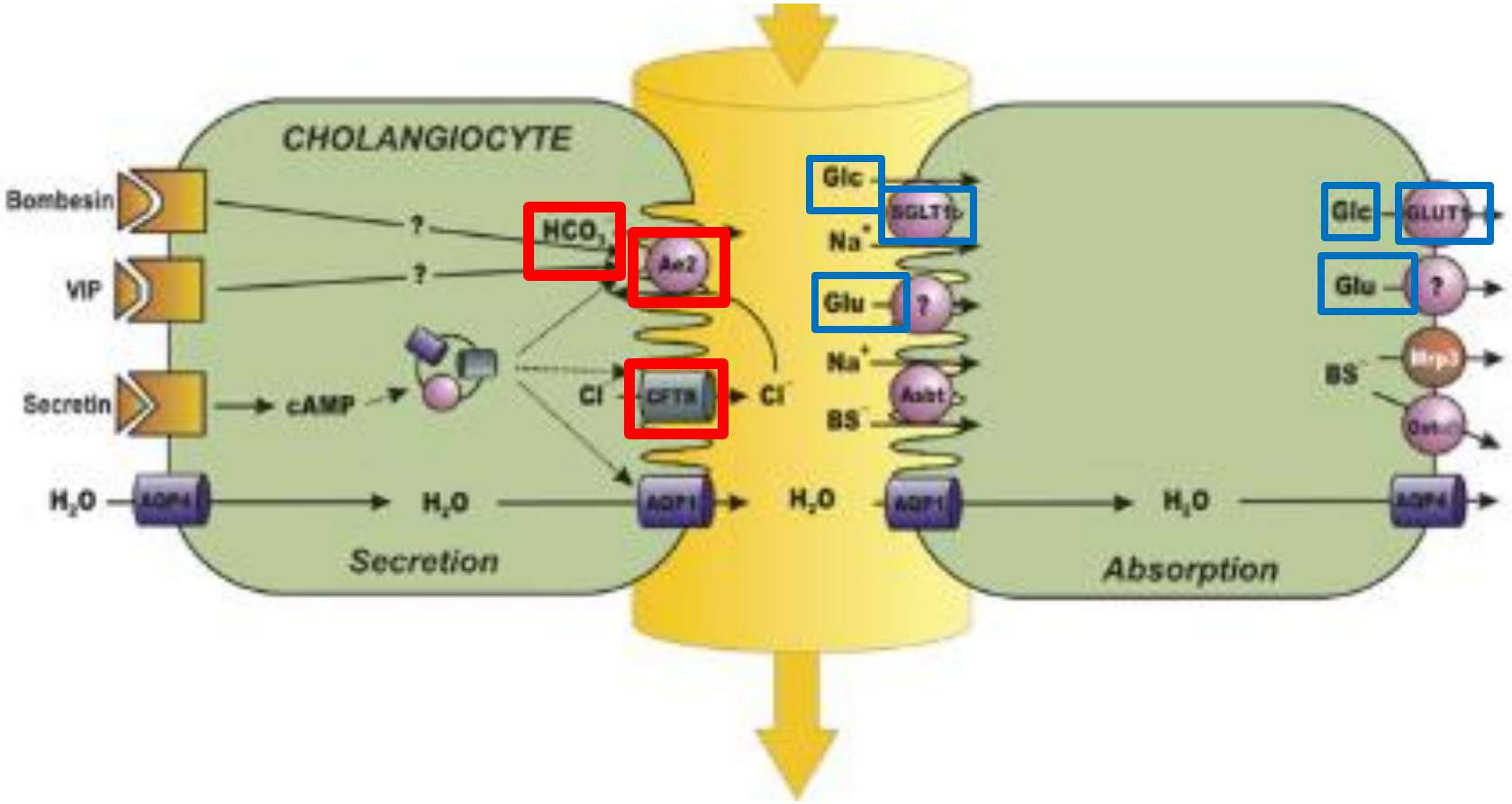
Clinically meaningful (Δ 10 mEq/L)

Overtime, more emphasis on bile

"Good bile"

+ production; sample at end of NRP

Bicarbonate Umbrella



Bile pH >7.5 may protect cholangiocytes from toxicity of bile salts

Active transporters:

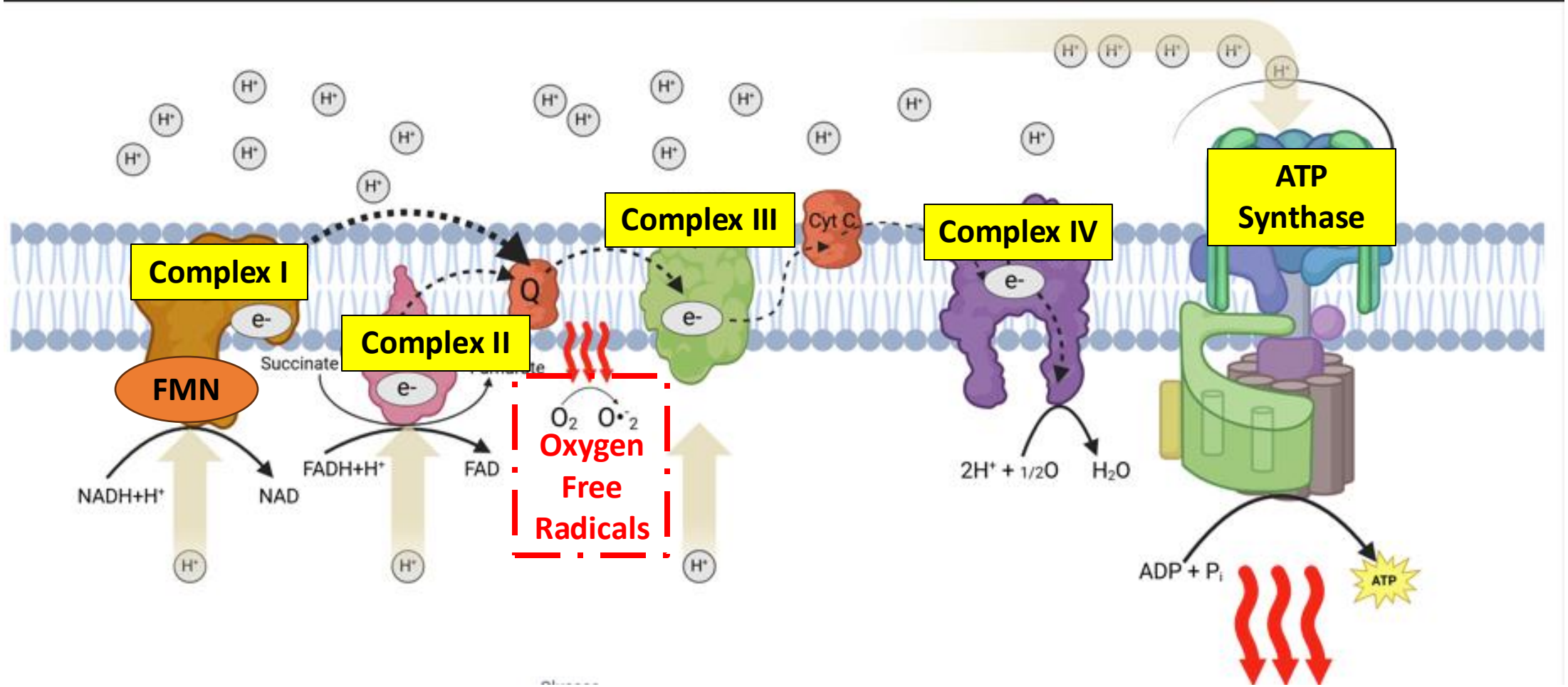
Bicarbonate is secreted via CFTR and AE2

Glucose is reabsorbed via SGLT-1 and GLUT-1

Hypothesis for 'good' bile: high pH; high bicarbonate; low glucose
Less risk for ischemic cholangiopathy ?

Clinical Science 2008;14:567-588

Viability assessment should be *sensitive* and *specific* to metabolic injury and recovery



Opportunity to assess extent of injury and recovery in mitochondria

Viability Assessment in Liver Transplantation (VAIL-Tx)

- **Collaboration with Dr. Uwe Christians; PhD students: Wanzhu Zhao, JoLynn Shinsako**

- **High-Dimensional Omics of Ischemia Reperfusion Injury**
  - Short: Define biomarkers of IRI
  - Mid: Assess complex integration and association with outcomes
  - Long: Therapeutic interventions

- **Sample liver, bile duct, bile, and blood; donors/recipients**
  - DCD
    - NMP; SCS; NRP
  - DBD
    - NMP; SCS
  - LDLT (Control)

iC42 integrated solutions in systems biology clinical research & development

Acknowledgements

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  - Carlos Goncalves, PhD
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  - Cassidy Yoshida, CUSoM
  - Kate Gustilo, CUSoM
  - David Chen, CUSoM
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  - Iván Rodríguez, MD








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clinical research & development

Thank you

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TuftsMedicine

Tufts University | School of Medicine

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DTI DONATION & TRANSPLANTATION INSTITUTE

THE UC San Diego Reimagine CENTER

The Intermountain Experience with NRP

Philippe Paci MDCM, MS, FRCS(C), FACS

May 22, 2025

Intermountain Health

Intermountain Health Transplant Services

- Non-academic program based at Intermountain Medical Center in Murray, UT
- Heart, liver, kidney, pancreas transplants
- Significant growth over the last 3 years
- In 2024:
  - 188 liver transplants
  - 267 kidney transplants
  - 5 pancreas transplants

Intermountain Health

Developing an NRP program

→ Historically, Intermountain liver transplant program was medium-sized.

2020	2019	2018	2017
79	53	39	52

→ Program had to adopt more aggressive approach to liver offers

- Use of HCV NAT+ livers (2017)
- Aggressive use of cDCD liver allografts (25-30% of allografts/year)

→ Growing liver program with growing OPO

- Despite this, still had about 2-4 cases of ischemic cholangiopathy/year leading to retransplant

How can we continue to grow while tapping into cDCD donors regionally, but limiting complications from using cDCD liver allografts?

Intermountain Health

Developing an NRP program

- → Resurgence in interest due to increasing use of TA-NRP with cardiac transplant teams
- → From European data: increased organ utilization, decreased complications for liver allografts compared to SCS
- → How can we continue to grow?
  - → While tapping into cDCD donors regionally,
  - → Limiting complications from using cDCD liver allografts
  - → Aiming to reproduce success from European centers

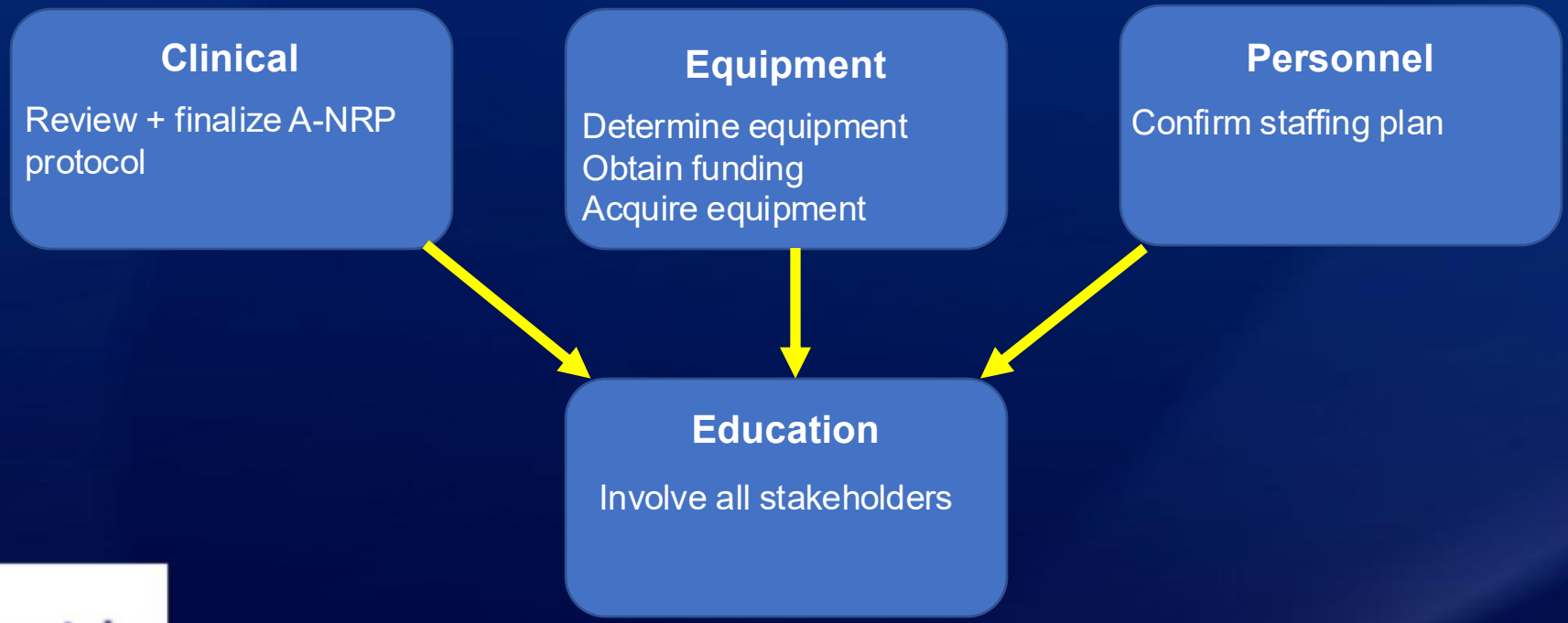
Intermountain Health

Developing an NRP program

→ January 2023: Attended Edinburgh NRP Masterclass.

→ Built the program in the next 8 months

- **Key milestones**

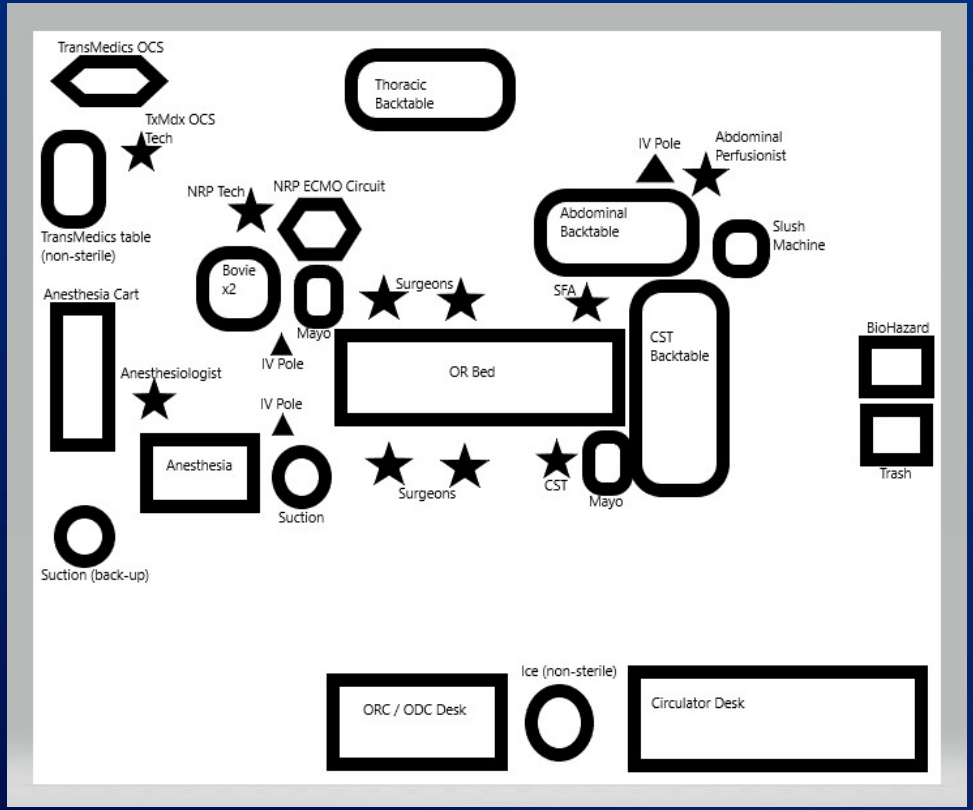


Intermountain Health

Consolidating and Scaling the Program

- Core Team
  - Lead surgeon
  - Assistant surgeon
  - **Perfusionist**

  - Scrub practitioner (OPO)
  - Additional team member (surgical assistant)



Intermountain Health

Key Milestones/Challenges

- A-NRP chosen because of ethical/logistical issues with TA-NRP
- Decided to model our protocol after the UK protocol
- First question – center-based vs OPO-based model
- Challenges with center-based model

Intermountain Health

Consolidating and Scaling the Program

- As the program was being built → huge education effort
  - Our own institution – hospital engagement
    - Changing views on TA-NRP
  - Local OPO – OPO engagement and collaboration with regional hospitals
  - Other regional OPOs (Oregon, Washington, California)

- Continued education
  - → Importance of pre-withdrawal huddle
  - → Discussion with OPO team members and other surgical recovery teams

- Importance of tracking institutional outcomes
  - → Need to know your own data to inform decisions impacting the program and ultimately patients

- Collaboration
  - Through CONCORD and colleagues in the field

Intermountain Health

IMC Clinical A-NRP Program

- Went live with our first case 8/30/2023

191 livers accepted

142 expired

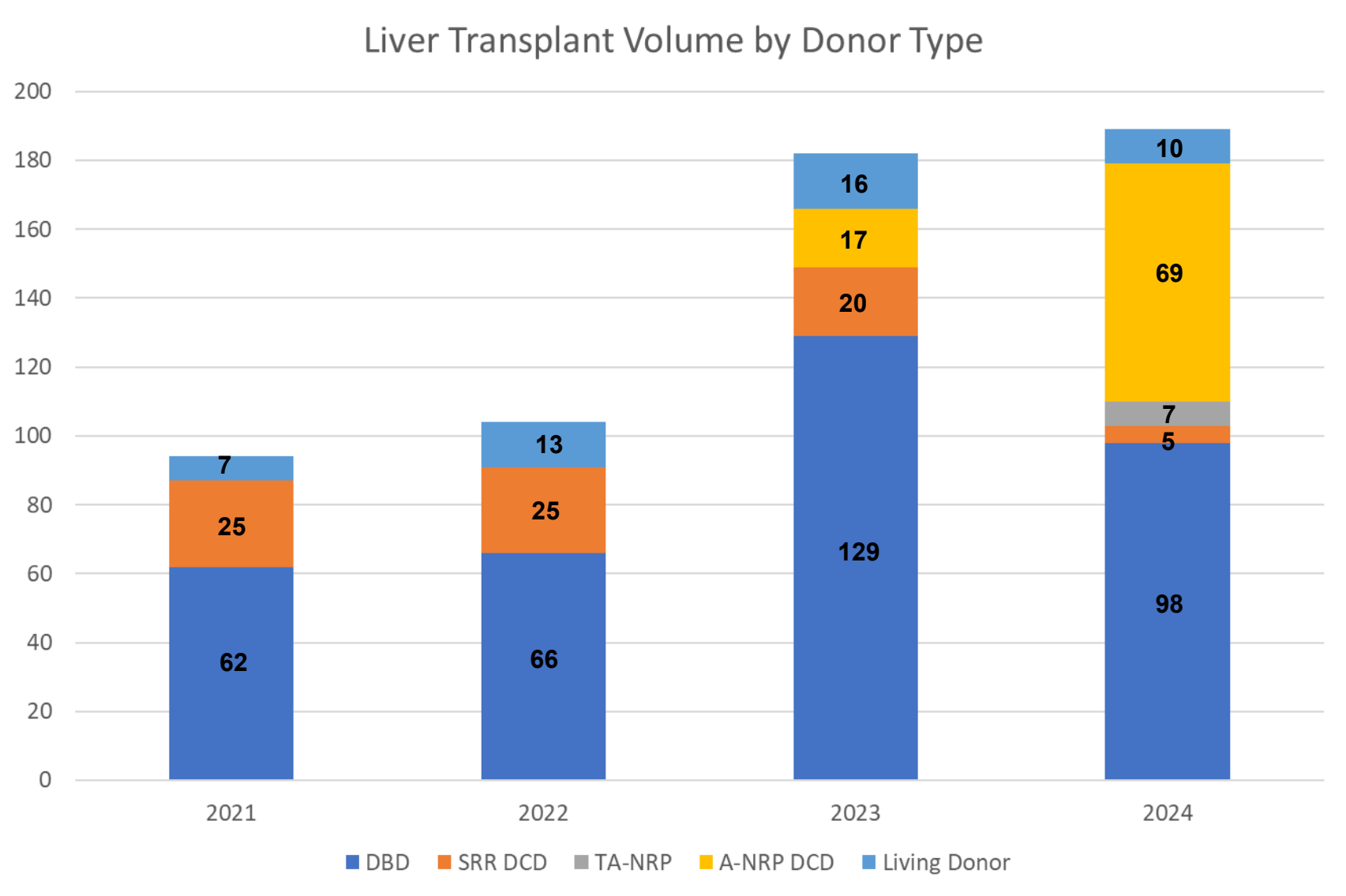
32 declined for quality

110 transplanted

>75% utilization

Intermountain Health

Impact of A-NRP on liver transplant volume



Considerations for the future

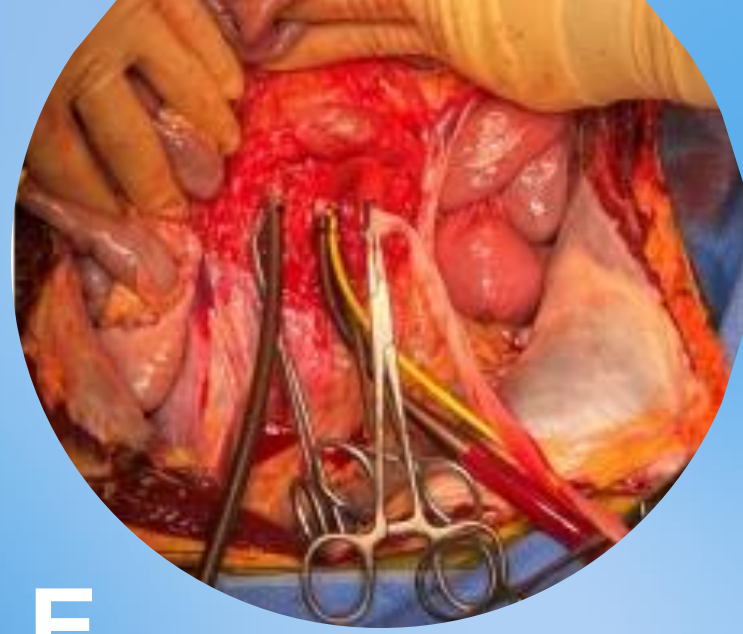
- Given the need to remain competitive regionally, push towards being more aggressive
  - No donor age limit
  - No tWIT limit
  - No recipient factors precluding use of A-NRP cDCD liver allografts

- Challenges of our program
  - Balancing the use of our center-based program with rise of OPO-based programs
  - Logistical limitations to having our team procure all livers
  - How to push the envelope without leading the procurement?
    - Financial incentives (center vs OPO)

- Challenges in the U.S.
  - Standardization

Intermountain Health

MAYO CLINIC

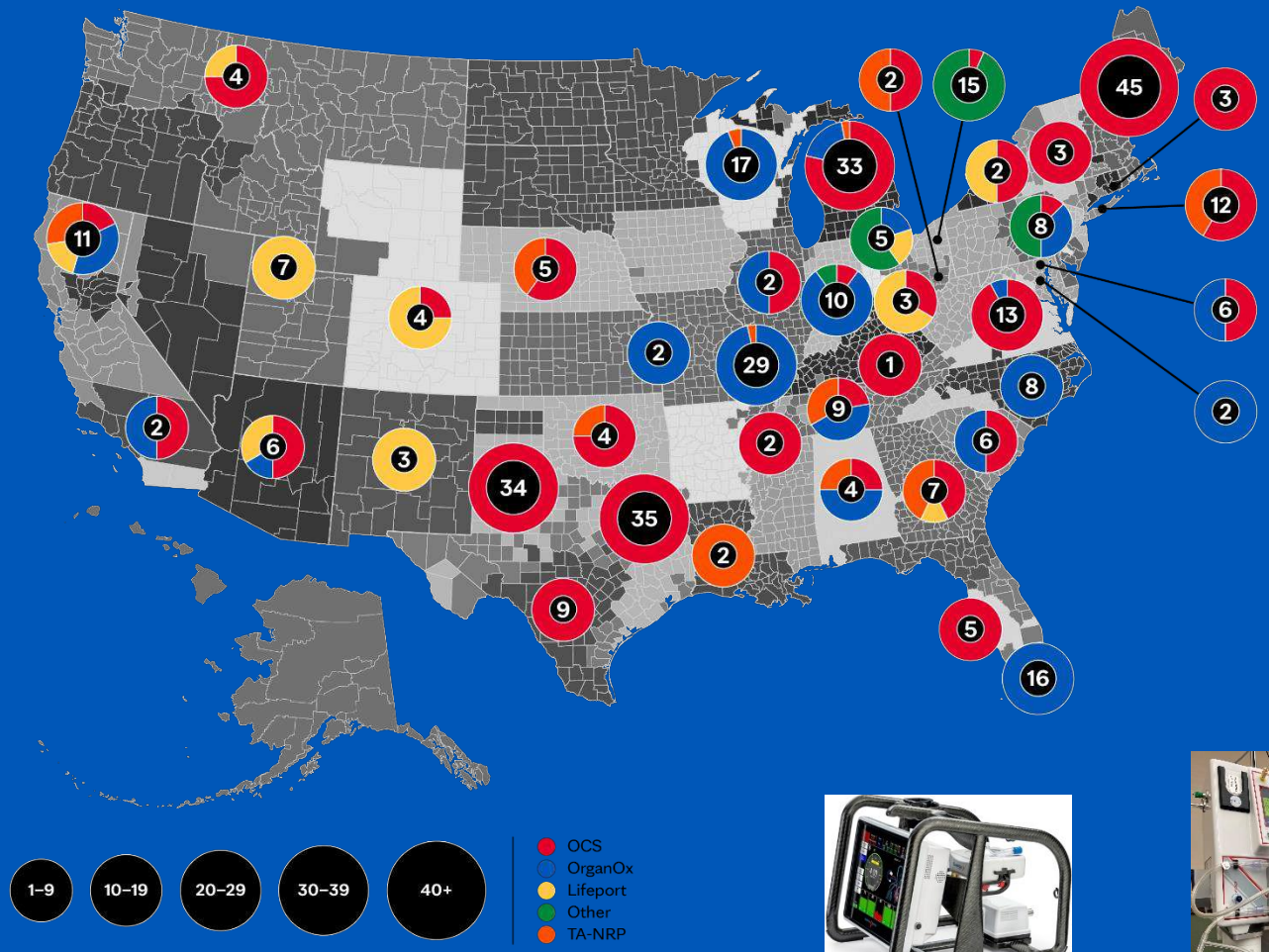


DEVELOPMENT OF A PORTABLE ABDOMINAL NORMOTHERMIC REGIONAL PERFUSION PROGRAM

THE MAYO CLINIC FLORIDA EXPERIENCE

Shennen Mao, MD
Assistant Professor of Surgery
Mayo Clinic Florida

MACHINE PERFUSION IN 2022



Croome KP, Mao S, Taner CB. The Current Landscape of Liver Transplantation After Ex Situ Machine Perfusion and Normothermic Regional Perfusion in the United States. Liver Transpl. 2022 Jun;28(6):1108-1112.

DEVELOPMENT OF AN ABDOMINAL NORMOTHERMIC REGIONAL PERFUSION PROGRAM

Departmental Support

Dedicated Multidisciplinary Team

Capital Investment

OPO and Family Support

DEDICATED MULTIDISCIPLINARY APPROACH

- Field Team
  - Surgeon
  - Perfusionist
  - Surgical Assistant
- Home Base Support Team
  - Procurement / Logistical Coordinators
  - Blood Bank
  - Pharmacy
  - Supply Chain

CAPITAL INVESTMENT

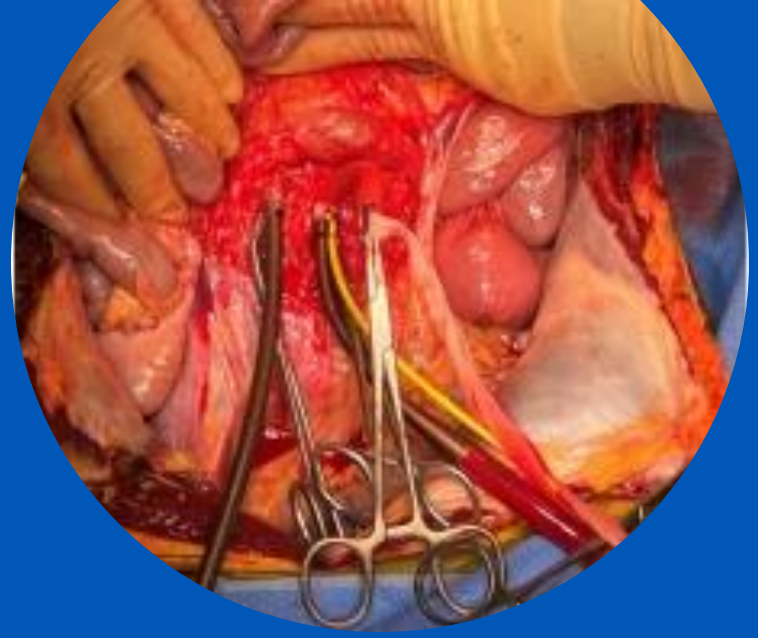
- Extracorporal Circuit (Quantum Transport System by Spectrum)
- Disposable Supplies
- Laboratory Monitoring Devices

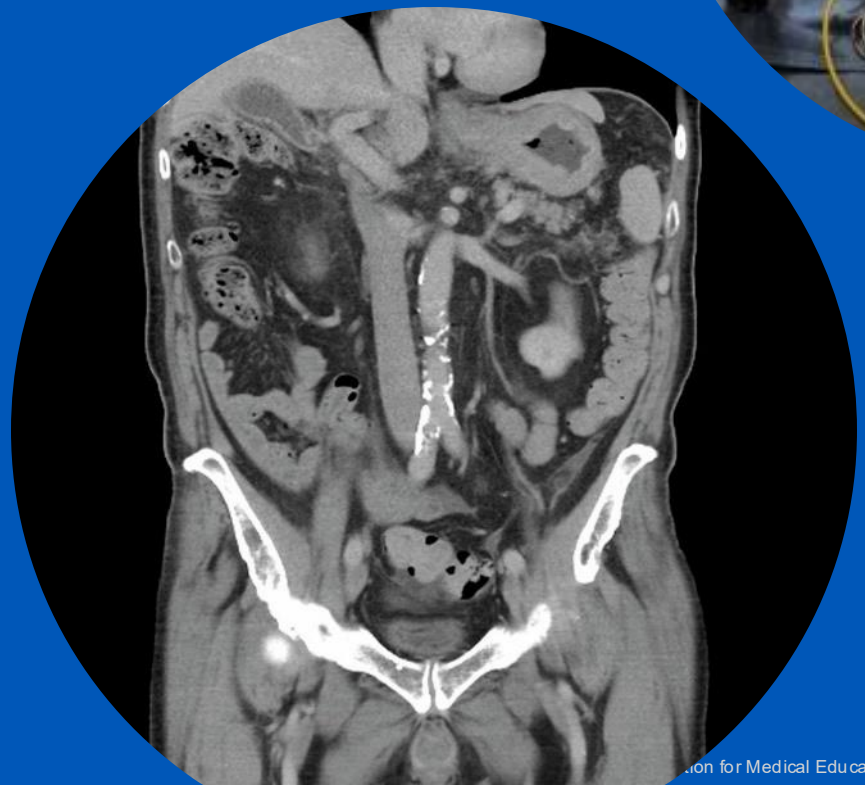
OPO AND FAMILY SUPPORT

- Educational Partnerships
  - Consideration of Cannulation Method (premortem consent)
  - Withdrawal in the OR
  - Family Support
- Donor Hospital Support
  - Extended Operating Time
  - Oxygenation and Power Supply
  - Laboratory Studies
  - Blood Bank
    - Donor Hct >30
    - Banked Blood Available

THE FIRST CASE:

- Local Hospital Based Donor Care Unit
- Liver / Kidney Donor
- Two Experienced Surgeons
  - Review All Imaging
    - Cannula Selection
    - Method of Occlusion
  - Cannulation Approach
  - Rehearsal with Support Team
- Backup Plan
- Commitment to Perfusion





ABDOMINAL NORMOTHERMIC REGIONAL PERFUSION

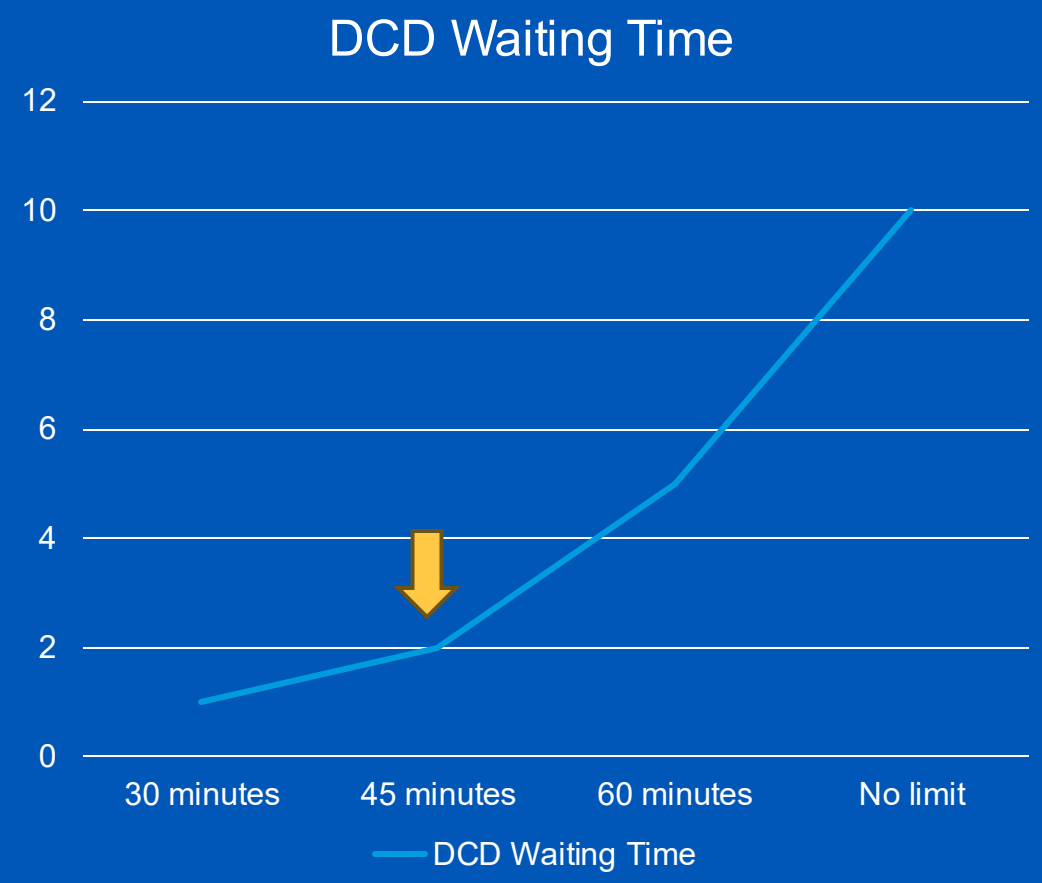
Case	Donor age (years)	Donor Weight (kg)Donor BMI (kg/m2)	Donor BMI	Pre-cannulation/ Abdominal-cannulation	Location	sBP50-Interval	Incision until A-NRP start	NRP run time	Organs
A	32	89	23.9	Abdominal -Cannulation	MCF	10min	5min	40 min	Kidneys, liver steatotic
B	39	74	27.7	Abdominal -Cannulation	Outside Hospital	8min	3min	61 min	Liver and kidneys
C	59	115	39.8	Abdominal -Cannulation	Outside Hospital	17min	6 min	15 min	Kidneys
D	58	127	42.6	Pre-cannulation	MCF	12min	2 min	78 min	Liver and kidneys
E	58	80	26.1	Abdominal -Cannulation	Outside Hospital	15min	7 min	35 min	Liver and kidneys
F	43	79	27.4	Abdominal -Cannulation	Outside Hospital	13min	5min	64 min	Liver only (on dialysis)
G	62	83	34.6	Abdominal -Cannulation	Outside Hospital	19min	3min	75 min	Kidneys
H	57	76	26.9	Abdominal -Cannulation	Outside Hospital	16min	4 min	94 min	Liver and kidneys
I	56	118	46.1	Abdominal -Cannulation	Outside Hospital	7min	2 min	65min	Liver and kidneys
J	28	88	29.5	Pre-cannulation	Outside Hospital	6min	1 min	65min	Liver and kidneys
K	37	69	23.9	Abdominal -Cannulation	Outside Hospital	3min	1 min	90min	Liver and kidneys
L	48	91	31.5	Pre-cannulation	MCF	11min	1 min	71min	Liver and kidneys
M	59	98	34	Pre-cannulation	Outside Hospital	7min	1 min	82min	Liver and kidneys
N						9min	3min	91min	Liver, Pancreas, kidneys
O						9min	1 min	61 min	Liver and kidneys
P						13 min	5 min	67 min	Liver and kidneys
Q						9 min	4 min	61 min	Liver and kidneys
R						8 min	2 min	62 min	Liver and kidneys
S						8 min	5 min	62 min	Liver and kidneys
T						12 min	4 min	158 min	Liver and kidneys
U	31	79	25.47	Pre-cannulation	MCF	9 min	2 min	75 min	Liver and kidneys
V	60	111	34.17	Pre-cannulation	Outside Hospital	13 min	1 min	65 min	Liver Only
W	18	57	22.3	Abdominal -Cannulation	Outside Hospital	13 min	4 min	63 min	Liver and kidneys
X	42	92	30.7	Abdominal -Cannulation	Outside Hospital	11 min	3 min	62 min	Liver and kidneys
Y	35	59	20.4	Abdominal -Cannulation	Outside Hospital				
Z	60	74	21.6	Abdominal -Cannulation	Outside Hospital				
AA	43	131	41.25	Abdominal -Cannulation	Outside Hospital	12 min	7 min	69 min	Kidneys, liver steatotic with large hemangioma
BB	41	50	18.8	Abdominal -Cannulation	Outside Hospital	13 min	2 min	98 min	Liver and kidneys
CC	47	81	26	Abdominal –Cannulation	Outside Hospital	13 min	4 min	63 min	Liver only (on dialysis)
DD	63	83	27	Abdominal –Cannulation	Outside Hospital	20 min	4 min	63 min	Liver and kidneys
EE	59	70	28.9	Pre-cannulation	MCF	7 min	3 min	86 min	Liver and kidneys
FF	48	99	31	Pre-cannulation	MCF	17 min	1 min	71 min	Liver and kidneys
GG	57	70	27	Abdominal –Cannulation	Outside Hospital	3 min	3 min	81 min	Liver and kidneys
HH	53	71	25	Abdominal –Cannulation	Outside Hospital	9 min	4 min	62 min	Liver and kidneys
II	66	65	22.3	Abdominal -Cannulation	Outside Hospital	15 min	5 min	60 min	Kidneys

- N=62 cases
- Median NRP run time 67 minutes
- Liver utilization rate 76%

Croome KP, Brown TE, Mabrey RL, Sonnenwald SL, Burns JM, Mao SA, Clendenon JN, Nguyen JH, Perry DK, Maddox RG, Taner CB. Development of a portable abdominal normothermic regional perfusion (A-NRP) program in the United States. Liver Transpl. 2023 Dec 1;29(12):1282-1291.

2025 EXPERIENCE

- 75% DCD Liver Transplants
  - Either NMP or NRP Utilized for All Donors
- Broad Donor Acceptance Criteria
  - No Upper Limit of Donor Age
  - Extended DCD Waiting Times
  - No Geographic Limitations
- Reduction in Dry Runs
  - Reduces Travel Burden
- Logistical Support
  - Allocation pre-serology
- Increase in Organs Acquired Per Donor

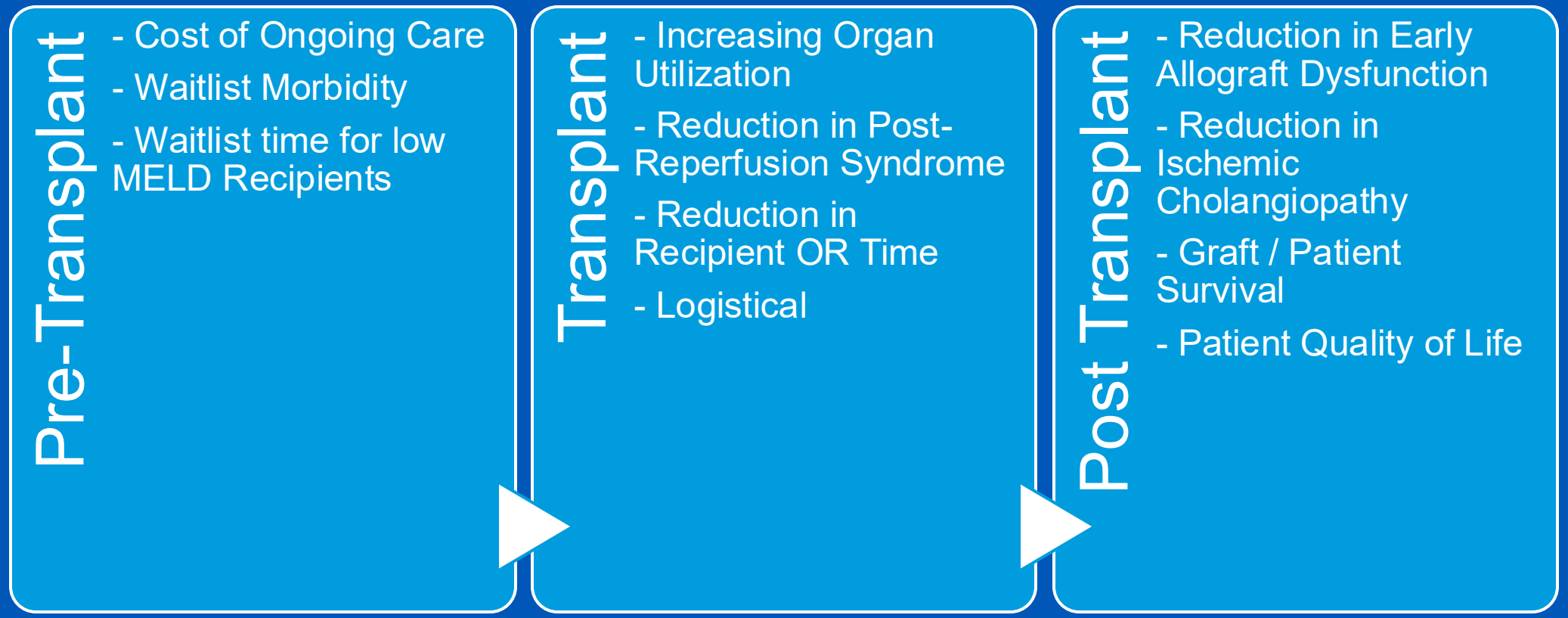


ABDOMINAL NRP – COST PER CASE

- Disposables
  - Tubing Sets
  - Cannulas
  - Pharmacy
  - Blood Bank
- Staffing (Perfusionist)
- Donor OR Time (Additional 1 – 2 hours)

$6344

VALUE OF NRP BY PHASE OF CARE



Evolution of NRP in the US

Anji Wall, MD, PhD, FACS

ORIGINAL CLINICAL SCIENCE

Early US experience with cardiac donation after circulatory death (DCD) using normothermic regional perfusion

Jordan R.H. Hoffman, MD, MPH,[a,1] William G. McMaster, MD,[a,1] Aniket S. Rali, MD,[b] Zakiur Rahaman, MD,[a] Keki Balsara, MD,[a] Tarek Absi, MD,[a] Melissa Levack, MD,[a] Marshall Brinkley, MD,[b] Jonathan Menachem, MD,[b] Lynn Punnoose, MD,[b] Suzanne Sacks, MD,[b] Mark Wigger, MD,[b] Sandip Zalawadiya, MD,[b] Lynne Stevenson, MD,[b] Kelly Schlendorf, MD,[b] JoAnn Lindenfeld, MD,[b] and Ashish S. Shah, MD[a]

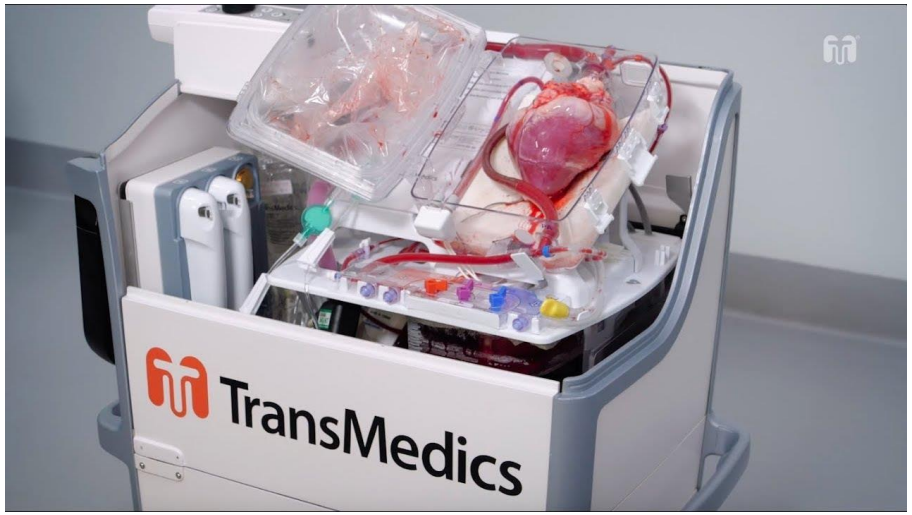


Table 4 Transplant Outcomes

Recipient ID	CI 24 hours post-transplant (L/min/m^2)	Inotrope score 24 post-transplant	PGD within 24 hours post-transplant	Post-transplant mechanical support	Biventricular function on post-transplant day 7 TTE (LVEF %/RV function)	First biopsy results (AMR/ACR)	ICU length of stay (days)	Hospital length of stay (days)	Alive at 30 days	Readmission within 30 days	Other adverse outcomes
1	3.3	4	None	None	60%/mild RV dysfunction	0/2R	9	20	Yes	Yes- COVID	AKI requiring CRRT
2	3.2	8	None	None	65%/mild RV dysfunction	0/0	3	15	Yes	No	
3	2.1	14	PGD-LV: mild	None	60%/normal RV function	0/0	7	29	Yes	No	
4	4	7	None	None	55%/normal RV function	0/0	10	29	Yes	No	AKI requiring CRRT
5	2.1	21	PGD-LV: mild	None	60%/mild RV dysfunction	0/1R	16	57	Yes	Yes- AMS	
6	3	15	PGD-LV: mild	None	60%/normal RV function	0/0	7	15	Yes	No	
7	3.3	32	PGD-LV: moderate	IABP	55%/normal RV function	0/1R	21	36	Yes	No	AKI requiring CRRT and HD at discharge, tracheostomy placement, stroke
8	4.9	19	PGD-LV: mild	None	65%/normal RV function	0/0	6	17	Yes	No	Stroke
9	4.4	19	PGD-LV: mild	None	65%/normal RV function	0/1R	8	16	Yes	No	
10	4.6	5	None	None	65%/normal RV function	0/0	5	9	Yes	No	
11	2.8	9	None	None	65%/normal RV function	0/0	10	16	Yes	Yes- volume overload	
12	3.1	8	None	None	60%/normal RV function	0/1R	4	10	Yes	No	
13	2.4	25	PGD-LV: moderate	IABP	55%/normal RV function	0/0	26	32	Yes	No	
14	3.4	17	PGD-LV: mild	None	65%/normal RV function	0/0	4	22	Yes	No	
15	3.7	11	PGD-LV: moderate	IABP	60%/moderate RV dysfunction	0/0	6	12	Yes	No	

ACR, acute cellular rejection; AKI, acute kidney injury; AMR, antibody mediated rejection; AMS, altered mental status; CI, cardiac index; BMI, body mass index; CRRT, continuous renal replacement therapy; DBD, donation after brain death; DCD, donation after circulatory death; ECMO, extracorporeal membrane oxygenation; HD, hemodialysis; IABP, intraaortic balloon pump; ICU, intensive care unit; LVEF, left ventricular ejection fraction; PGD: primary graft dysfunction; PGD-LV, left- ventricle primary graft dysfunction; TTE, transthoracic echocardiogram.

Bystander Organs

Table 1 Donor Characteristics

Donor ID[a]	Age (years)	Sex	Ethnicity	BMI (kg/m^2)	Donor distance from transplant center (nautical miles)	Reason for admission	Active hepatitis C[b]	CPR time (minutes)	Pre-donation LVEF (%)	Pre-donation RV function	Other organs procured
1	29	Female	CA	24	219	Injury/trauma	No	0	60	Normal	Liver, kidney
2	25	Male	CA	22	100	Injury/trauma	No	0	55	Normal	Liver, kidney
3	12	Male	CA	27	333	Injury/trauma	No	8	75	Normal	Liver, kidney
4	26	Male	CA	28	160	Injury/trauma	Yes	0	63	Normal	Liver, kidney
5	16	Male	CA	26	470	Suicide	No	0	61	Normal	Liver, kidney
6	33	Female	CA	33	593	Hypoxia	No	20	55	Normal	Liver, kidney
7	28	Male	CA	27	136	Injury/trauma	No	0	60	Normal	Liver, kidney
8	22	Male	CA	24	691	Hypoxia	No	1	70	Normal	Liver, kidney, lung
9	21	Male	CA	22	574	Injury/trauma	No	0	68	Normal	Liver, kidney, lung
10	30	Male	CA	26	250	Injury/trauma	No	15	55	Normal	Liver, kidney
11	23	Male	CA	32	500	Hypoxia	No	0	70	Normal	Kidney
12	19	Female	CA	19	292	Injury/trauma	No	0	55	Normal	Liver, kidney
13	18	Male	CA	28	137	Injury/trauma	No	0	60	Normal	Kidney
14	16	Male	CA	28	612	Injury/trauma	No	0	65	Normal	Liver, kidney, lung
15	34	Male	CA	29	531	Hypoxia	No	13	55	Normal	Liver, kidney

AA, African American; BMI, body mass index; CA, Caucasian American; CPR, cardiopulmonary resuscitation; LVEF, left ventricular ejection fraction; RV, right ventricle.

[a]Donor and recipient ID correspond such that individual donor-recipient pairs are identified

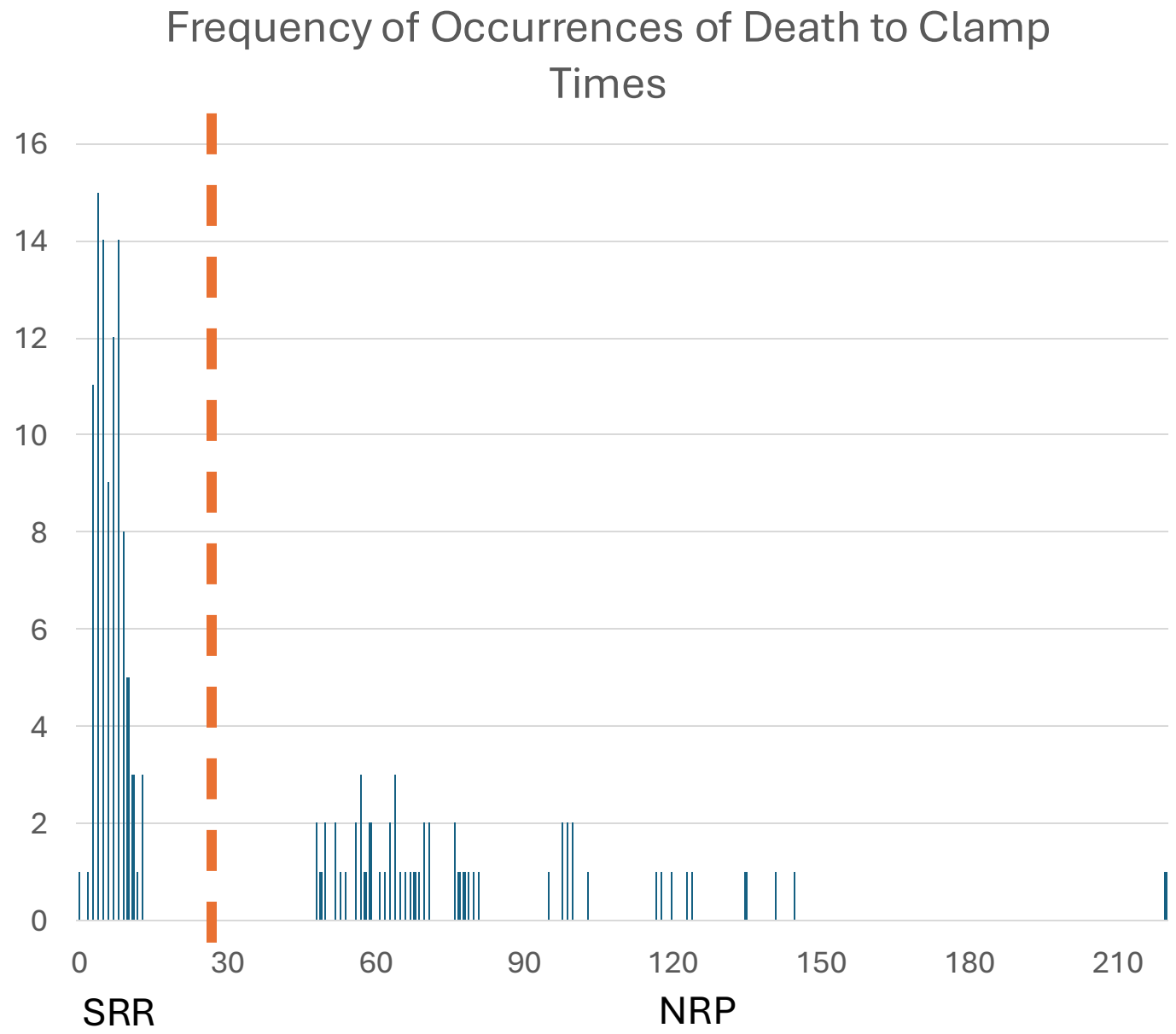
[b]Antibody and nucleic acid amplification test (NAT) positive.

How does TA-NRP impact abdominal transplant recipient outcomes in the US?

Study Aims

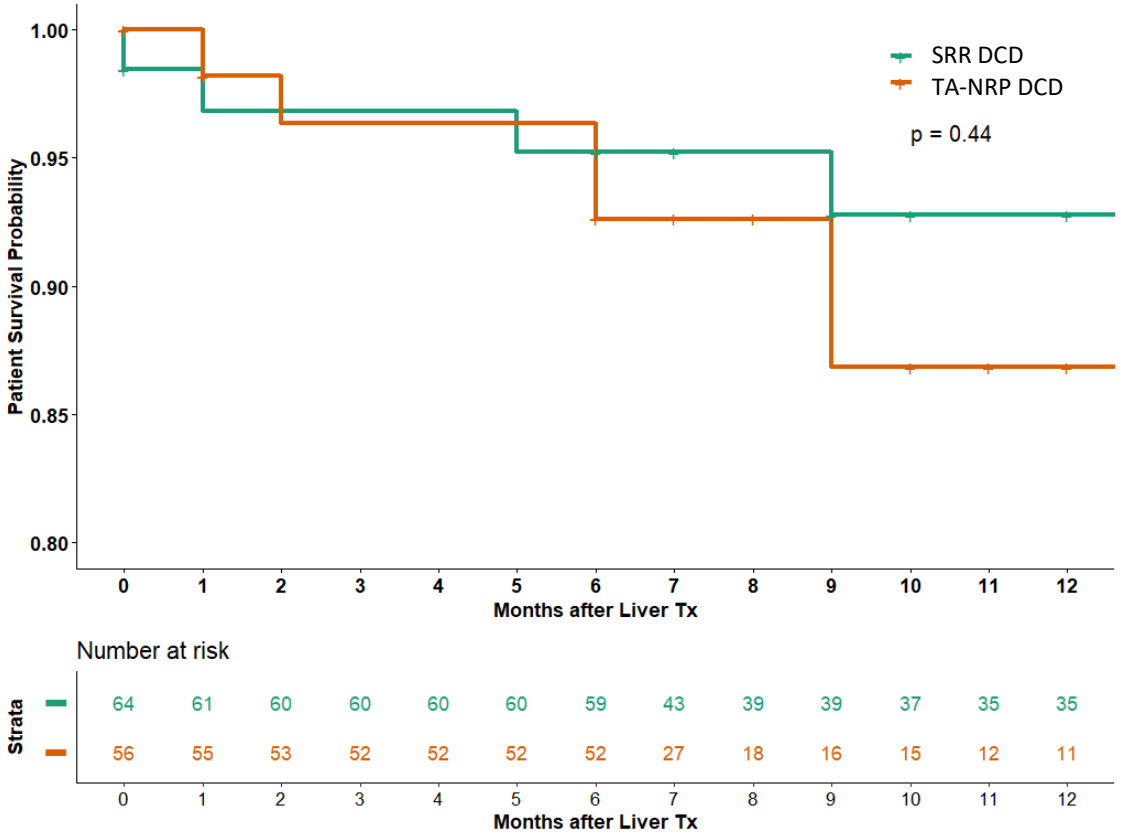
1) Develop a method to distinguish between cardiac TA-NRP and SRR DCD donors using UNOS data
2) Compare outcomes for liver transplant recipients of cardiac DCD donors by donor procurement technique
3) Compare outcomes for kidney transplant recipients of cardiac DCD donors by donor procurement technique

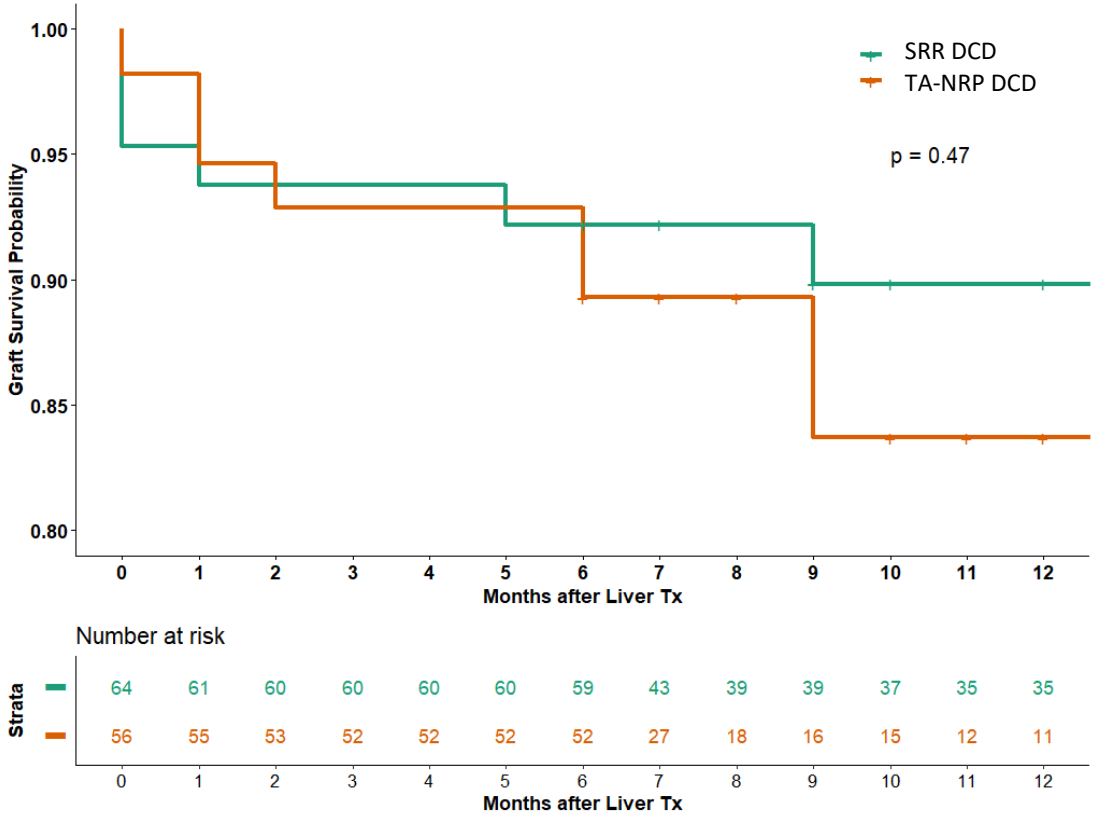
Pilot data: Can we use death to clamp time to distinguish between SRR and NRP?



Trend toward higher liver utilization rates

	TA-NRP DCD (n=85)	SRR DCD (n=117)	P value
Donor Age, median (IQR), years	28 (21-34)	31 (25-36)	.020
Male Gender, No. (%)	76 (89.4)	96 (82.1)	.211
Donor BMI, median (IQR), $kg.m^{-2}$	26.6 (24.1-29.3)	26.8 (24.9-31.1)	.161
Kidney donor profile index, median (IQR)	0.19 (0.10-0.31)	0.23 (0.14-0.39)	.051
Death to clamp time, median (IQR), mins	67 (57-99)	6 (4-8)	<0.001
Organs transplanted			
Heart, No. (%)	85 (100)	117 (100)	
Liver, No. (%)	61 (71.8)	68 (58.1)	.065
Kidneys, No. (%) 1 kidney 2 kidneys	 5 (5.9) 76 (89.4)	 7 (6.0) 107 (91.5)	.753
Double lung, No. (%), Single Lung, No. (%)	4 (4.7%), 10 (11.8%)	1 (0.9%), 16 (13.7%)	.247
Pancreas, n (%)	7 (8.2)	4 (3.4)	.136
Organs transplanted per donor, median (IQR)	4 (3- 4)	4 (3- 4)	.254
Warm ischemia time, median (IQR), mins	NA	21.0 (18.0-24.5)	NA





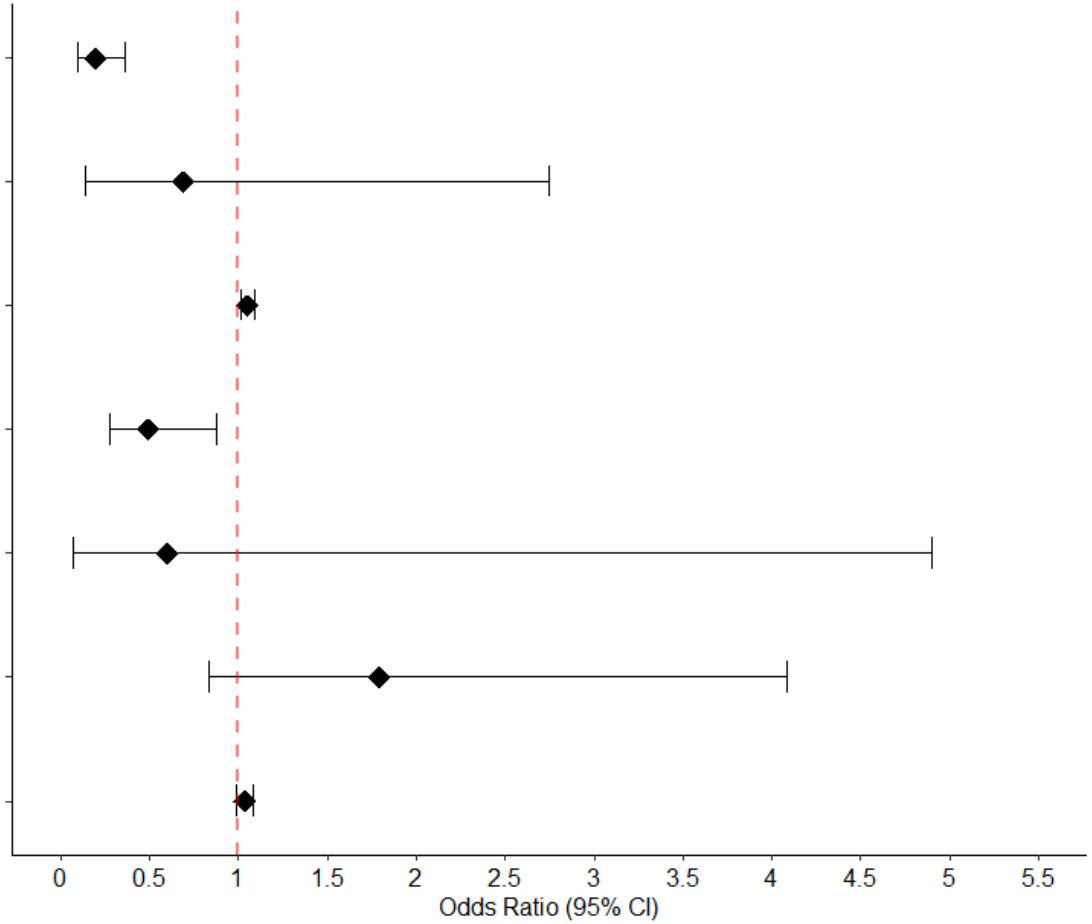
No difference in liver transplant patient or graft survival

	TA-NRP DCD (n= 118)	SRR DCD (n=200)	P value
Donor age, median (IQR), years	27.0 (21.0-34.0)	31.0 (25.0-36.0)	.001
Donor male gender, No. (%)	106 (89.8)	168 (84.0)	.198
Donor BMI, median (IQR), $kg.m^{-2}$	27.2 (24.4-29.9)	27.2 (24.9-31.4)	.224
Kidney donor profile index, median (IQR)	0.18 (0.10-0.31)	0.28 (0.14-0.41)	<.001
Cold Ischemic Time, median (IQR), hrs	17.8 (13.7-22.7)	18.7 (14.0-22.4)	.411
Recipient Delayed Graft Function, No. (%)	15 (12.7)	84 (42.0)	<.001
Recipient death with a functioning graft, No. (%)	2 (1.7)	4 (2.0)	1.000
Kidney Pumped, No. (%)	79 (66.9)	140 (70.4)	0.611

Lower rates of kidney delayed graft function with NRP

Logistic regression model: NRP is the strongest contributor to decreasing the odds of DGF

	OR	95% CI
Perfusion Type: TA-NRP DCD	0.198	0.101, 0.365
SLK	0.693	0.137, 2.744
Cold Ischemia Time	1.051	1.017, 1.09
Kidney Pump	0.493	0.274, 0.879
KDPI	0.601	0.071, 4.896
Donor Gender: Male	1.793	0.835, 4.086
Donor Age	1.037	0.991, 1.087



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Leading Internal Medicine, Improving Lives

Ethics, Determination of Death, and Organ Transplantation in Normothermic Regional Perfusion (NRP) with Controlled Donation after Circulatory Determination of Death (cDCD): American College of Physicians Statement of Concern

Approved by the Board of Regents on April 17, 2021

Violates the dead donor rule when the heart restarts

Causes death with the occlusion of cerebral circulation

Is not adequately disclosed to donor families

Can be replaced with ex situ machine perfusion

Volume 22 • Issue 5 • MAY 2022

American Journal of TRANSPLANTATION

A need for ethical and legal clarity

THE OFFICIAL JOURNAL OF

AST AMERICAN SOCIETY OF TRANSPLANTATION ASTS

WILEY

VIEWPOINT

Applying the ethical framework for donation after circulatory death to thoracic normothermic regional perfusion procedures

Describe the framework used for the analysis of ethical acceptability of DCD donation

Analyze the specific practice of thoracic normothermic regional perfusion (TA-NRP) DCD within this framework

Authors conclude that TA-NRP DCD:

- Meets the ethical standards of informed consent, non-maleficence, the dead donor rule, and irreversibility, thus should be considered ethically acceptable
- May improve organ yields and recipient outcomes
- Should be supported by professional organizations

AJT

Wall et al

Created by the AJT Editorial Office

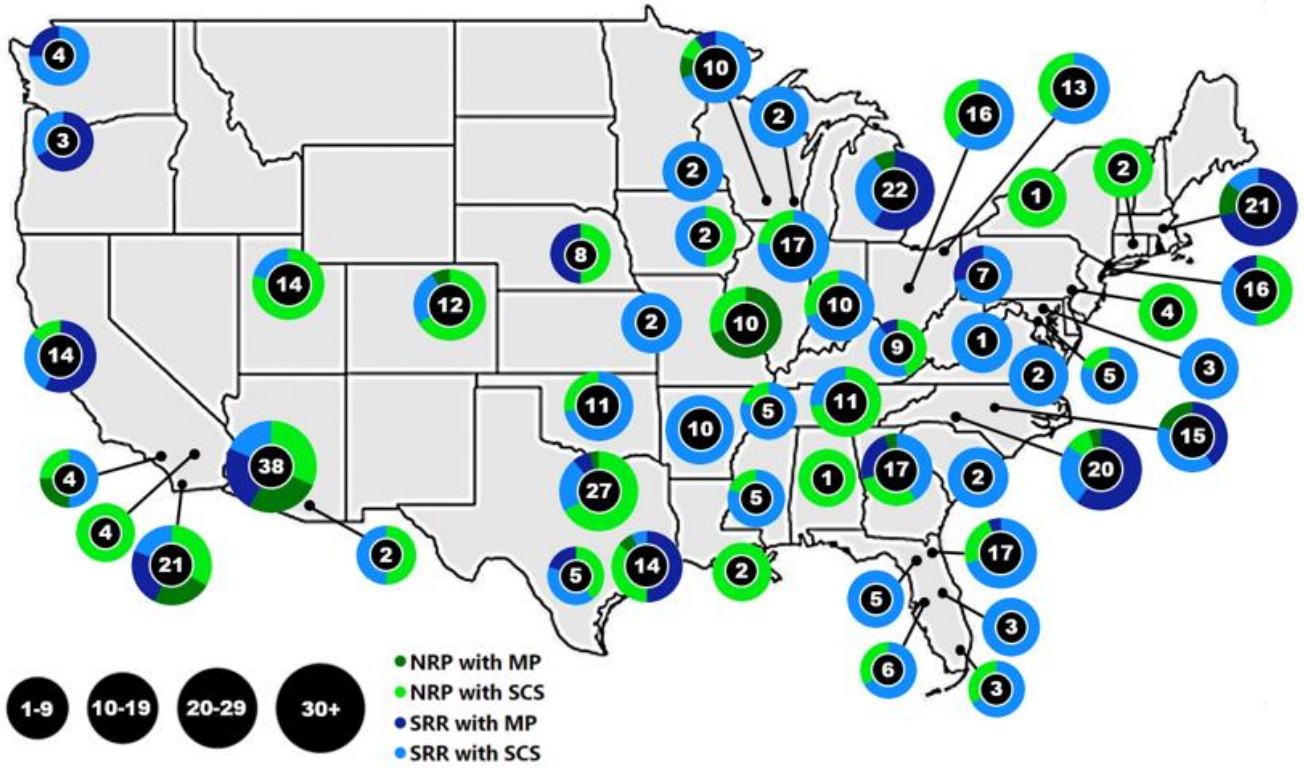
10.1111/ajt.16959

Scholarly attitudes toward NRP

		TA-NRP (n=46 attitudes)			A-NRP (n=28 attitudes)			NRP, unspecified (n=16 attitudes)		
	Countries	For	Neutral	Against	For	Neutral	Against	For	Neutral	Against
	Canada (n=13 attitudes)	0	7	0	1	2	0	0	2	1
	Europe (n=29 attitudes)	5	4	1	14	2	0	2	1	0
	United States (n=48 attitudes)	12	8	9	3	6	0	4	4	2

A scoping review of the legal and ethical challenges with the use of normothermic regional perfusion in controlled donation after circulatory determination of death from 2005 to 2023; da Graca, Briget et al. American Journal of Transplantation

Liver transplants from cardiac DCD donors



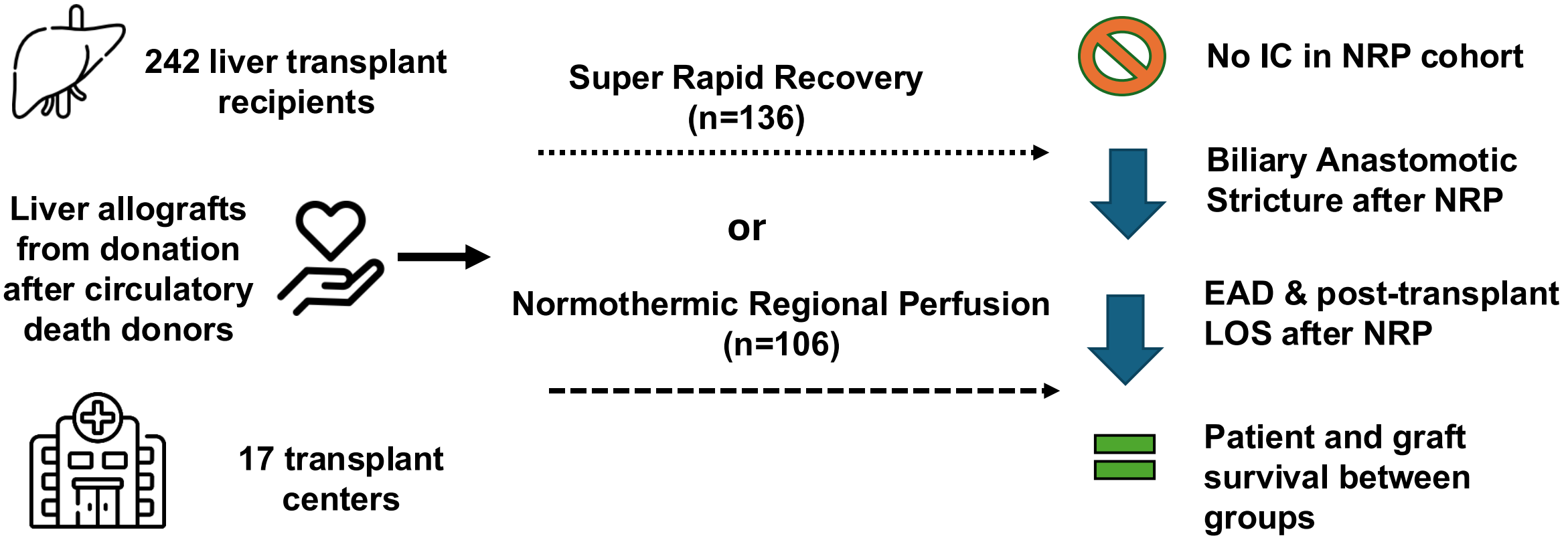
Brief Communication

The current landscape of in situ and ex situ machine perfusion utilization for liver grafts from cardiac donation after circulatory death donors in the US

Anji Wall [1,*], Matthew Snoddy [1], Jinyu Du [1], Johanna Bayer [1], Sebastian Danobeitia [1], Seung Hee Lee [1], Eric Martinez [1], Amar Gupta [1], Gege Ran [2], William F. Parker [3], Sumeet K. Asrani [4], Giuliano Testa [1]

- The procurement technique is determined by the cardiac team
- Most liver transplant programs use a variety of donors based on procurement technique and storage strategy

Retrospective multi-center US liver transplant outcomes after normothermic regional perfusion versus standard super rapid recovery from controlled donation after circulatory death donors



Icons from: https://www.flaticon.com/free-icons/hospital" title="hospital icons">Hospital icons created by Freepik - Flaticon

Brubaker AL, Sellers MT et al, *JAMA Surg*, 2023

Slide courtesy of Aleah Brubaker

Consensus

The American Society of Transplant Surgeons Consensus Statement on Normothermic Regional Perfusion

Anji E. Wall, MD, PhD,[1] Bradley L. Adams, JD,[2] Aleah Brubaker, MD, PhD,[3] Cherylee W.J. Chang, MD,[4] Kristopher P. Croome, MD,[5] Jennifer Frontera, MD,[6] Elisa Gordon, PhD, MPH,[7] Jordan Hoffman, MD, MPH,[8] Lewis J. Kaplan, MD, FCCP, FCCM,[9,10] Deepali Kumar, MD, FRCPC,[11] Josh Levisky, MD, MS,[12] Eduardo Miñambres, MD, PhD,[13] Brendan Parent, JD,[14] Christopher Watson, MD, BChir,[15] Ajmal Zemmar, MD, PhD,[16] and Elizabeth A. Pomfret, MD, PhD[17]

Abstract. On June 3, 2023, the American Society of Transplant Surgeons convened a meeting in San Diego, California to (1) develop a consensus statement with supporting data on the ethical tenets of thoracoabdominal normothermic regional perfusion (NRP) and abdominal NRP; (2) provide guidelines for the standards of practice that should govern thoracoabdominal NRP and abdominal NRP; and (3) develop and implement a central database for the collection of NRP donor and recipient data in the United States. National and international leaders in the fields of neuroscience, transplantation, critical care, NRP, Organ Procurement Organizations, transplant centers, and donor families participated. The conference was designed to focus on the controversial issues of neurological flow and function in donation after circulatory death donors during NRP and propose technical standards necessary to ensure that this procedure is performed safely and effectively. This article discusses major topics and conclusions addressed at the meeting.

(*Transplantation* 2024;108: 312–318).

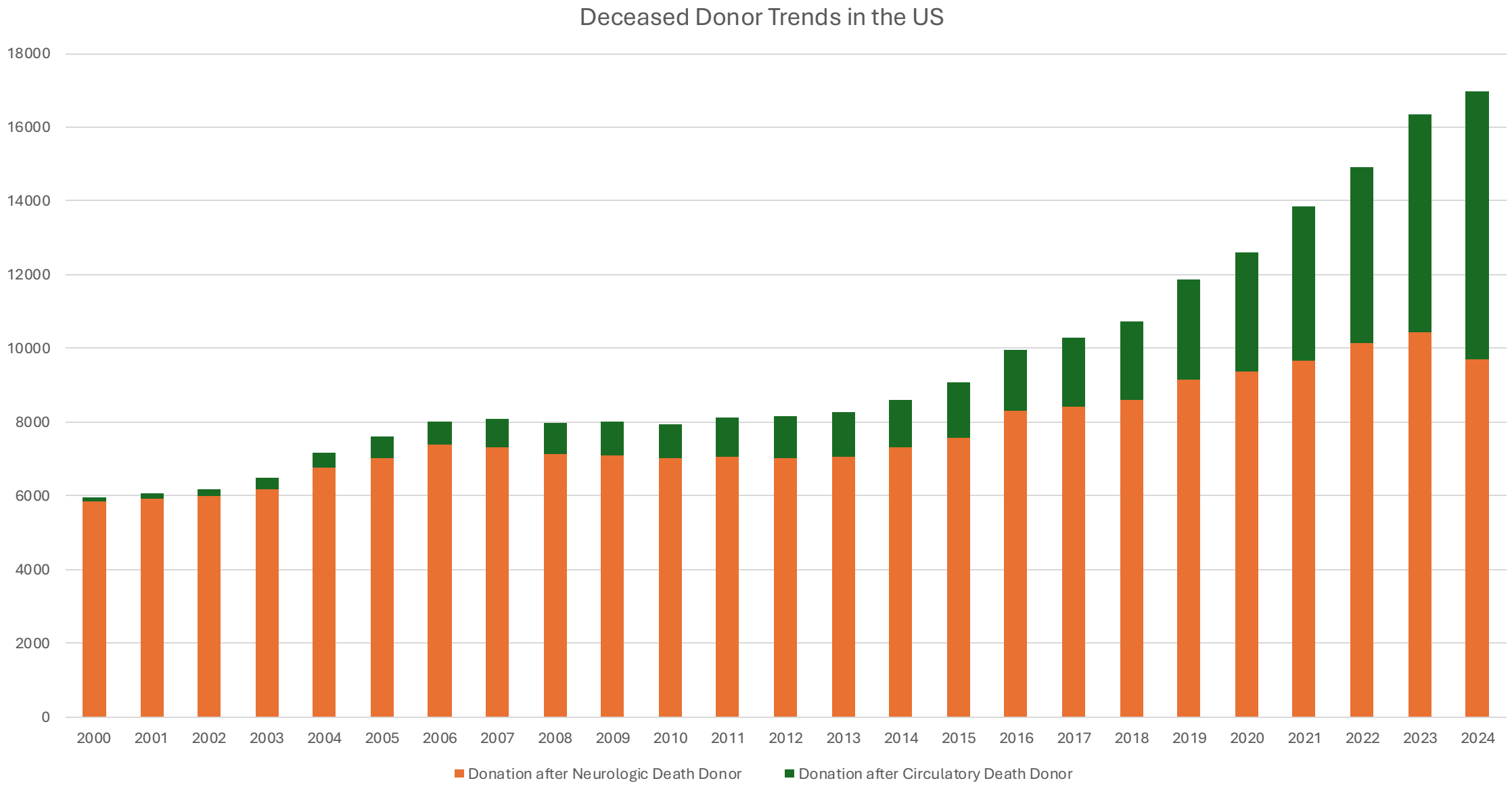
Standardization

American Society of Transplant Surgeons Normothermic Regional Perfusion Standards: Ethical, Legal, and Operational Conformance

Anji E. Wall, MD, PhD,[1] Shaheed Merani, MD, PhD,[2] Jason Batten, MD,[3] Bonnie Lonze, MD, PhD,[4] Kristin Mekeel, MD,[5] Michael Nurok, MD, PhD,[6] Jennifer Prinz, RN, BSN, MPH-HPA,[7] John Gil, MD, MS,[8] Elizabeth A. Pomfret, MD, PhD,[9] and James V. Guarrera, MD[10]

Background. The American Society of Transplant Surgeons convened a multidisciplinary working group to address operational, ethical, and legal considerations surrounding normothermic regional perfusion (NRP) procurement. **Methods.** The working group, comprising members from American Society of Transplant Surgeons and AST across various disciplines including transplant surgery, hepatology, critical care, and bioethics, collaborated to formulate recommendations and guidance for NRP procurement. **Results.** The following topics were identified by the group as essential standards that need to be addressed for ethical, legal, and operational conformance: terminology; conceptualization of death in the context of NRP; and communication, logistics, and training and competency. **Conclusions.** Fourteen recommendations that support the ethical and legal acceptability of NRP in the United States and set expectations for the conduct of NRP procedures are provided.

(*Transplantation* 2024;108: 1655–1659).


Deceased Donor Trends in the US
18000
16000
14000
12000
10000
8000
6000
4000
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2022
2023
2024
Donation after Neurologic Death Donor
Donation after Circulatory Death Donor

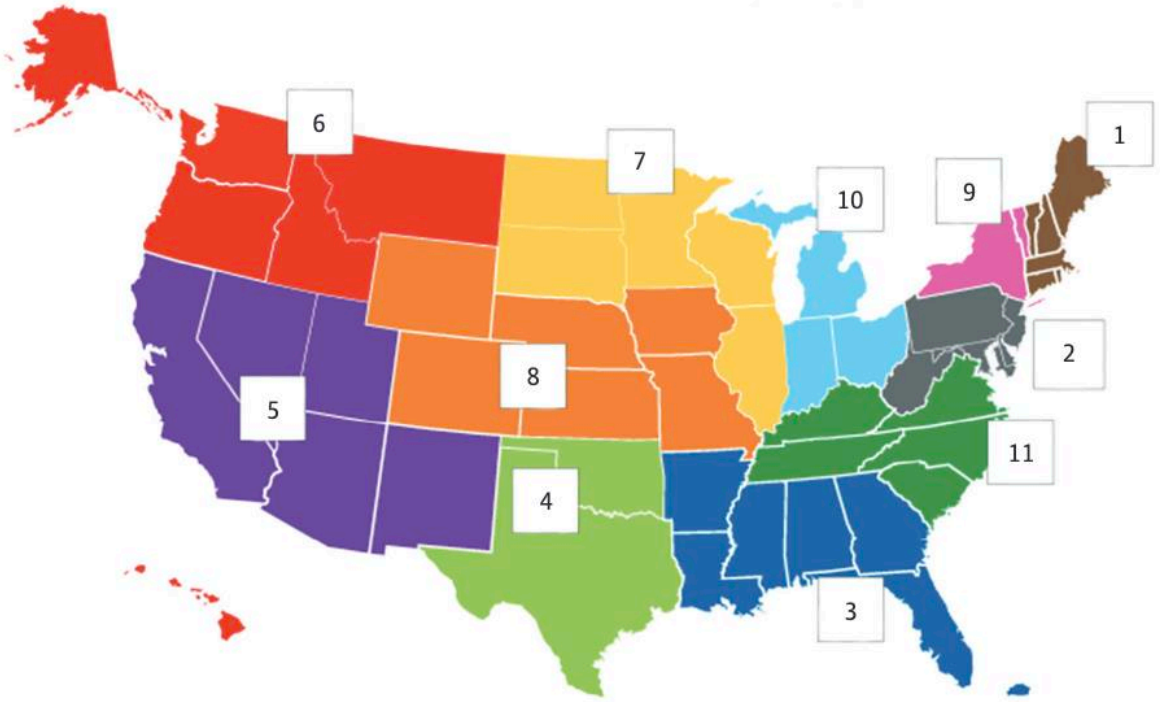
JAMA Network | Open

Original Investigation | Surgery

Normothermic Regional Perfusion Experience of Organ Procurement Organizations in the US

Marty T. Sellers, MD, MPH; Jennifer L. Philip, MD; Aleah L. Brubaker, MD, PhD; Roxane L. Cauwels, MBA; Kristopher P. Croome, MD, MS; Jordan R. Hoffman, MD; Nikole A. Neidlinger, MD, MBA; Andrea M. Reynolds, BFA; Anji E. Wall, MD, PhD; John M. Edwards, RN

Figure 2. Normothermic Regional Perfusion (NRP) Case Volume by Organ Procurement and Transplantation Network (OPTN) Region

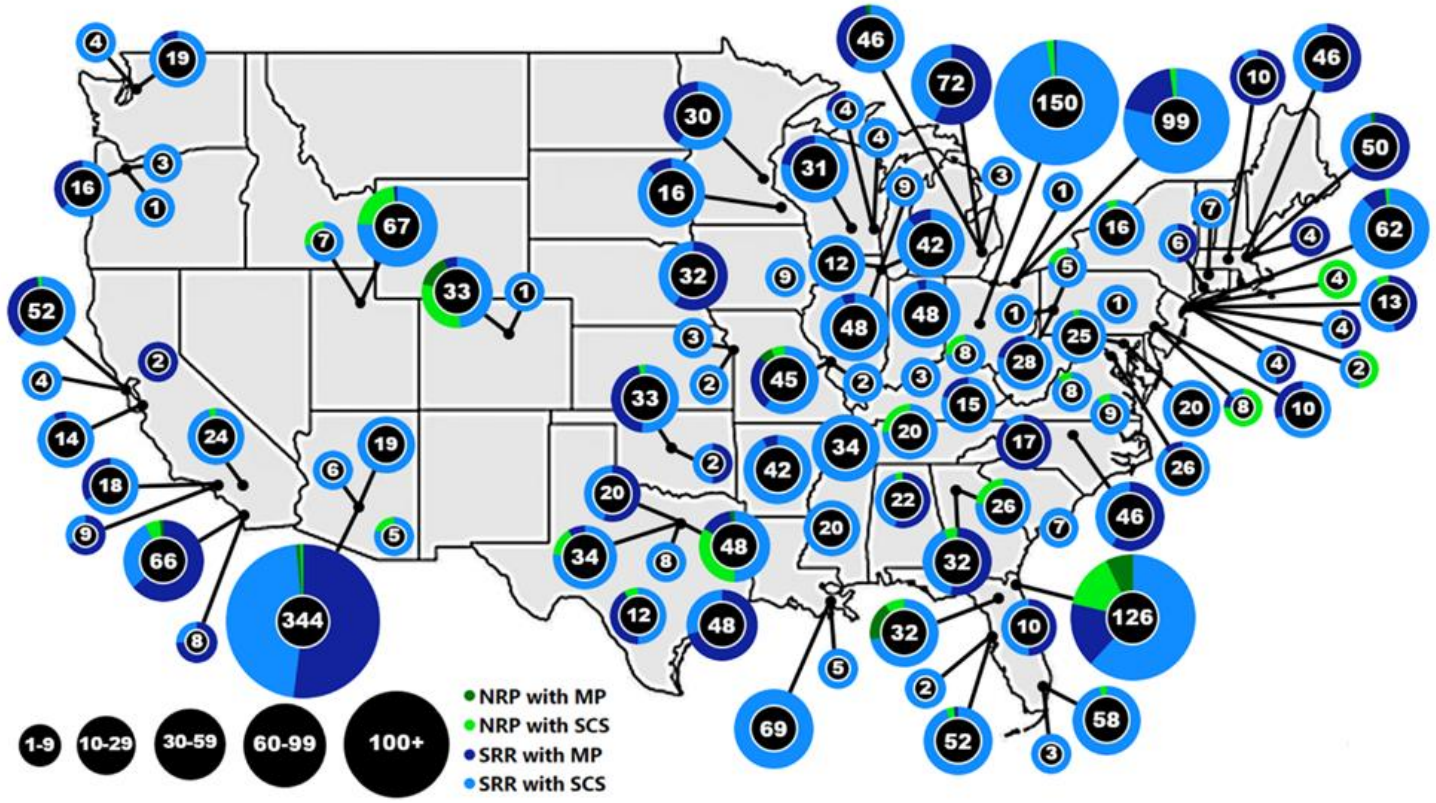


OPTN region	Total cases, No.		
	TA-NRP (n = 421)	A-NRP (n = 185)	Total (N = 606)
1	0	4	4
2	21	15	36
3	45	75	36
4	59	40	99
5	98	9	107
6	0	0	0
7	12	0	12
8	77	3	80
9	28	9	37
10	33	3	36
11	48	27	75

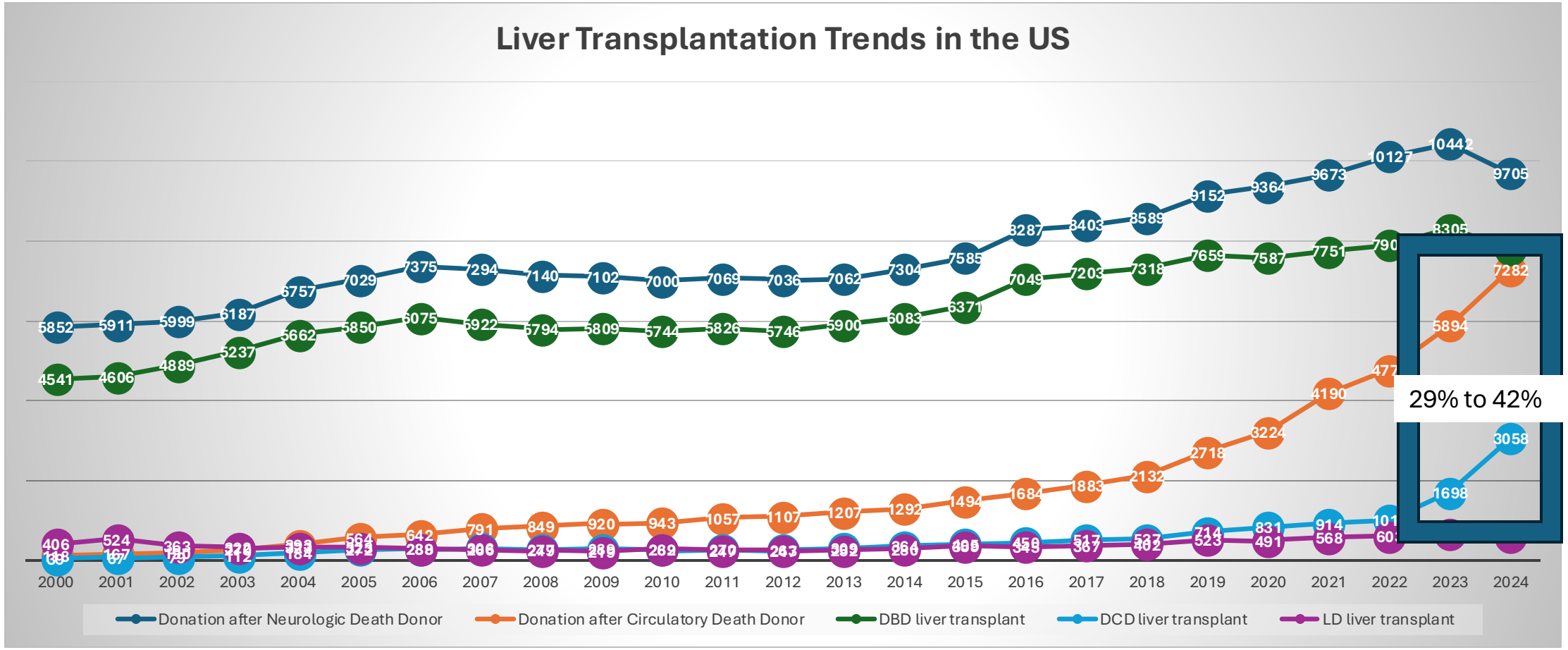
A-NRP indicates abdominal NRP; TA-NRP, thoracoabdominal NRP.

Liver transplants from abdominal DCD donors

- Fewer programs use NRP
- Most abdominal-only procurements are rapid recovery
- NRP is less accessible for abdominal-only donors



DCD liver transplantation rates are increasing



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Q&A
QUESTIONS & ANSWERS