

# Crystalloids and the appeal for balanced solutions. What's the evidence and does it really matter?

Andrew Shaw  
MB FRCA FCCM FFICM

Professor and Chief  
Cardiothoracic Anesthesiology  
Vanderbilt University Medical Center

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Dr Robert Lewins

DR. LEWINS ON INJECTION OF SALINE SALTS INTO THE VEINS. 257

INJECTION  
OF  
SALINE SOLUTIONS INTO THE  
VEINS.  
*Adapted with notes in Malignant Cholera.*

[We have been favoured with the following curious and interesting document, addressed to the Central Board of Health.]

Sir,—I conceive it to be my duty to let you know, for the information of the Central Board of Health, that the great desideratum of restoring the natural current in the veins and arteries, of improving the colour of the blood, and recovering the function of the lungs in cholera asphyxia, may be accomplished by injecting a weak saline solution into the veins of the patient. To Dr. Thomas Latta, of this place, is due the merit of first having recourse to this practice. He has tried it in six cases; three of which I have seen, and assisted to treat. The most wonderful and satisfactory effect is the immediate consequence of the injection. To produce the effect referred to, a large quantity must be injected. *from five to ten pounds* in an adult, and repeated at longer or shorter intervals, as the state of the pulse, and other symptoms, may indicate. Whenever the pulse fails, more fluid ought to be thrown in to produce an effect upon it, without regard to quantity. In one of the cases I have referred to, 120 ounces were injected at once, and repeated to the amount of 330 ounces in 12 hours. In another, 376 ounces were thrown into the veins between Sunday, at 11 o'clock a.m. and this day, (Tuesday) at 4 p.m.; that is, in the course of 53 hours, upwards of 31 pounds!

The solution that was used consisted of two drachms of muriate, and two scruples of carbonate of soda, to sixty ounces of water. It was at the temperature of 108 or 110°.

The apparatus employed for injecting was merely one of Reid's common syringes, (the fluid being put into a vessel rather deep and narrow) with a small pipe fitted, that it might easily be introduced into an incision in the veins of the usual size that is made in bleeding. It may, however, be well to keep in mind that in the event of the operation being frequently repeated, it may be advisable to inject by different veins. I forbear at present to enter further into the particulars, nor have we had sufficient experience to speak decisively on the subject. I may, however, mention that the idea of having recourse to this remedy in cholera occurred to Dr. Latta, from being convinced (which I am also) that the evacuations upwards and downwards are in reality the serum of the blood; that it is the duty of the physician to replace it as speedily as possible by injecting a fluid, as similar to the serum as can be formed artificially, directly into the veins, which has been done here with wonderful, and so far as we can yet judge, excellent effect. An immediate return of the pulse, an improvement in the respiration and in the voice, an evolution of heat, an improvement in the appearance of the patient, with a feeling of comfort, are the immediate effects. The quantity necessary to be injected will probably be found to depend upon the quantity of serum lost, the object of the practice being to place the patient in nearly his ordinary state as to the quantity of blood circulating in the vessels.

I have, &c.  
(Signed) ROBERT LEWINS, M.D.  
Fellow of the Royal College of Physicians, and  
Member of the Lethic Board of Health.  
Leith, 4, Quality Street,  
May 15, 1832.  
To H. Maclean, Esq.  
Secretary to the Central Board of Health.

“Whenever the pulse fails, more fluid ought to be thrown in, without regard to quantity”

“The most wonderful and satisfactory effect is the immediate consequence of the injection.”

“The quantity necessary to be injected will probably be found to depend upon the quantity of serum lost.”

“The solution that was used consisted of two drachms of muriate, and two scruples of carbonate of soda to sixty ounces of water.”

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Lewins: London Medical Gazette 1832

## Lancet editorial 1832

284 THE CASES OF CHOLERA SUCCESSFULLY TREATED

depth of the sound, for the lower the note, the larger the extension with the albumen; the effect appeared like a fine web, formed with mechanical precision. From various experiments, Mr. Faraday thought he could establish as a principle, that all fluids were influenced by the same law, and that the intestine was produced and sustained by the agitation of the surface was dependent upon the conversion of the peristaltic impulse into a lateral one, so as to occasion the alternate and geometric transference to the depth of the liquid employed.

After the lecture, Mr. Faraday exhibited a portrait of Ellen, Davy's first wife.

He pronounced a eulogy upon that great philosopher and mathematician, who was an honorary member of the institution.

Mr. Faraday also announced that the gold medal of the institution had been conferred this year on Gay Lussac for his law of decomposition in chemistry.

### THE LANCET.

London, Saturday, June 2nd, 1832.

Two papers which we publish this day on the effects produced in several desperate cases of cholera by the injection into the veins of water containing the salts of the blood in solution, will be read with the most lively interest and satisfaction.

From the conjoint testimony of the highly-respectable individuals who have conducted the various cases, it appears certain that of fifteen hopeless and abandoned cases, five were rescued from apparently certain death by the treatment adopted, while of those which passed fatal, all but one had been complicated with such extensive organic disease, that no method of medication could do more than postpone a little the fatal event. That therefore the injection seems to have succeeded. In short, according to the evidence before us, the method has only failed in one case in which it had been fairly tried—that is, where no organic disease had pre-existed, and where enough of life was left to sustain the least anticipation of success.

The most sterling fact connected with the details of the treatment is the great quantity of fluid injected. In one case, nearly 7 lbs. were at once thrown in to the subcutaneous vein, and in six hours this was infused. But in this very case, a dangerous example of the last stage of a protracted attack of cholera, after extreme purging and vomiting had denied the help during—when the pulse had been imperceptible for hours, the skin livid, and the veins lost, the patient completely recovered! While the injection was performing, the pulse rose, the heat returned, the lividity disappeared, the countenance became fresh and healthy, and in short the patient underwent a change more like the workings of a successful resuscitative agent, than the effect of the intervention of medical science.

The case thus related to is we think one of the most interesting recorded in the annals of our profession. It gives us at least this all important information, that the injection of water in these great quantities is not necessarily fatal or even a feasible measure. It further teaches us to presume that as organic chemistry improves, so our knowledge of the relation between the blood and venous system of different kinds increases, the art of treating disease in general will be placed on a more solid and certain foundation. It teaches us to boldly we may proceed when some of our scientific data are before us, and it thus dispels the all too cowardly quality which has hitherto prevented the principle of its treatment in question from being considered as a fact.

With respect to the quantity of water employed, two circumstances are to be borne in mind; first, that the quantity which enters the quantity of blood in the whole body at the mean of thirty-five pounds only, not upon no more or experimental facts; secondly, that the blood flows at such a small proportion of the fluids which the body generally contains—which induces

**“A suitable clinical investigation is required... the mass of the profession is unable to decide; and thus, instead of any uniform mode of treatment, every town and village has its different system or systems, while the daily lists of mortality proclaim the general inefficiency of the whole.”**

VANDERBILT UNIVERSITY  
MEDICAL CENTER

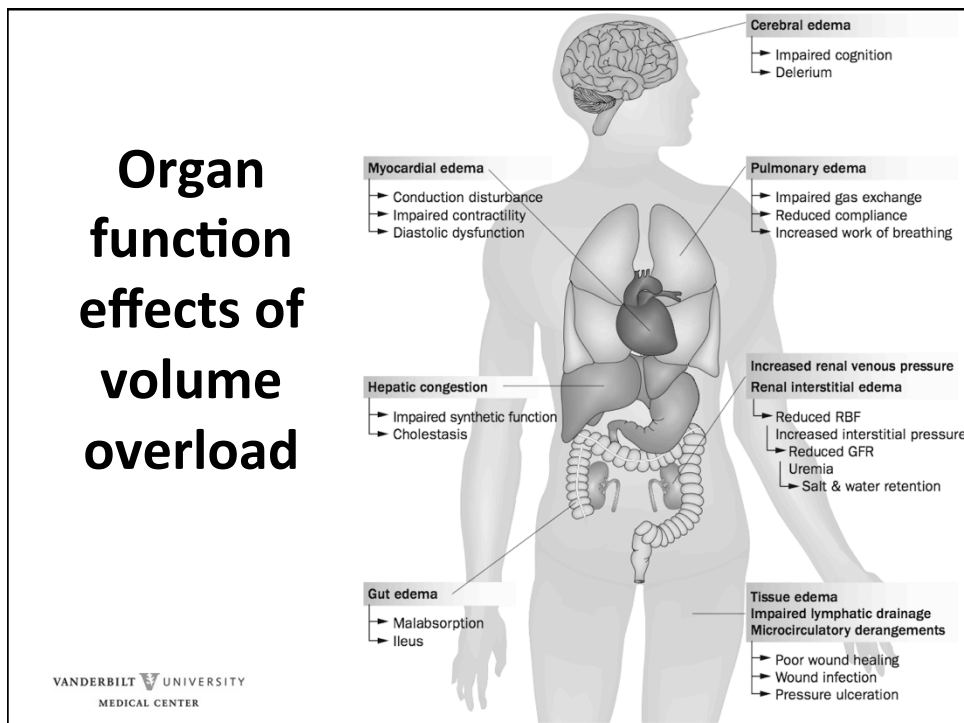
Lancet 1832

## Is fluid *amount* important ?



VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Organ function effects of volume overload



## Outcome benefits of fluid restriction

Reference	Study type	Population	n	Average fluid balance in less-positive group	Average fluid balance in more-positive group	Renal function measure	Renal outcome with more-restrictive fluid balance strategy	Principal outcome with more-restrictive fluid balance strategy
ARDS Clinical Trials Network (2006) <sup>88</sup>	Multicenter RCT	ARDS	1,000	-136 ml on day 7	+6,992 ml on day 7	Need for RRT; change in creatinine	No difference	Shorter duration of ventilation and ICU stay
Martin <i>et al.</i> (2005) <sup>96</sup>	Single-center RCT	Mixed ALI	40	-5,480 ml on day 5	-1,490 ml on day 5	Change in creatinine	No difference	Improved oxygenation
Martin <i>et al.</i> (2002) <sup>95</sup>	Single-center RCT	ALI after trauma	37	-3,300 ml on day 5	+500 ml on day 5	Change in creatinine	No difference	Improved oxygenation
Mitchell <i>et al.</i> (1992) <sup>127</sup>	Single-center RCT	Mixed ICU needing PAC	102	+142 ml	+2,239 ml	Change in creatinine	Small rise in creatinine	Shorter duration of ventilation and ICU stay
Bouchard <i>et al.</i> (2009) <sup>20</sup>	Retrospective observational	Mixed ICU with AKI	542	<10% rise	>10% rise	Dialysis independence	Improved	Decrease in mortality
Payen <i>et al.</i> (2008) <sup>6</sup>	Retrospective observational	Mixed ICU with or without AKI	3,147	-1,000 ml	+3,000 ml	Renal SOFA score	Improved	Decrease in mortality in patients with AKI
Vidal <i>et al.</i> (2008) <sup>72</sup>	Prospective observational	Mixed ICU with elevated or normal IAP	83	+5,000 ml	+9,000 ml	Renal SOFA score	Improved	Normal IAP associated with less organ failure and shorter ICU stay
Adesanya <i>et al.</i> (2008) <sup>128</sup>	Retrospective observational	Surgical ICU	41	+5 kg	+8.3 kg	Change in creatinine	No difference	Shorter duration of ventilation and ICU stay
McArdle <i>et al.</i> (2007) <sup>87</sup>	Retrospective observational	Surgical ICU	100	+7,500 ml	+10,000 ml	Change in creatinine	No difference	Decrease in postoperative complications
Arlati <i>et al.</i> (2007) <sup>99</sup>	Prospective observational	Burns ICU	24	+7,500 ml	+12,000 ml	Urine output	No difference	Decrease in organ dysfunction score

VANDERBILT UNIVERSITY  
MEDICAL CENTER

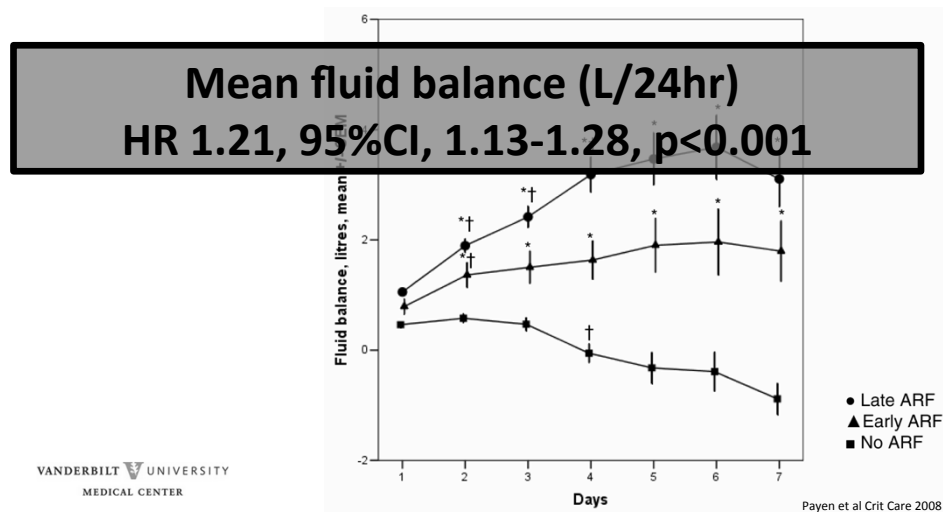
Prowle, J. R. *et al.* *Nat. Rev. Nephrol.* **6**, 107–115 (2010)

## Research

## Open Access

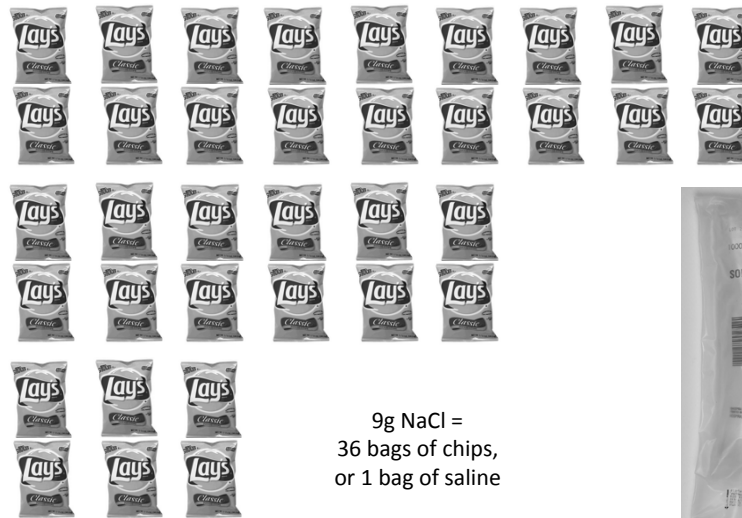
**A positive fluid balance is associated with a worse outcome in patients with acute renal failure**

Didier Payen<sup>1</sup>, Anne Cornélie de Pont<sup>2</sup>, Yasser Sakr<sup>3</sup>, Claudia Spies<sup>4</sup>, Konrad Reinhart<sup>3</sup>, Jean Louis Vincent<sup>5</sup> for the Sepsis Occurrence in Acutely Ill Patients (SOAP) Investigators

**Is fluid *amount* important ?**

- Excess fluid leads to adverse outcomes
- When fluid given is blinded – the ratio of crystalloid : colloid is generally 1.3 : 1
- NOT 3:1 as is widely believed
- Why are fluids not afforded the same respect as other intravenous drugs?

## Is *crystalloid type* important ?



9g NaCl =  
36 bags of chips,  
or 1 bag of saline

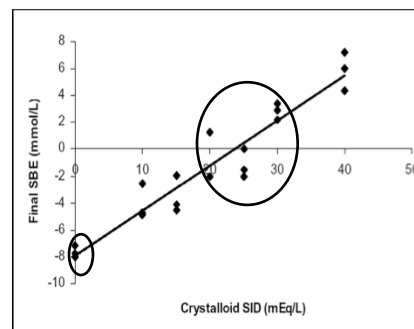
VANDERBILT UNIVERSITY  
MEDICAL CENTER



## Fluid Therapy Basics

Not all IV Fluids are created equal...

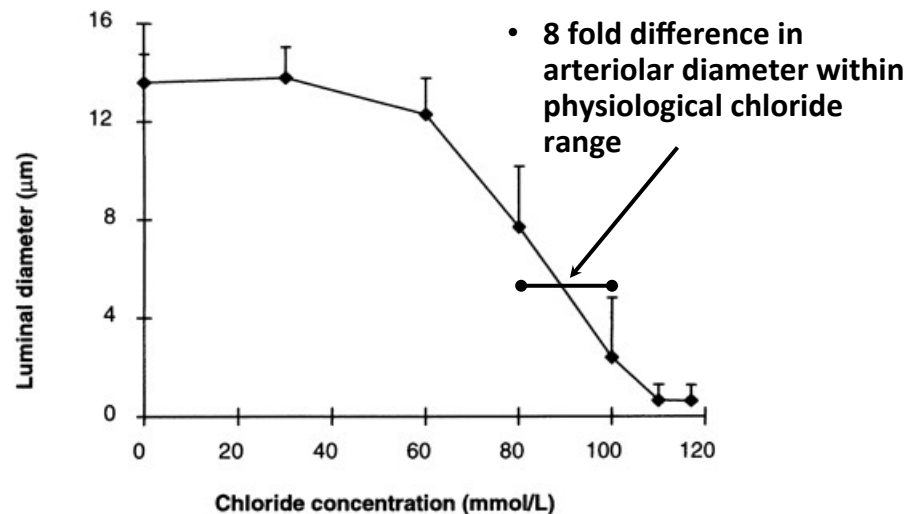
- A “balanced” fluid has the physiological electrolyte composition of plasma
- Balanced fluids do not cause the hyperchloremic acidosis associated with 0.9% saline



- Base excess after infusion is determined by the strong ion difference (SID) of the fluid infused.
- The red circle represents 0.9% NaCl, the blue circle represents balanced crystalloid

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## The importance of chloride: arteriolar vasoconstriction



VANDERBILT UNIVERSITY  
MEDICAL CENTER

Hansen et al, Hypertension 1998; 32:1066–1070

## Abnormal Saline

- **0.9% saline contains Na and Cl in equal amounts (154 meq/l)**
- Unlike plasma
- Adding NaCl to plasma increases the relative Cl concentration more than that of Na
- 0.9% saline reduces plasma SID and leads to hyperchloremic metabolic acidosis

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## The Abuse of Normal Salt Solution

George H. Evans, JAMA 1911

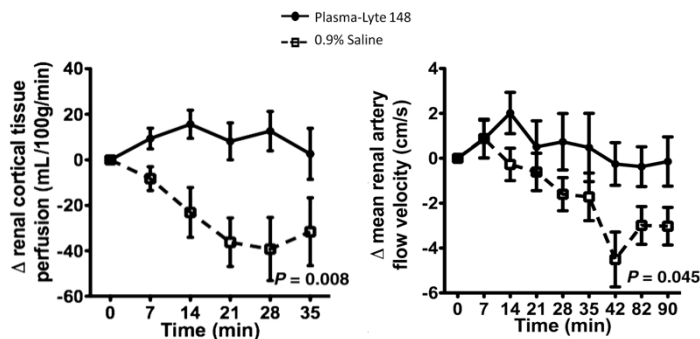
**“One cannot fail to be impressed with the danger...(of) the utter recklessness with which salt solution is frequently prescribed, particularly in the postoperative period...”**

**“...the disastrous role played by the salt solution is often lost in light of the serious conditions that call forth its use.”**

VANDERBILT UNIVERSITY  
MEDICAL CENTER



## 2L of Saline versus Balanced Crystalloid in Healthy Volunteers



Chowdhury et al (2012) Ann Surg

VANDERBILT UNIVERSITY  
MEDICAL CENTER

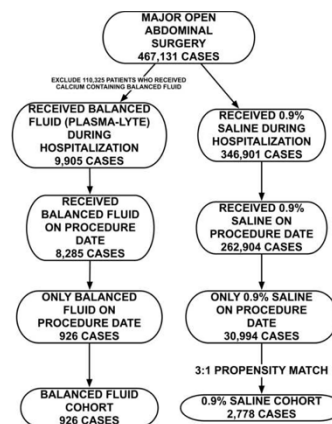
## FEATURE

## Major Complications, Mortality, and Resource Utilization After Open Abdominal Surgery

### 0.9% Saline Compared to Plasma-Lyte

Andrew D. Shaw, MB, FRCA, FCCM,\* Sean M. Bagshaw, MD,† Stuart L. Goldstein, MD,‡ Lynette A. Scherer, MD,§  
Michael Duan, MS,|| Carol R. Schermer, MD,¶ and John A. Kellum, MD#

- **Retrospective analysis of a prospectively collected data asset (Premier database)**
- **Major (non cardiac) surgery**
- **>30,000 patients who received 0.9% saline or balanced crystalloid alone on day of surgery**



(Ann Surg 2012;00:1–9)

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Risk adjusted major complications and resource use - All patients

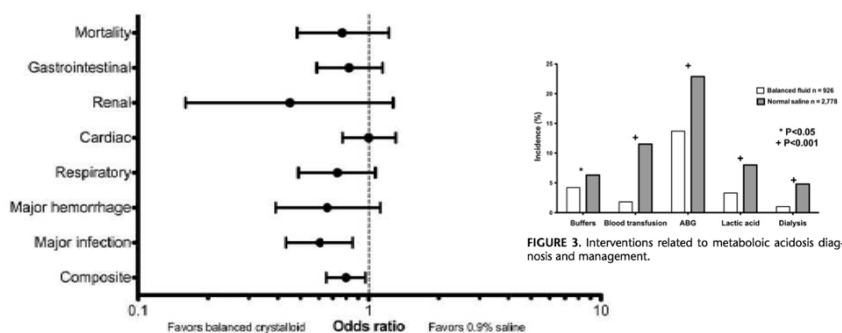


FIGURE 3. Interventions related to metabolic acidosis diagnosis and management.

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Shaw et al (2012) Ann Surg



## Risk adjusted outcomes non-elective surgery

(NNT 29)

Outcome	Balanced	Saline	P value
n	296	20,047	-
All cause mortality (%)	3.7	7.2	0.019
Major morbidity (%)	36	41	0.01
Minor morbidity (%)	35	42	0.01
Post op ventilation (%)	13.2	18.7	0.02
Discharged home (%)	86	78	$7 \times 10^{-6}$
30 day readmit rate (%)	30	31	NS

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Shaw et al (2012) Ann Surg



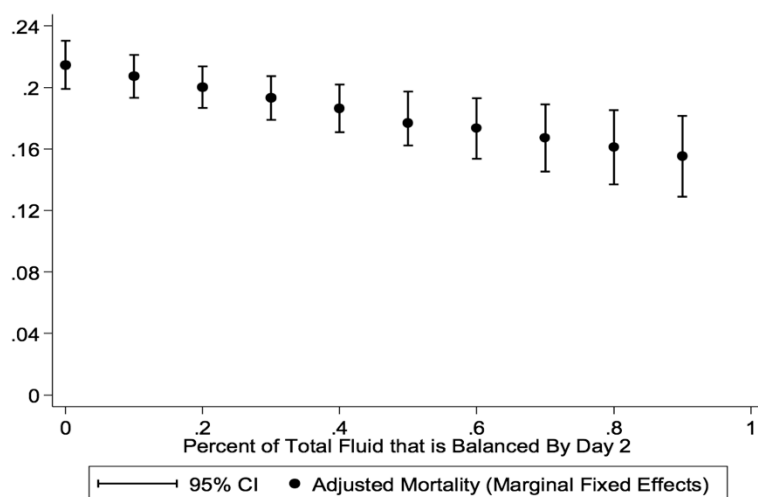
## Association Between the Choice of IV Crystalloid and In-Hospital Mortality Among Critically Ill Adults With Sepsis

Karthik Raghunathan, MD, MPH<sup>1,2</sup>; Andrew Shaw, MB, FRCA, FFICM, FCCM<sup>1</sup>;  
Brian Nathanson, PhD<sup>3</sup>; Til Stürmer, MD, PhD<sup>4</sup>; Alan Brookhart, PhD<sup>4</sup>; Mihaela S. Stefan, MD<sup>5</sup>;  
Soko Setoguchi, MD, DrPH<sup>6</sup>; Chris Beadles, MD, PhD<sup>2</sup>; Peter K. Lindenauer, MD, MSc<sup>7</sup>

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Raghunathan et al (2014) Crit Care Med

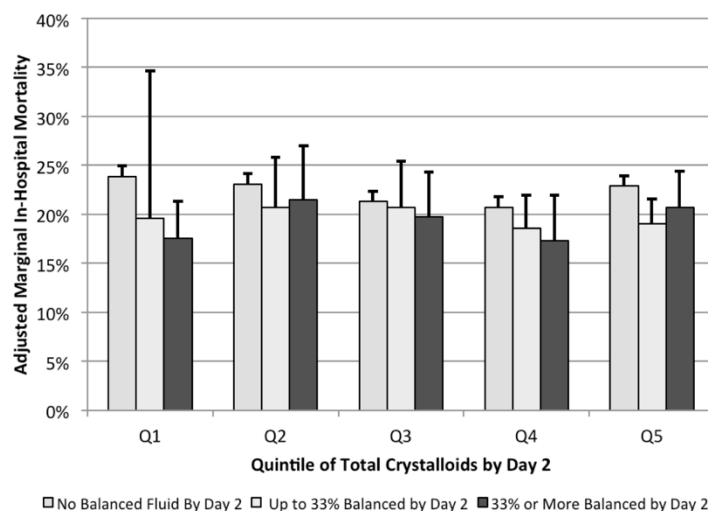
## Mortality Dose Response



VANDERBILT UNIVERSITY  
MEDICAL CENTER

Raghuathan et al (2014) Crit Care Med

## Total Volume Received Dose Response



VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Yunos et al 2012

PRELIMINARY  
COMMUNICATION

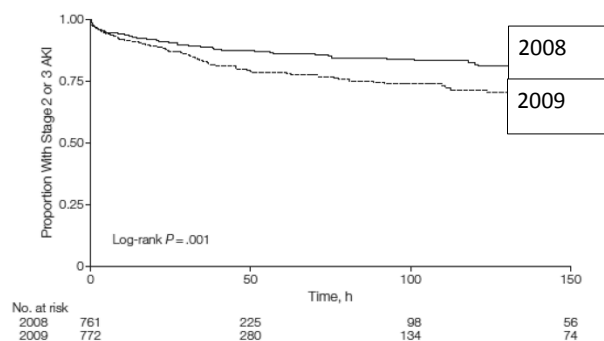
### Association Between a Chloride-Liberal vs Chloride-Restrictive Intravenous Fluid Administration Strategy and Kidney Injury in Critically Ill Adults

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Yunos et al (2012) JAMA

## KDIGO 2&3

**Figure 1.** Development of Stage 2 or 3 Acute Kidney Injury (AKI) While in the Intensive Care Unit (ICU)



Stage 2 or 3 defined according to the Kidney Disease: Improving Global Outcomes clinical practice guideline.

VANDERBILT UNIVERSITY  
MEDICAL CENTER

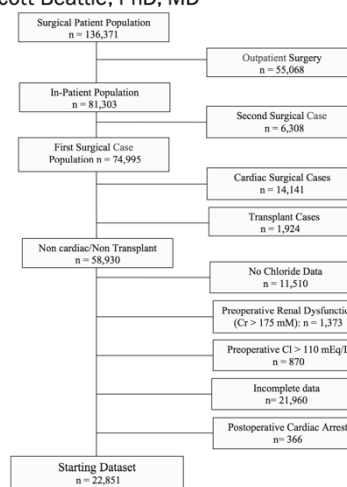
Yunos et al (2012) JAMA

## Hyperchloremia After Noncardiac Surgery Is Independently Associated with Increased Morbidity and Mortality: A Propensity-Matched Cohort Study

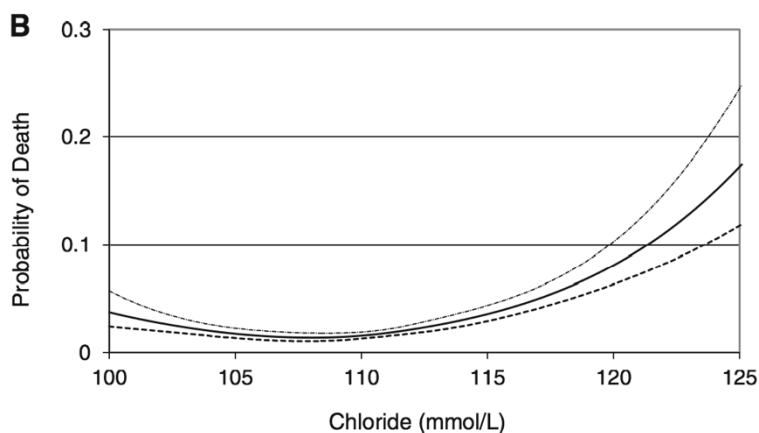
Stuart A. McCluskey, PhD, MD,\* Keyvan Karkouti, MSc, MD,\*† Duminda Wijeyesundara, PhD, MD,\* Leonid Minkovich, PhD, MD,\* Gordon Tait, PhD,\* and W. Scott Beattie, PhD, MD\*

- **Observational cohort study**
- **Major (non cardiac) surgery**
- **23000 patients**
- **4266 of 4955 who developed high serum chloride propensity matched to patients who did not**

VANDERBILT UNIVERSITY  
MEDICAL CENTER



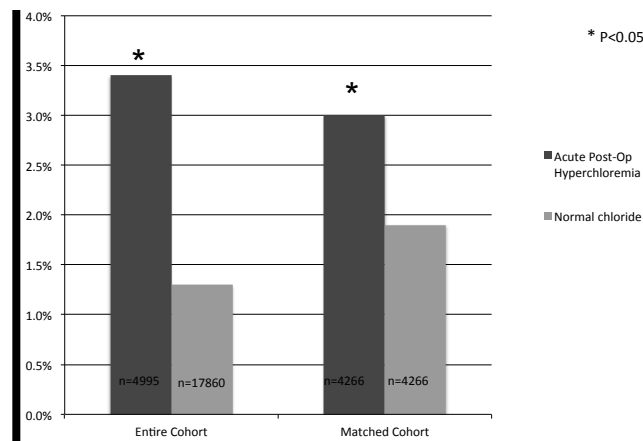
## Chloride and mortality



VANDERBILT UNIVERSITY  
MEDICAL CENTER

**CME Hyperchloremia After Noncardiac Surgery Is Independently Associated with Increased Morbidity and Mortality: A Propensity-Matched Cohort Study**

Stuart A. McCluskey, PhD, MD,\* Keyvan Karkouti, MSc, MD,\*† Duminda Wijeyesundara, PhD, MD,\* Leonid Minkovich, PhD, MD,\* Gordon Tait, PhD,\* and W. Scott Beattie, PhD, MD\*



VANDERBILT UNIVERSITY  
MEDICAL CENTER

Anesth Analg 2013;117:412-21

Intensive Care Med  
DOI 10.1007/s00134-014-3505-3

ORIGINAL

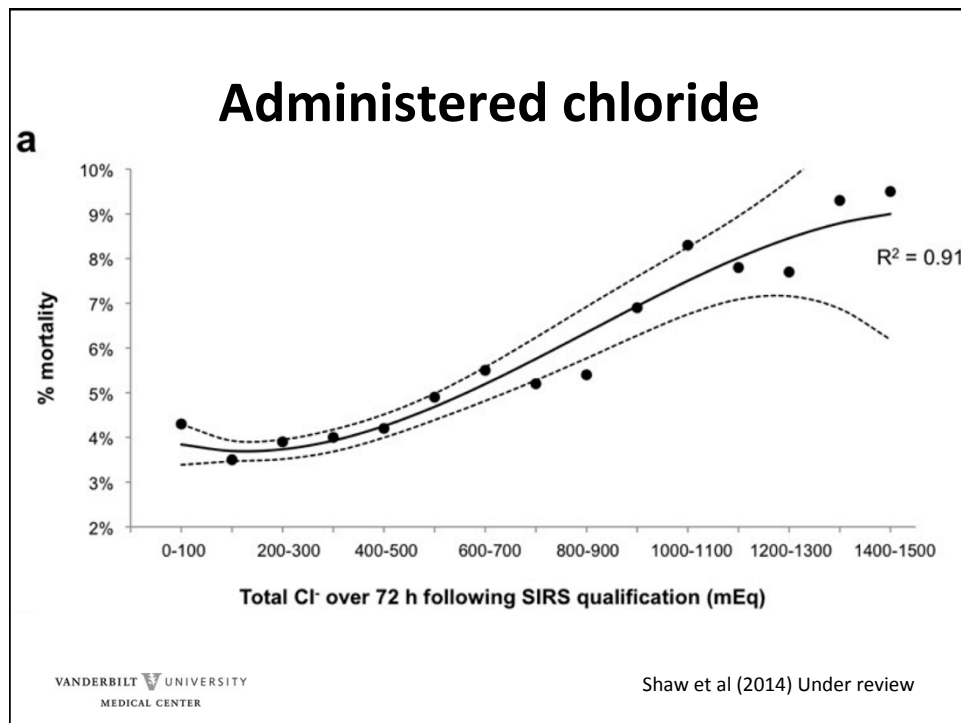
Andrew D. Shaw  
Karthik Raghunathan  
Fred W. Peyerl  
Sibyl H. Munson  
Scott M. Paluszkiwicz  
Carol R. Schermer

**Association between intravenous chloride load during resuscitation and in-hospital mortality among patients with SIRS**

- **109,836 adult patients with SIRS from Cerner health facts database**
- **Baseline risk adjustment as well as APS included in outcomes model**
- **Effect of volume adjusted chloride load on mortality**

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Shaw et al (2014) Int Care Med



Systematic review

### Meta-analysis of high- versus low-chloride content in perioperative and critical care fluid resuscitation

M. L. Krajewski<sup>1</sup>, K. Raghunathan<sup>1,2</sup>, S. M. Paluszkiwicz<sup>3</sup>, C. R. Schermer<sup>4</sup> and A. D. Shaw<sup>5</sup>

<sup>1</sup>Department of Anesthesiology, Duke University Medical Center, and <sup>2</sup>Anesthesiology Service, Durham VA Medical Center, Durham, North Carolina, <sup>3</sup>Boston Strategic Partners, Boston, Massachusetts, <sup>4</sup>Baxter Healthcare Corporation, Deerfield, Illinois, and <sup>5</sup>Department of Anesthesiology, Vanderbilt University Medical Center, Nashville, Tennessee, USA

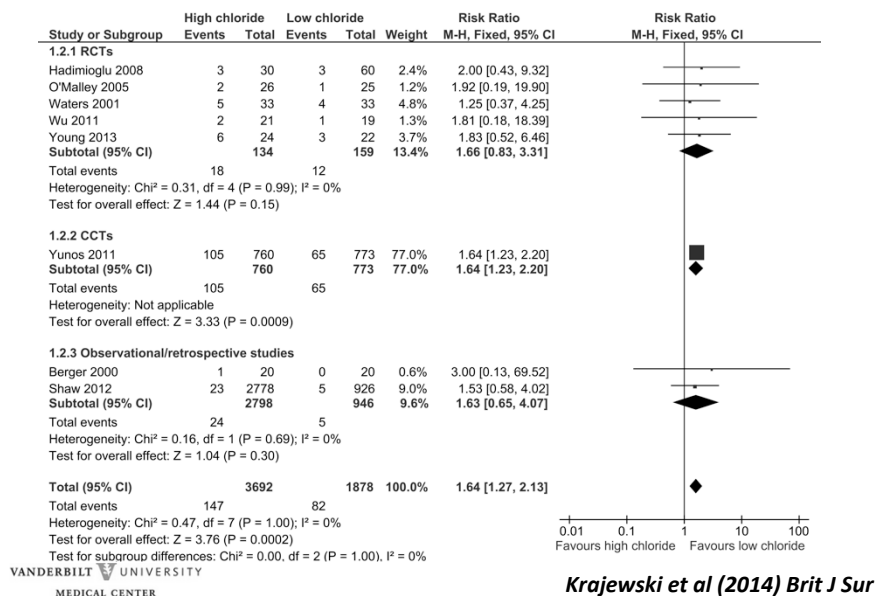
Correspondence to: Professor A. D. Shaw, Division of Cardiothoracic Anesthesiology, Vanderbilt University Medical Center, Nashville, Tennessee 37232-8274, USA (e-mail: andrew.shaw@vanderbilt.edu)



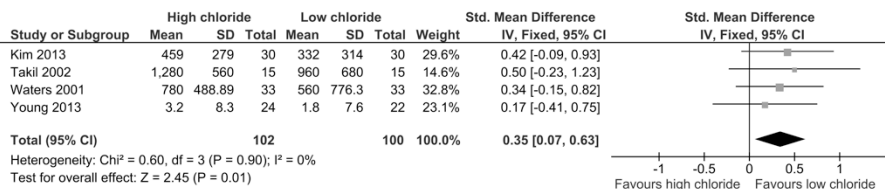
VANDERBILT UNIVERSITY  
MEDICAL CENTER

Krajewski et al (2014) *Brit J Sur*

## AKI



## Blood transfusion volume



## ORIGINAL ARTICLE

## Saline Versus Plasma-Lyte A in Initial Resuscitation of Trauma Patients

### A Randomized Trial

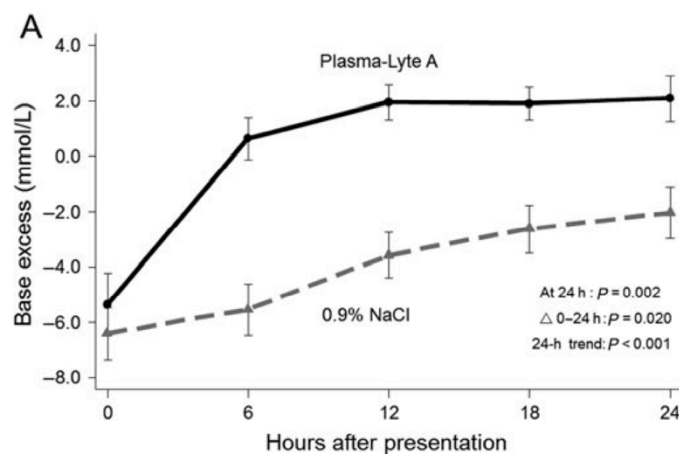
Jason B. Young, MD, PharmD, Garth H. Utter, MSc, MD, Carol R. Schermer, MD, MPH, Joseph M. Galante, MD, Ho H. Phan, MD, Yifan Yang, MD, Brock A. Anderson, MD, and Lynette A. Scherer, MD

- DBRCT of 65 trauma patients
- Plasma Lyte vs 0.9% saline
- Primary EP change in Base Excess first 24 hrs
- Deferred consent to allow immediate inclusion

VANDERBILT UNIVERSITY  
MEDICAL CENTER

(Ann Surg 2013;00:1–8)

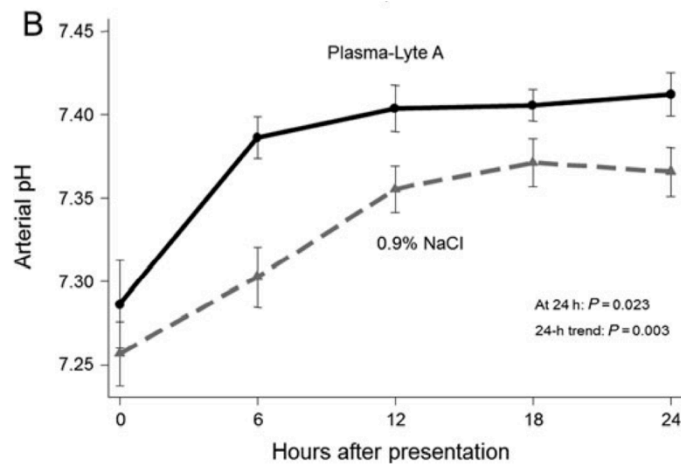
## Base Excess



VANDERBILT UNIVERSITY  
MEDICAL CENTER

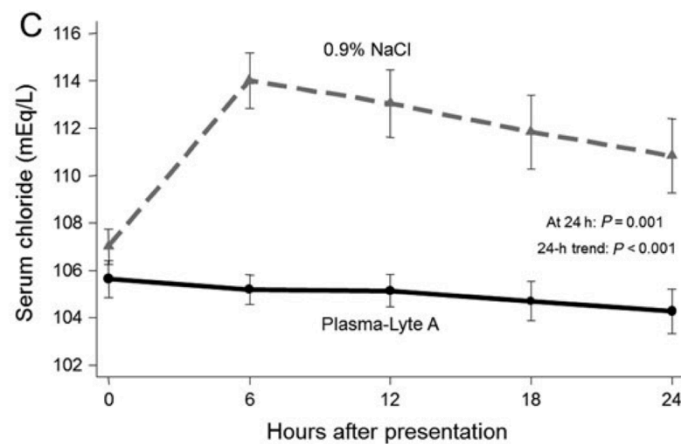


## pH

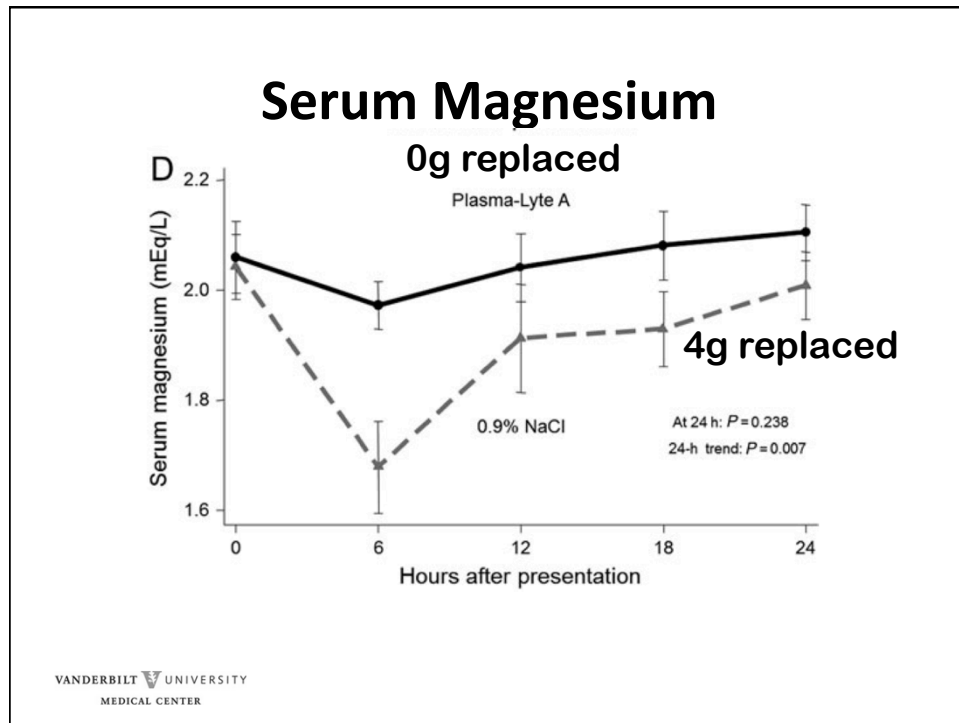


VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Serum chloride



VANDERBILT UNIVERSITY  
MEDICAL CENTER



## Mg supplementation

A thorough cost analysis is beyond the scope of this article, but based on information from our center, a 1-L bag of 0.9% NaCl costs \$0.86/L and Plasma-Lyte A costs \$1.62/L, a cost difference of 76 cents. The cost of standard IV magnesium replacement is \$5.19 per 2 g and does not include the cost for nursing care to administer the infusion.

# Cost-minimization analysis of two fluid products for resuscitation of critically injured trauma patients

CAITLIN A. SMITH, JEREMIAH J. DUBY, GARTH H. UTTER, JOSEPH M. GALANTE,  
LYNETTE A. SCHERER, AND CAROL R. SCHERMER

VANDERBILT UNIVERSITY  
MEDICAL CENTER

Am J Health-Syst Pharm—Vol 71 Mar 15, 2014

## Cost-minimization analysis of two fluid products for resuscitation of critically injured trauma patients

Table 2.  
Electrolyte Levels and Replacement Amounts, by Treatment Group<sup>a</sup>

Variable	0.9% Sodium Chloride Injection (n = 24)	Plasma-Lyte A (n = 22)	p <sup>b</sup>
Mean ± S.D. concentration			
Magnesium, mg/dL			
6 hr	1.7 ± 0.40	2.0 ± 0.20	0.004
24 hr	2.0 ± 0.30	2.1 ± 0.24	0.24
Potassium, meq/L			
6 hr	4.0 ± 0.62	3.8 ± 0.49	0.22
24 hr	4.1 ± 0.52	4.2 ± 0.63	0.34
Calcium, mg/dL			
6 hr	7.9 ± 0.95	7.9 ± 1.28	0.82
24 hr	8.1 ± 0.54	8.3 ± 0.60	0.28
Phosphate, mg/dL			
6 hr	3.7 ± 1.01	3.0 ± 0.88	0.03
24 hr	3.2 ± 0.92	3.4 ± 0.96	0.59
Amount replaced within 24 hr, median (IQR)			
Magnesium, g	4.0 (2.5–4.0)	0 (0–2.0)	<0.001
Potassium, meq	0 (0–20)	5 (0–20)	0.49
Calcium, g	0.5 (0–3.0)	1.50 (0–5.25)	0.46
Phosphate, mmol	0	0	0.52
Patients receiving electrolyte replacement within 24 hr, no. (%)			
Magnesium	21 (87.5)	6 (27.3)	<0.001
Potassium	9 (37.5)	12 (54.5)	0.25
Calcium	12 (50)	12 (54.5)	0.76
Phosphate	1 (4.2)	2 (9.1)	0.60

<sup>a</sup>IQR = interquartile range.

<sup>b</sup>Calculated via chi-square test, Student's t test, or Wilcoxon rank sum test.

VAI

## Cost-minimization analysis of two fluid products for resuscitation of critically injured trauma patients

Table 3.

Average Daily Cost of Magnesium Replacement at Study Site, by Treatment Group

Expense Item	0.9% Sodium Chloride Injection (n = 24)			
	Cost (\$) Including Labor		Cost (\$) Excluding Labor	
	Administration of 2 g Magnesium	Administration of 4 g Magnesium	Administration of 4 g Magnesium	Plasma-Lyte A (n = 22)
Mean $\pm$ S.D. resuscitation fluid cost (per 24 hr) <sup>a</sup>	7.65 $\pm$ 4.92	7.65 $\pm$ 4.92	7.65 $\pm$ 4.92	20.46 $\pm$ 12.94 <sup>b</sup>
Safety syringe with attached needle (1 unit)	0.72 <sup>b</sup>	0.72 <sup>b</sup>	0.72 <sup>b</sup>	0.00
0.9% sodium chloride i.v. flush, 10 mL	1.34 <sup>b</sup>	1.34 <sup>b</sup>	1.34 <sup>b</sup>	0.00
Surgical gloves (pair)	0.17 <sup>b</sup>	0.17 <sup>b</sup>	0.17 <sup>b</sup>	0.00
Tubing (single tubing)	1.82 <sup>b</sup>	1.82 <sup>b</sup>	1.82 <sup>b</sup>	0.00
Alcohol wipes (per swab)	0.01 <sup>b</sup>	0.01 <sup>b</sup>	0.01 <sup>b</sup>	0.00
Drug acquisition cost	6.77 <sup>b</sup>	13.54	13.54 <sup>b</sup>	0.00
Labor cost (for average) <sup>d</sup>	7.56 <sup>b,c</sup>	7.56 <sup>b,c</sup>	...	...
Total (per 24 hr)	26.04	32.81	25.25	20.46

<sup>a</sup>Based on obfuscated threshold cost of \$0.85/L for 0.9% sodium chloride injection and \$2/L for Plasma-Lyte A.<sup>b</sup>Cost reflects administration of two 2-g doses of magnesium sulfate, which is the common practice for magnesium replacement at the study site.<sup>c</sup>Calculated using U.S. Bureau of Labor Statistics data on mean nurse compensation in California; assumes mean nursing time of 9.2 minutes (4.6 minutes per infusion).<sup>d</sup>Not applicable.

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## When should we give abnormal saline?

- Rarely
- Traumatic brain injury
- HCl loss (severe vomiting)

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Conclusions

- **The circumstantial evidence that high chloride solutions are harmful continues to mount**
- **There are no data suggesting 0.9% saline is beneficial**
- **New multicenter cardiac surgical data suggest balanced crystalloids are the fluids of choice for both cardiac surgery and in SIRS patients.**

VANDERBILT UNIVERSITY  
MEDICAL CENTER

## Thank You

VANDERBILT UNIVERSITY  
MEDICAL CENTER