Harborview Medical Center

Glucose Monitoring and Outcomes

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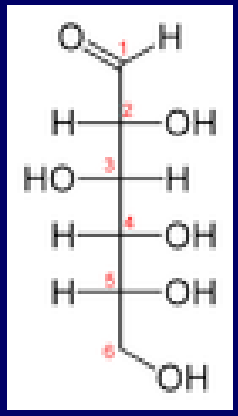
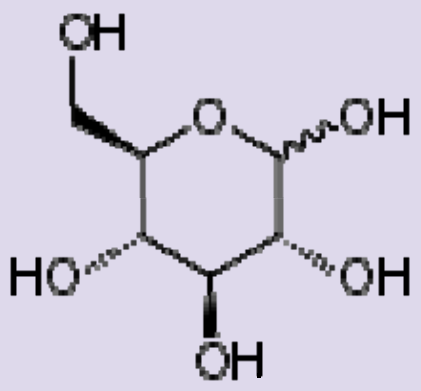
Society for Pediatric Anesthesia 2010



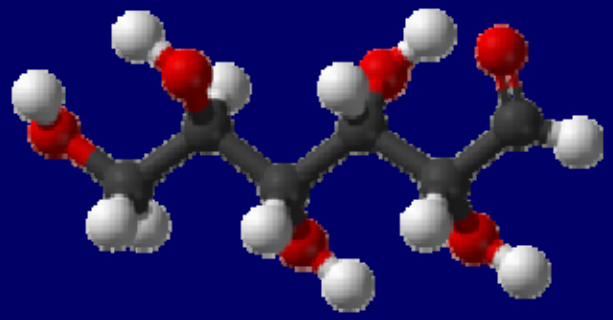
Greetings from Seattle, WA

Disclosure

- None



Goals

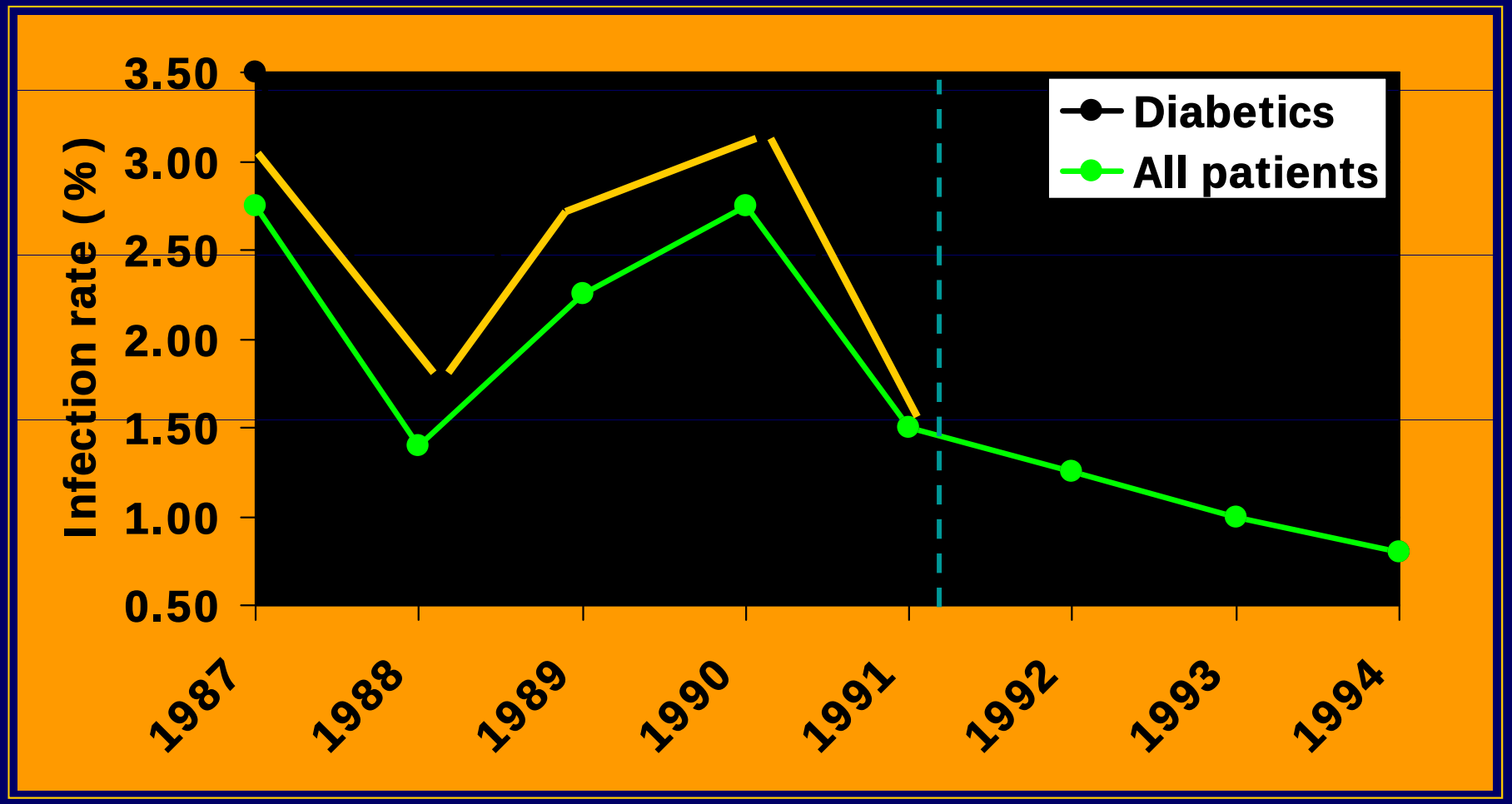


1. To highlight the importance of glucose
2. To summarize glucose homeostasis and madness, and targets
3. To present results of a recent glucose monitoring study
4. To evaluate glucose monitoring technologies

1. Why is Glucose Important ?

- Perioperative glucose control
  - *Patient safety practices and targets*, *AHRQ*
  - *Measures of quality*
  - *http://www.ahrq.gov/clinic/ptsafety/*
- 86% in critically ill children and linked to low survival
  - Srinivasan. Ped Crit Care Med. 2004
- Poor outcomes post cardiac, sepsis, burns
- Two ongoing pediatric trials
  - Control of Hypergylcemia in Pediatric ICU “CHIP “ UK
  - Trial of Euglycemia in Cardiac Surgery (TECS); Boston

Strict Diabetic Protocol Decreases Surgical Site Infection rate



RCT in Pediatric Cardiac Surgery

- N = 700
- Case: 70-100 vs. 101-216
- Endpoints
  - CCU Stay, Inflammation, hypoglycemia, death
- Intensive group
  - Less CCU stay, less inflammation, less death
  - 25% hypoglycemia

Vlasselaers et al. Lancet 2009

Harm From Hyperglycemia

- Perioperative Cardiac
  - Gandhi GY, *Mayo Clinic Proceedings*, 2005.
    - 30% risk death for every 20 mg/dL increase in glucose
  - Neidecker et al, J Cardiothorac Anes. 2005.
    - Glucose-free Solutions cause hypoglycemia during repair of Congenital Heart Diseases
- Perioperative Non-Cardiac
  - McGirt MJ, *Neurosurgery*, 2006.
    - Operative day glucose associated with perioperative stroke, TIA, MI, and death in CEA
- Preop Tight ICU control does not improve outcomes in open heart surgery
  - Chan RP et al. Clinics. 2009.

Impaired Glycemic Control during General Anesthesia in Adults

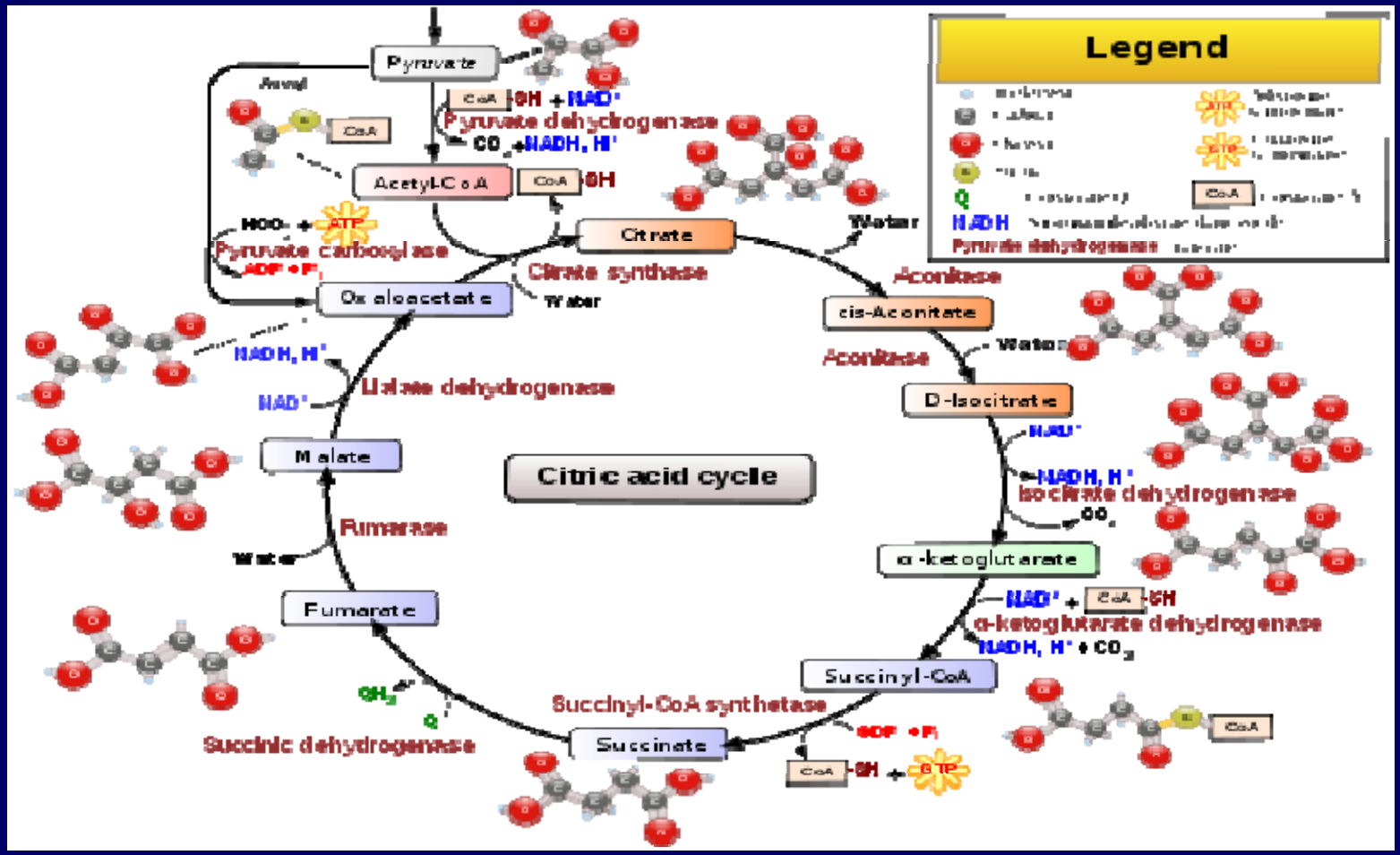
- Hormones were measured before inhalation of anesthesia, after 5 and 10 hours, and at 1, 6, and 12 hours after the end of inhalation.
- Epinephrine and norepinephrine concentrations higher in ISF group
- Glucose increased both during and after surgery, insulin increased only after surgery, and glucagon decreased during surgery in both groups.
- No significant glucose differences between groups
- Impaired insulin secretion

Nishiyama, J Clin Anesth 2005

2. Glucose Homeostasis

- Name *glukus* (γλυκύς), meaning "sweet"
- Energy source and metabolic intermediate
- Product of photosynthesis
- Starts cellular respiration
- D form biologically active “Dextrose”
- Gluconeogenesis from pyruvate
- Glycogenolysis from glycogen
- Less deactivation of enzymes

Digested and taken up by the body in the intestines, stored in liver and muscles as glycogen, distributed and utilized in tissues as free glucose



Glucose Madness:
Does Not Mean You Eat Bad Food Groups…

- Hypoglycemia and Hyperglycemia
- Abnormalities common during surgery
- Many condition types
  - surgery, sepsis, burns, stroke, trauma
- Condition severity
  - Critical illness
- Young age
- Anesthesia

What causes the High ?

- Increased glucose production
  - epinephrine, norepinephrine, glucagon
- Insulin resistance
  - cortisol, growth hormone, TNF-a, IL-1
- Protein catabolism
- Increase O_2 consumption

•"If one accepts the concept of hyperglycemia of injury or infection as beneficial by promoting cellular glucose uptake, then modest degrees of hyperglycemia should be tolerated… the level of glycemia should be high enough to maximize cellular glucose uptake… 160 – 200 mg/dL."

Mizock BA, The American Journal of Medicine, 1995.

Why is Hyperglycemia Harmful ?

- Pro-Inflammatory
  - Increase TNF-α, IL-1β, IL-6
- Impaired complement function
  - Despite increase complement products
- Impaired neutrophil function
  - Poor chemotactic migration
  - Poor phagocytic activity
- Pro-coagulant
- Nitric oxide dysregulation
- Disturbance of lipid profile

Turina M, *Crit Care Med*, 2005.
Vanhorebeek I, *Curr Opin Crit Care*, 2005.

What about the Low ?

- 1967: 6 cases of neonatal hypoglycemia and pathological sequelae
- MRI of 35 term neonates with symptomatic hypoglycemia (glucose <45 mg/dL or 2.6 mmol/L); white matter abnormalities in 94%, with severe abnormalities noted in 43%. At 18-mo follow-up, 26/35 exhibited some level of impairment. *Burns CM, et al. Pattern of cerebral injury and neurodevelopmental outcomes after symptomatic neonatal hypoglycemia. Pediatrics 2008;122:65–74*
- Hypoglycemia is associated with an increase in morbidity and mortality in PICU patients. *Wintergerst KA, et al. Association of hypoglycemia, hyperglycemia, and glucose variability with morbidity and death in the pediatric intensive care unit. Pediatrics 2006;118:173–9*

Metaanalysis including NICE SUGAR Trial Griesdale CMAJ 2009

- 26 trials involving of 13,567 patients
- No benefit with intensive insulin compared with conventional therapy
- Of the 14 trials that reported hypoglycemia, the pooled RR with intensive insulin was 6.0 (95% CI 4.5-8.0).
- Overall, insulin therapy increased the risk of hypoglycemia and conferred no overall mortality benefit among critically ill adults.
- **Yet, surgical patients appearing to benefit from intensive insulin therapy (RR death 0.63, 95% CI 0.44-0.91);**

Currently Intraoperative Glucose Targets Vary

- Best data from adults and in children for for ICU LOS > 3 days and post cardiac surgery ICU patients
- Avoid glucosuria
- Judgement
- Need measurement guidelines
- Need identification of populations

3. Intraoperative Hypergylcemia
Results of TBI Study

Sharma D, et al. Anesth & Analg. 2009

Background

- **Hyperglycemia may increase brain lactate and worsen brain acidosis after TBI**

❖ **Hyperglycemia after adult and pediatric TBI is associated with poor outcome**

- ❖ *Michaud CJ, et. al., J Trauma 1991;31:1356-62.*
- ❖ *Chiaretti A, et al., Childs Nerv Syst. 1998;14:455-59.*
- ❖ *Cochran A, et al., J Trauma 2003 Dec; 55(6) 1035-38.*

❖ **HG treatment threshold is controversial because it may be transient and tight control is associated with markers of neuronal distress**

- ❖ *Parish RA, Webb KS., J Trauma 1988;28:517-19.*
- ❖ *Van den Berghe G, et al., Neurology 2005; 64(8): 1348-53.*
- ❖ *Vespa P, et al., Crit Care Med 2006; 34: 850-56.*

Aims

- Primary
  - To examine the incidence and risk factors for perioperative hyperglycemia in children with TBI
- Secondary
  - Estimate the incidence of hypoglycemia
  - Determine whether hyperglycemia is transient or persistent
  - Describe treatment of hyperglycemia

Methods

- IRB approval
- Retrospective cohort study
- Harborview Medical Center
- Glucose data from following periods from LIS:
  - Preoperative (from ED admission to OR arrival)
  - Intraoperative (during general anesthesia)
  - Immediate postoperative (1st 24 hours after surgery)

Patients

Inclusion Criteria:

- Children ≤ 13 years
- Urgent / emergent craniotomy for TBI (1994 to 2004)

Exclusion Criteria:

- History of diabetes mellitus
- Repeat intracranial surgery after surgery for TBI

Definitions

- ***3 Study periods:*** **preop, intraop, immediate post op**
- ***Hyperglycemia (HG):*** **serum glucose ≥ 200 mg/dL**
- ***Transient HG:*** **any episode of HG during any one period**
- ***Persistent HG:*** **HG during 2/3 periods**
- ***Hypoglycemia:*** **serum glucose < 60mg/dL**

Table 1. Perioperative Clinical Characteristics of 105 Children with Traumatic Brain Injury (TBI)

Age in yr	5.3 ± 3.7 (range 0–12)
Male gender	65 (62%)
Type of injury	
Isolated TBI	94 (89.5%)
TBI with extracranial injury	11 (10.5%)
Type of TBI	
Subdural hematoma (SDH)	53 (51%)
Extradural hematoma (EDH)	23 (22%)
Intracerebral hematoma (ICH)	11 (11%)
Multiple lesions	10 (10%)
GCS	8.8 ± 5.6 (range 3–15)
Duration of preoperative period (min)	85.5 (range 12–405)
Duration of anesthesia (min)	180 (range 60–420)
Patients receiving mannitol	55 (52%)
Patients with hypotension	56 (53%)
Patients with fever	16 (15%)
Patients with intracranial pressure monitoring	11 (11%)
In-hospital mortality	15 (14.3%)

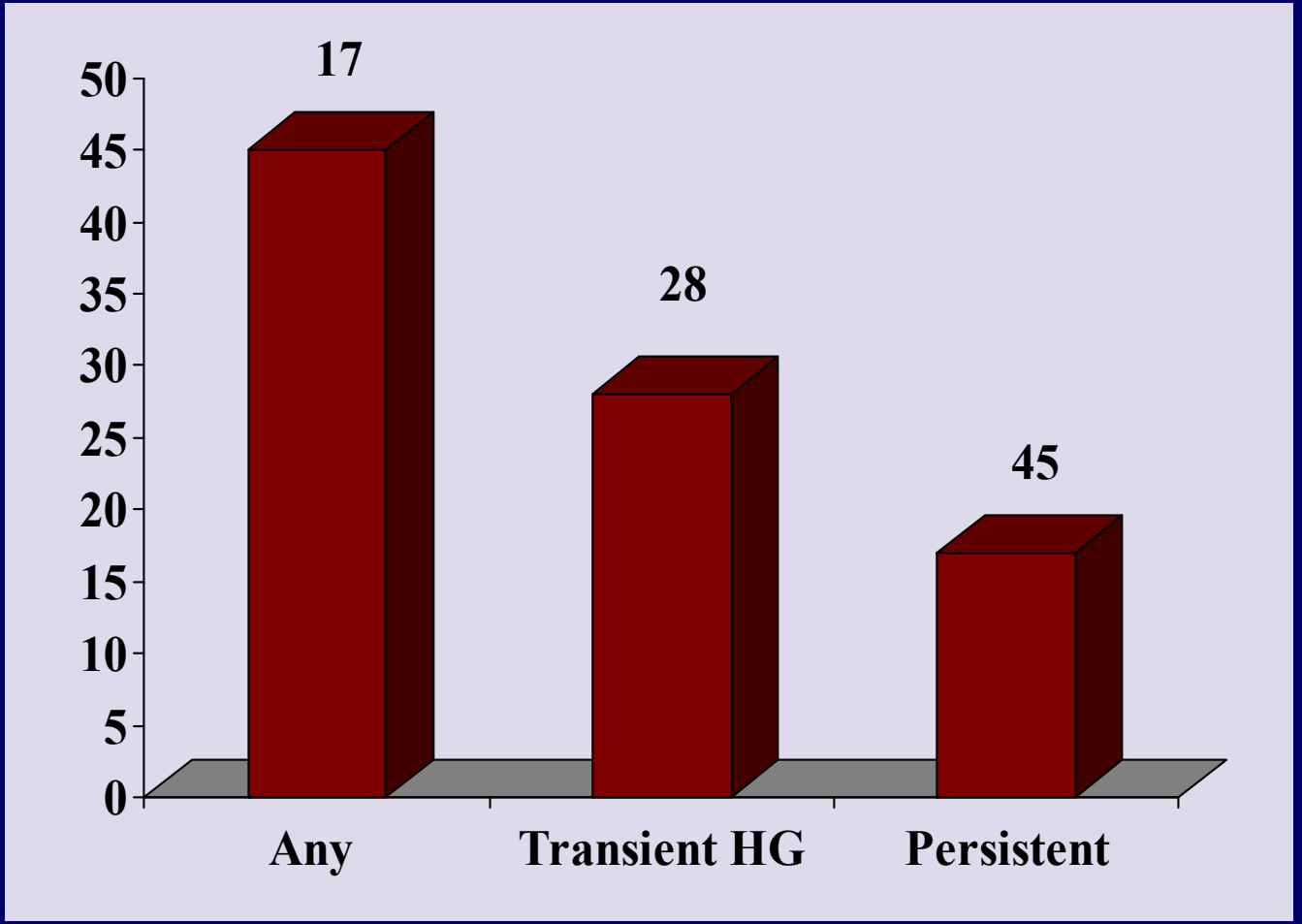
Data expressed as mean ± SD (range), median (range) or number (%).

GCS = Glasgow Coma Scale score; Hypotension = systolic BP <5th percentile; Fever = temperature >38.5°.

Arterial Glucose Sampling Frequency

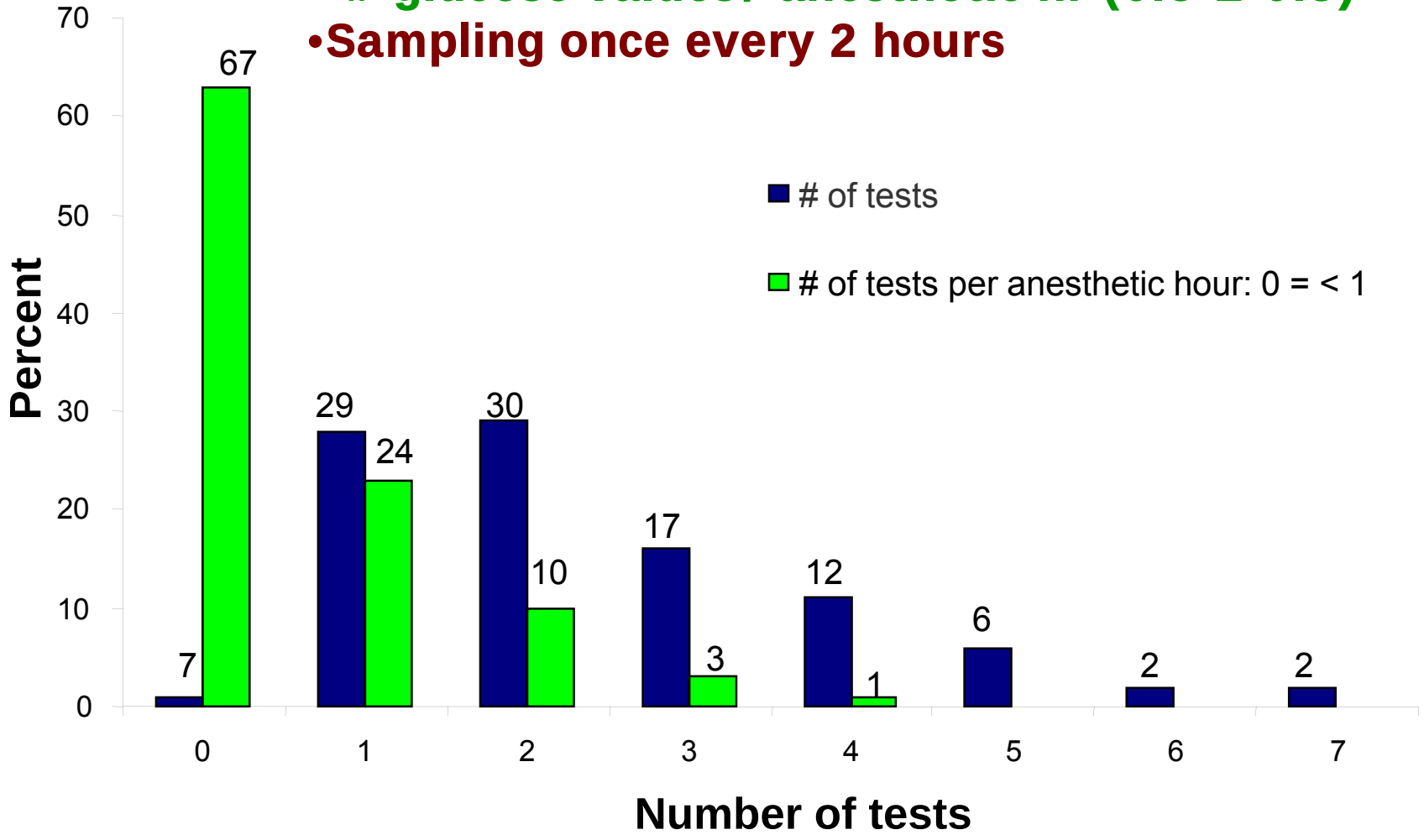
- **During Each Study Period:**
  - **Preoperative → 86 (82%)**
  - **Intraoperative → 94 (89%)**
  - **Immediate postoperative → 101 (97%)**
- **Intraoperative**
  - **The average anesthetic time was 3.3 hours (range 1-7 hrs)**
  - **Average glucose sampling frequency was once every 2 hours**
  - ***64% children had glucose sampled less frequently than once per hour during general anesthesia***

Transient vs. Persistent Hyperglycemia

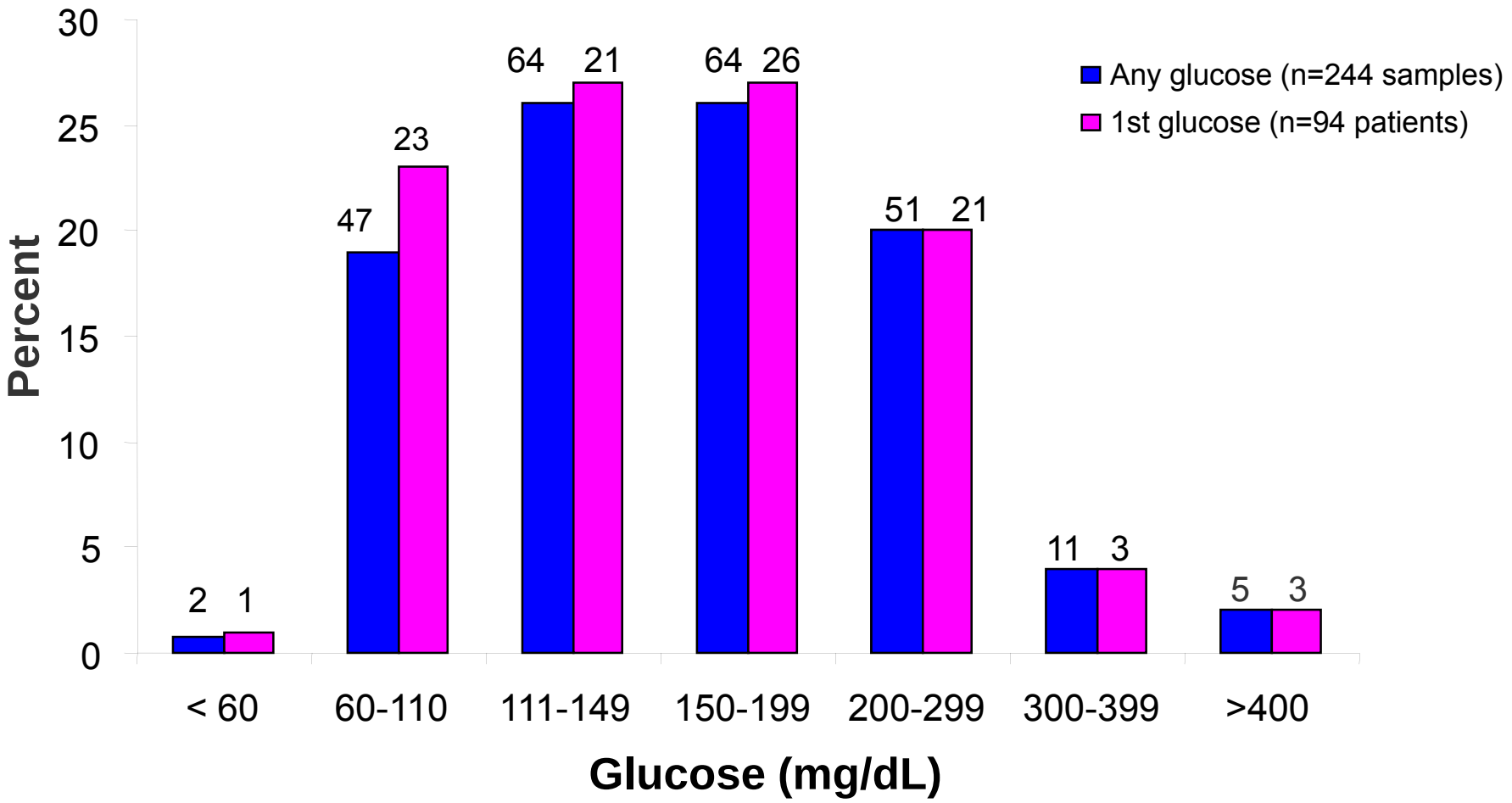


Distribution of Intraoperative Testing (n=105)

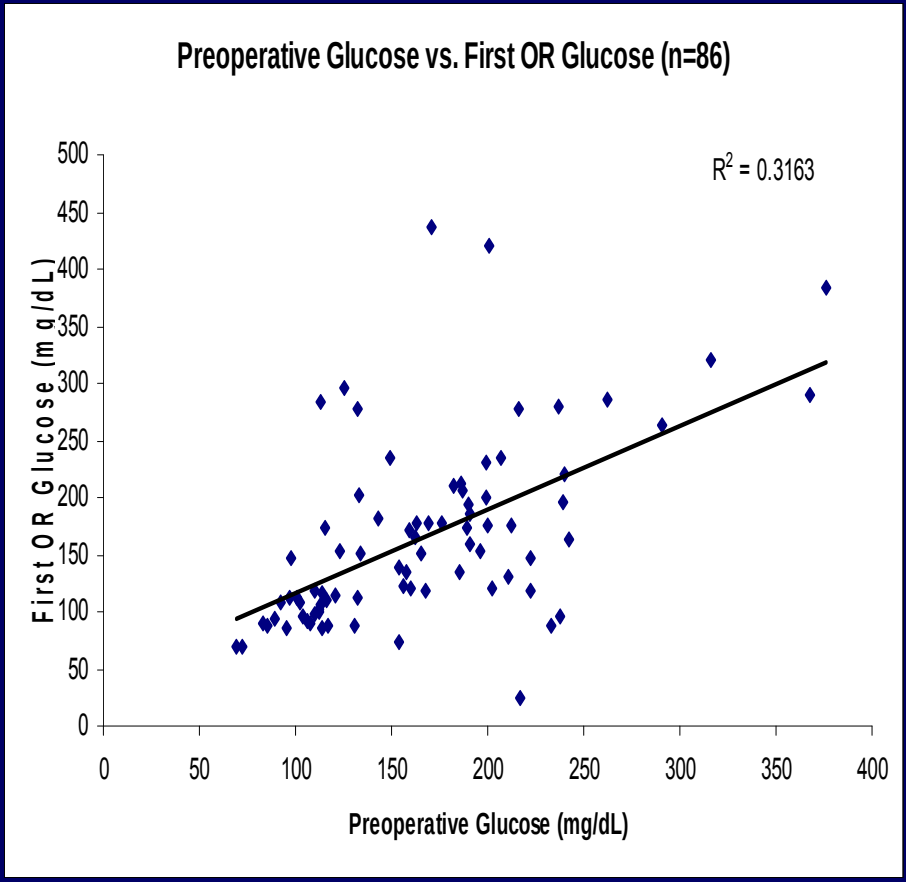
- Total of 244 tests obtained
- 94 patients had ≥ 1 check; 7 missing values
- **# glucose values/ anesthetic hr (0.5 ± 0.8)**
- **Sampling once every 2 hours**

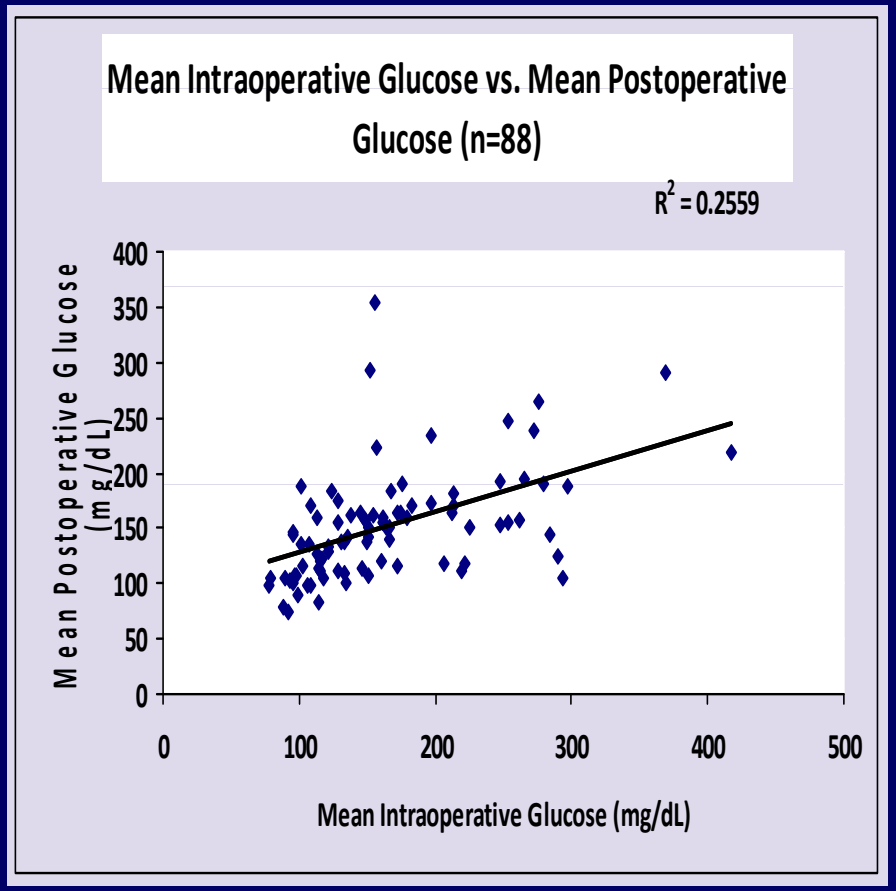


Distribution of Intraoperative Glucose Data (n=94)

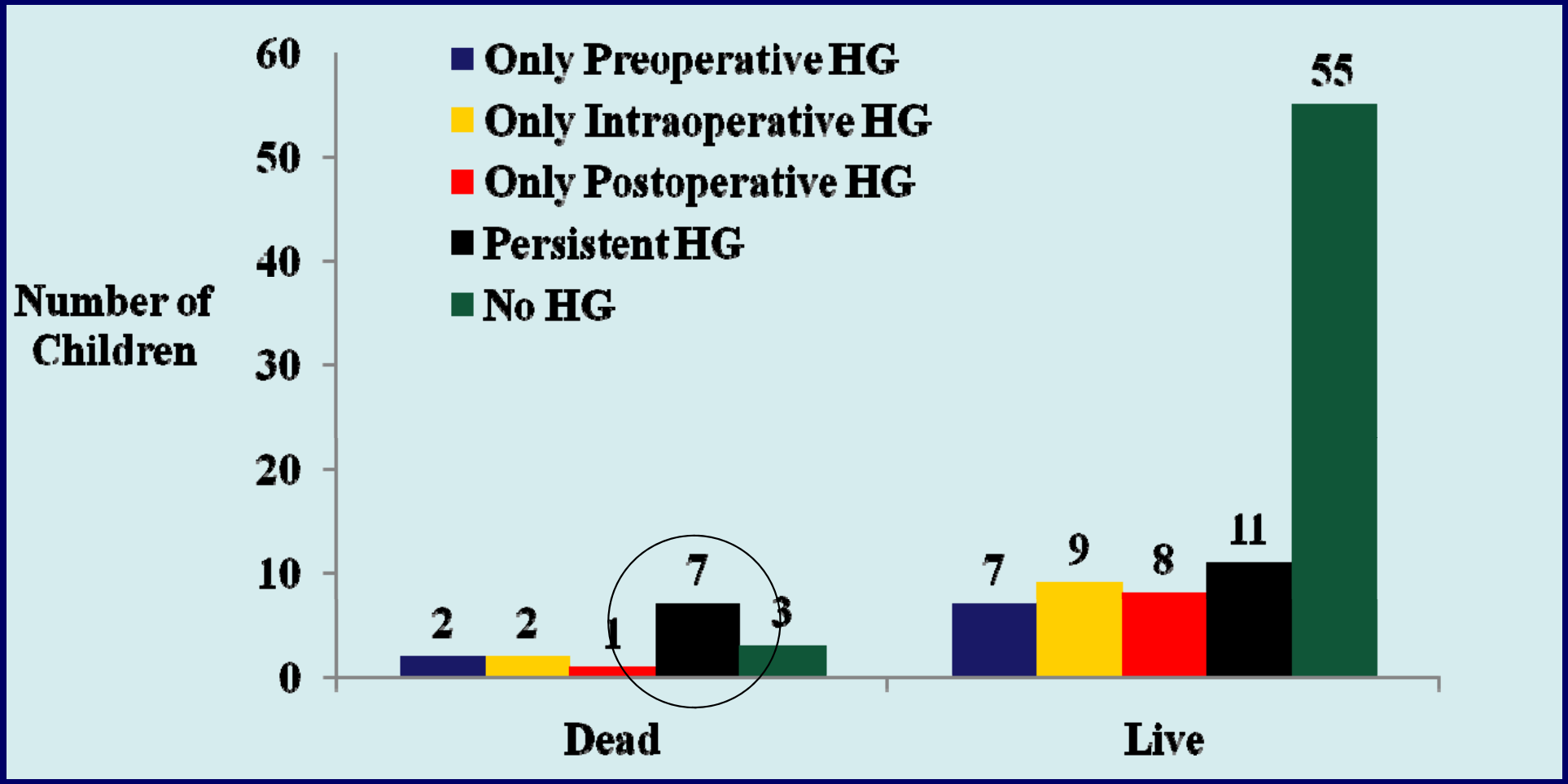


No Correlation between Glucose between Study Periods





Persistent Hyperglycemia and Death



Most common pattern among dead was persistent HG

Independent Predictors of Perioperative Hyperglycemia (n=47/105)

Risk Factors	*AOR (95% CI)*
Age < 4 years (n=43)	**3.7 (1.3-10.5)**
ED GCS ≤ 8 (n=53)	**7.5 (2.6-21.5)**
Multiple lesions with SDH (n=11)	**23.9 (2.1-268.8)**
Isolated SDH (n=23)	**3.2 (0.9-11.6)**

Additional variables entered into model were sex, death. All multiple lesions had SDH. ED = Emergency Department, GCS = Glasgow Coma Scale Score, SDH = Subdural Hematoma

Glucose By Study Period

Table 2. Perioperative Glucose Data in 105 Children with Traumatic Brain Injury

	Preoperative (86 patients with 95 values)	Intraoperative (94 patients with 244 values)	Immediate postoperative (101 patients with 292 values)
Average first glucose (mg/dL)	156 (69–379)	165 (24–492)	150 (72–418)
Median glucose (mg/dL)	158.5 (69–379)	149.5 (78–418)	146.0 (75–355)
Patients with hyperglycemia	22 (26%)	30 (32%)	24 (24%)
Patients with hypoglycemia	0	2 (2%)	1 (1%)
Hypoglycemic episodes	0	2 (1%)	1 (0.3%)
Patients treated with insulin	0	6 (9%)	0

Data expressed as median (range) or number (percent).

Hyperglycemia = glucose ≥200 mg/dL; hypoglycemia = <60 mg/dL; Preoperative period = period from emergency department admission to arrival in operating room and immediate postoperative period = the first 24 h after surgery.

**Did not receive insulin*

Who Developed Hypoglycemia ?

Table 4. Clinical Characteristics of Children with Traumatic Brain Injury with Intraoperative Hypoglycemia

Age	Gender	Intracranial lesion	Preoperative glucose (mg/dL)	No. glucose tests (number per anesthetic hour)	Glucose range (mg/dL)	First glucose (mg/dL)	Last glucose (mg/dL)	Lowest glucose (mg/dL)	Dextrose dose[a]	Postdextrose glucose (mg/dL)
5 mo	M	EDH	217	5(1)	24–145	24	116	24	14 mL	145
6 yr	F	EDH	69	3(1)	52–143	69	89	52	—	—

EDH = extradural hematoma.

[a] Dextrose was administered as D_{25} injection.

Limitations

- Retrospective
- Glucose sampling bias
- No long term outcome data
- Single institution
- Somewhat arbitrary definitions
- Estimates may not be accurate

Main Study Findings

1. 25-33% children with TBI requiring craniotomy had perioperative hyperglycemia
2. Young age, severe TBI and multiple lesions with SDH predicted perioperative HG
3. Persistent HG was common and most common outcome was death
4. Insulin treatment threshold was high but hypoglycemia was not rare
5. Preoperative glucose did not correlate with intraoperative glucose

Implications

- ***More frequent or continuous glucose sampling during anesthesia will yield more accurate estimates of the burden of hypo- and hyperglycemia in pediatric TBI***

4. Glucose Monitoring Technologies: *Trial by Fire ?*

- Intermittent
  - Central Lab Devices (CLD)
  - Point of Care (POC)
    - Small, cheap, and quick turn around point of care
    - Devices are available and used
    - Self monitoring blood glucose (SMBG) devices
      - Lack of accuracy of home glucose meters esp in the hypoglycemic range
      - Home devices remarketed to hospitals without testing for efficacy in perioperative setting !!!
- Continuous

POC Characteristics

- Pro
  - Cheaper
  - Quick turn around time
  - Smaller volumes (< 10µL)
- Con
  - Lack of accuracy
  - Brands
    - Abbott (iStat, Precision)
    - Hemocue (Hemocue)
    - Lifescan (One touch)
    - Roche (Accucheck)
    - Bayer (Elite)

POC Measurement Techniques

- Glucose molecule too small to measure
- Indirect enzymatic technique
- Three enzymes are used
  - Hexokinase which phosphorylates glucose to glucose 6 phosphate to glucose 6 phosphate dehydrogenase via NADH, which is measured (CLD)
  - Glucose oxidase which oxidizes glucose to gluconic acid and H2O2, which is proportional to glucose; number given
  - Glucose 1-dehydrogenase converts glucose to gluconolactone and NADH, which is measured

What is the Process ?

1. Blood is applied to the testing strip.
2. Using an enzyme, glucose is reacted with another compound to generate a colored product (proportional to glucose amount)
3. Reflectance photometry quantifies the intensity of the colored product generated by the enzymatic reaction.
4. A light source emits light of a specific wavelength onto the test strip; more color absorbs more light.
5. A detector captures the reflected light, converts it to an electronic signal, and translates that signal to its corresponding glucose concentration. (The more glucose, the more electrons)
6. Electrochemistry quantifies the number of electrons generated by the oxidation of glucose. A mediator captures the electrons; when the voltage is applied, the electrons are transferred to and counted at the electrodes.
7. A detector converts the resulting current to an electronic signal and translates that signal to its corresponding glucose concentration.

POC Accuracy

- Devices FDA regulated and should be within 10% error
- Numerous studies
- Glucose results accurate 26-56% and are most of time falsely elevated leading to inappropriate insulin Rx
- OR accuracy unknown.
- POCs should not be used in perioperative setting and in trials

- Aug 2009, FDA warning against POC use of GDH systems in patients on PDialysis and receiving immunglobulins.

Slater Maclean, Diabetes Technol Ther, 2008

Table 1. Confounding Variables in Glucose Measurement

Variable	Methodology affected[a]	
	GO	GD
Whole blood	↓	↓
Arterial	↑	↑
Capillary	↑	↑
Postprandial state	↑	↑
Hematocrit		
Anemia	↑	↑
Polycythemia	↓	↓
Oxygen concentration		
Hypoxia	↑	—
Oxygen therapy	↓	—
pH (6.8–7.55)	—	—
Low pH	—/↓	—
High pH	—/↑	—
Hypothermia	↑	↓/↑
Hypotension	↑	↓/↑
Drugs		
Ascorbic acid	↓	↓/—
Acetaminophen	↓	↑
Dopamine	—	↓
Icodextrin	—	↑
Mannitol	↑	—

Reprinted from Duncan et al.,[34] with permission.
GO = glucose oxidase; GD = glucose dehydrogenase.
[a] Changes relative to venous plasma measured as central laboratory.

- GDH technique is better because
  - Insensitive to ambient oxygen
  - Less electrochemical interference
- All POCs measure whole blood glucose but report plasma glucose
- Hemocue more reliable over range of Hcts but beware false high glucose readings in anemia
- Overall variability 20%

Where to Measure ?

- ADA recommends venous sample for closest accuracy
- Arterial glucose > capillary > Venous
- Hypotension, capillary glucose lowest and may underestimate systemic vascular glucose levels
- NICE-SUGAR study mixed sources
- VanDeBerghe arterial samples

Q: Has variability in glucose measurement technique contributed to the high incidence of hypoglycemia or to the failure to show benefit of insulin treatment ?

Pros and Cons of Continuous Monitors

- *Pros*
  - Prospective, retrospective
  - Single point and trends
  - Alarms
  - Reduction in AIC
  - Less hypoglycemia
  - Less anemia
- *Cons*
  - Calibration and drift
  - Filtering of noisy signals
  - Capillary blood glucose to sensor time lags
  - Fault detection for sensor degradation and dropouts
  - Clot formation
  - No IVF if intravenous technique
  - hypotension
  - Alarm fatigue
  - lipodystrophy

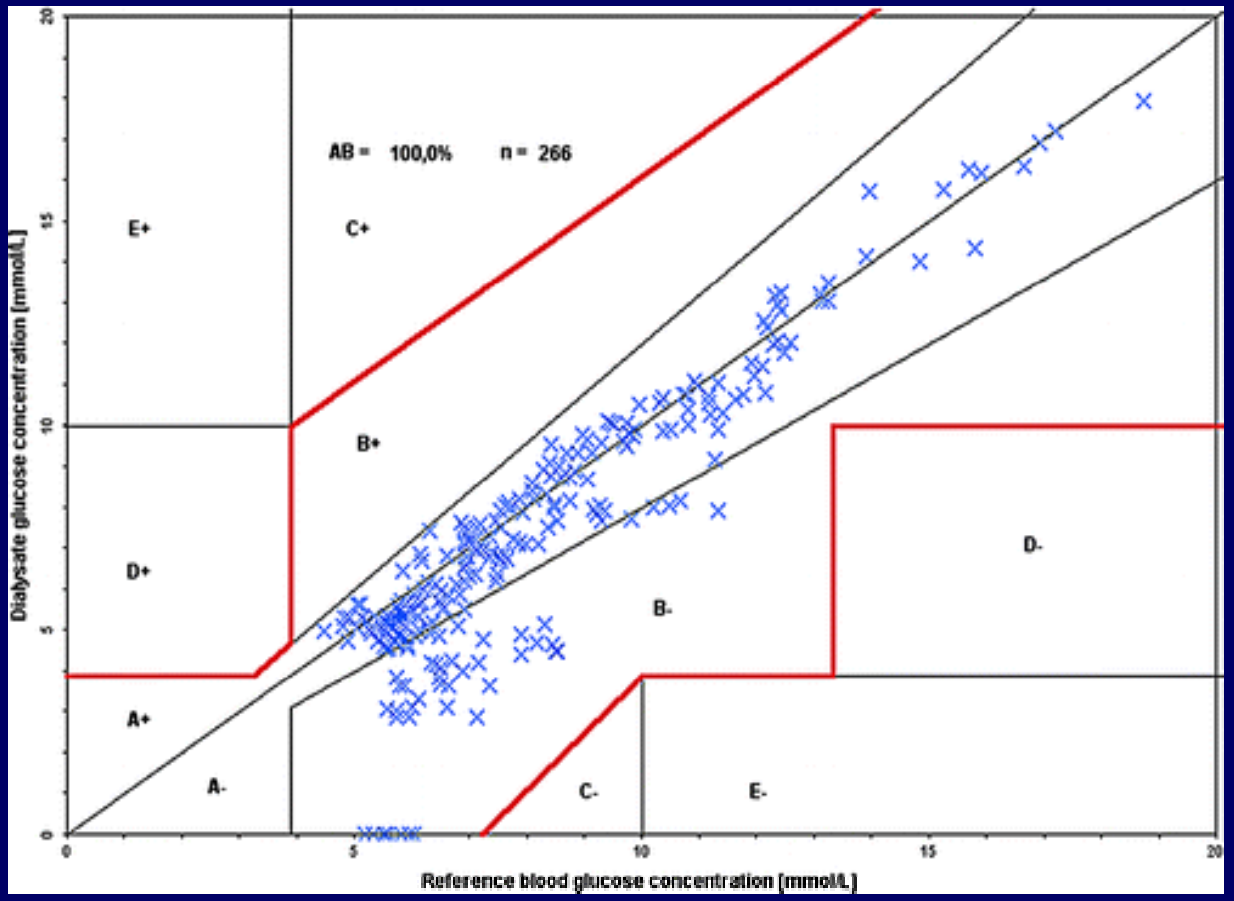
Beqwuette. J Diabetes Sci Technol, 2010

SQ Continuous Glucose Monitors

- Type I Diabetic Patients
- Enzymatic sensors-inserted subcutaneously in the abdomen
- Microdialysis fluid extraction
- Estimates blood glucose by interstitial fluid glucose concentration.
- ISF data calibrated with capillary blood glucose samples
- The sensor measures the level of glucose in the tissue every 10 seconds and sends the information via a wire to a pager-sized device called a "monitor" that you attach to a belt or the waistline of your pants.
- The system automatically records an average glucose value every 5 minutes for up to 72 hours

Clarke Error Grid of Comparison

All values zones A & B
•clinically accurate or benign
Zone C = overcorrection
Zone D = failure to detect
Zone E = erroneous



Data Errors

- 56 SQ samples every 15 minutes for 2 hours
- The relationship between the current measured by the CGMS Gold and BG was learned by an AR model, allowing its RT estimation
- 98.5% of paired points fell in zones A+B of the Clarke error grid analysis
- **Measurements for hypoglycemia meeting International Organization for Standardization (ISO) criteria were less (88.7%).**

Leal Y et al. J Diabetes Sci Technol, 2010

Experience

- Only two devices FDA approved for > 7 years (2006)
- Medtronic MiniMed Paradigm REAL-time system
- DexCom Seven RT-CGM

The Juvenile Diabetes Research Foundation Continuous Glucose Monitoring Study Group. Continuous glucose monitoring and intensive treatment of type 1 diabetes. *NEJM. 2008;359:1-13*

- RCT of 322 adults and children with AIC 7-10 receiving intensive therapy for type 1 diabetes to a group with CGM vs. control group with a blood glucose meter.
- Outcome was the change in AIC level at 26 weeks
- Change in AIC levels in the two study groups varied markedly according to age group (P=0.003), with a significant difference among patients 25 years of age or older that favored the continuous-monitoring group
- No difference in groups for children

Feasibility of SQ CMG

- SQ microdialysis for long-term glucose monitoring in neonatal intensive care
- Thirteen infants (10 neonates) with gestational ages of 30.2 to 45.6 weeks were investigated by microdialysis of subcutaneous adipose tissue and blood sampling. Subcutaneous microdialysis was performed for a median (range) duration of 9 (4-16) days
- Recovery rate glucose 96%
- 93% sensitivity and 92% specificity with blood glucose
- Subcutaneous microdialysis allowed the detection of asymptomatic hypoglycemias

Baumeister, MD et al, Pediatrics 2001
Diabetes Research Network, 2009

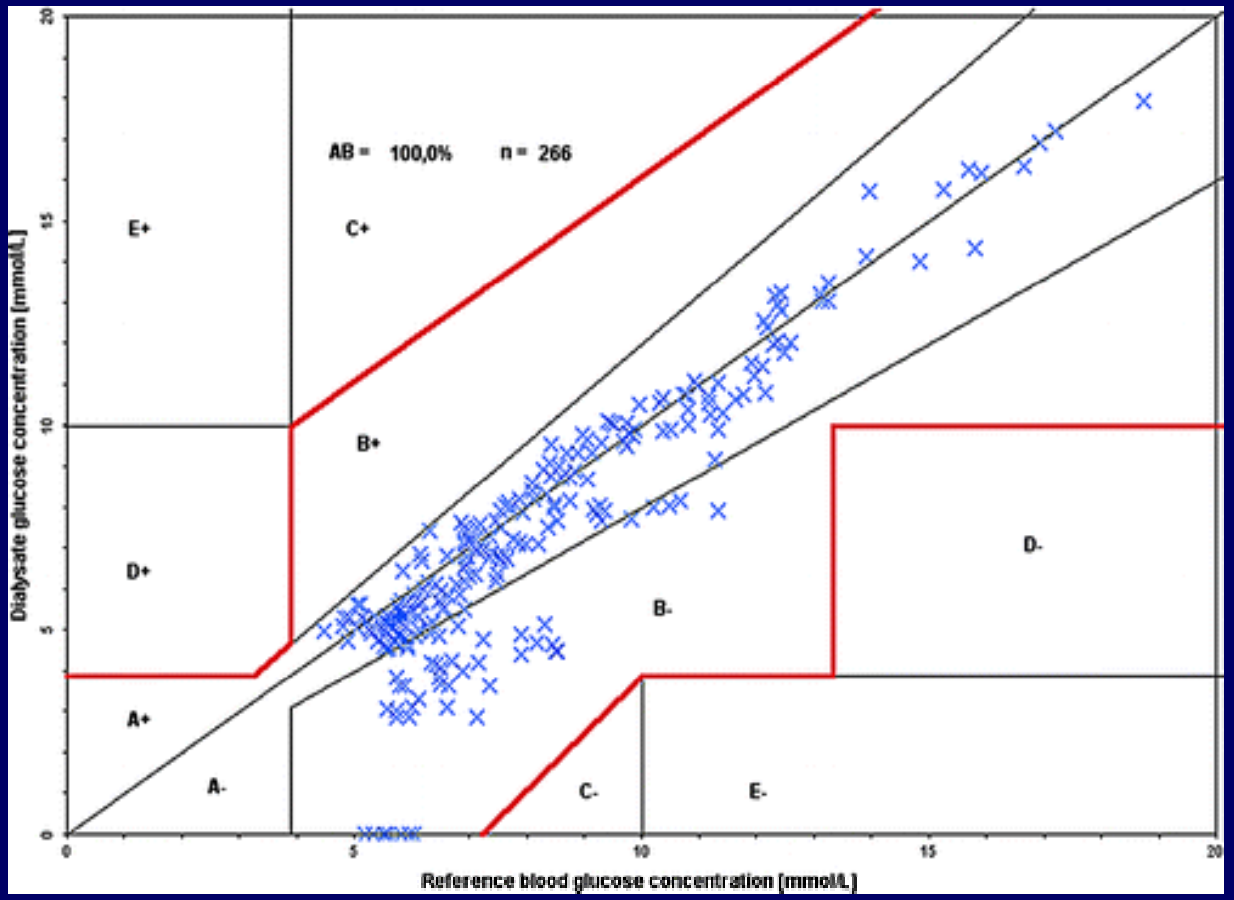
Feasibility of Using Intravenous Microdialysis Catheter Technique

- CMA 64 IView (Sweden)
- Cubital and distal arm vein glucose compared with plasma glucose other arm
- 14 patients with Acute coronary syndrome (n=11) or heart failure (n=3)
- Data 8 time points for I hour/day for 3 days
- 4/14 with no congruence between BG and MD
- No complications

Hage et al. Diabetes Tech and Ther. 2009

Clarke Error Grid of Comparison

263 matched pairs
14% difference
82% between referenced values
All values zones A & B
•clinically accurate or benign
Zone C = overcorrection
Zone D = failure to detect
Zone E = erroneous



Anesthetic management of pediatric patients with insulinoma using continuous glucose monitoring

- Manabe et al. Masui. 2009 Jun;58(6):757-9. Article in Japanese
- 10% glucose infusion was required to avoid hypoglycemia.
- Then, insulin infusion was continued to maintain blood glucose level around 150 mg x dl(-1).
- All glucose management was guided with CMG.
- First case report to show the feasibility and usefulness of CMG in management of pediatric insulinoma patients.

Summary

- Glucose targets vary are more liberal
- Using glucose data from our clincial practice will help us understand the burden of the pathophysiology
- POCS limitations must be acknowledged
- Continuous monitoring may become the standard of care but limitations exist
- Inteaoperative data are needed

Discussion ??

Anesthesiology. 2010 Mar 8. Role of Intraoperative and Postoperative Blood Glucose Concentrations in Predicting Outcomes after Cardiac Surgery.
Duncan AE, Abd-Elsayed A, Maheshwari A, Xu M, Soltesz E, Koch CG.

- Compare the ability of perioperative glucose concentrations and glycemic variability to predict adverse outcomes. Risk associated with decreasing increments of glucose concentrations, hypoglycemia, and diabetic status was also examined.
- 4,302 patients who underwent cardiac surgery between 2005-2007
- Both GlcOR and GlcICU predicted risk for mortality and morbidity. Increased postoperative glycemic variability was associated with increased risk for adverse outcomes.
- Severe hyperglycemia (GlcOR and GlcICU > 200 mg/dl) was associated with worse outcomes; however, decreasing increments of GlcOR did not consistently reduce risk.
- GlcOR less than or equal to 140 mg/dl was not associated with improved outcomes compared with severe hyperglycemia, despite infrequent hypoglycemia. Diabetic status did not influence the effects of hyperglycemia.

INTENSIVE INSULIN THERAPY IN CRITICALLY ILL PATIENTS

GREET VAN DEN BERGHE, M.D., PH.D., PIETER WOUTERS, M.SC., FRANK WEEKERS, M.D., CHARLES VERWAEST, M.D., FRANS BRUYNINCKX, M.D., MIET SCHETZ, M.D., PH.D., DIRK VLASSELAERS, M.D., PATRICK FERDINANDE, M.D., PH.D., PETER LAUWERS, M.D., AND ROGER BOUILLON, M.D., PH.D.

- Prospective Randomized Controlled Trial
- 1548 Ventilated Surgical ICU Patients
- Intensive vs. Conventional Glucose Control
- 80 – 110 mg/dL vs. 180 – 200 mg/dL

The New England Journal of Medicine

NOVEMBER 8, 2001

Acknowledgments

- Deepak Sharma, MD (neuroanesthesia fellow)
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- Monica S. Vavilala, MD
- NICHD/NIH/K23
- Harborview Anesthesia Research Center

Glucose vs. Glucose-free Solutions on Blood Glucose during Total Repair of Congenital Heart Diseases

- N = 40 children requiring CPB (no circ arrest)
- 20 LR vs. 20 D5W both at 3mL/k/hr
- Data at baseline through 24 hours postop
- Glucose increased with CPB in both groups
- Glucose range 40-239
- 3 children with hypoglycemia; all in LR
- Glucose variability noted

Neidecker et al. J Cardiothorac Vasc Anesth. 1997 Jun;11(4):409-10.

The NEW ENGLAND JOURNAL of MEDICINE

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Intensive Insulin Therapy in the Medical ICU

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Hypoglycemia			
Patients experiencing hypoglycemia* - No (%)	19 (3.1%)	111 (18.7%)	< 0.001
Patients experiencing 2 or more hypoglycemic events - No (%)	5 (0.8%)	23 (3.9%)	< 0.001
Level of blood glucose during hypoglycemia (mg/dl) (M±SD)	31 ± 8	32 ± 5	0.5

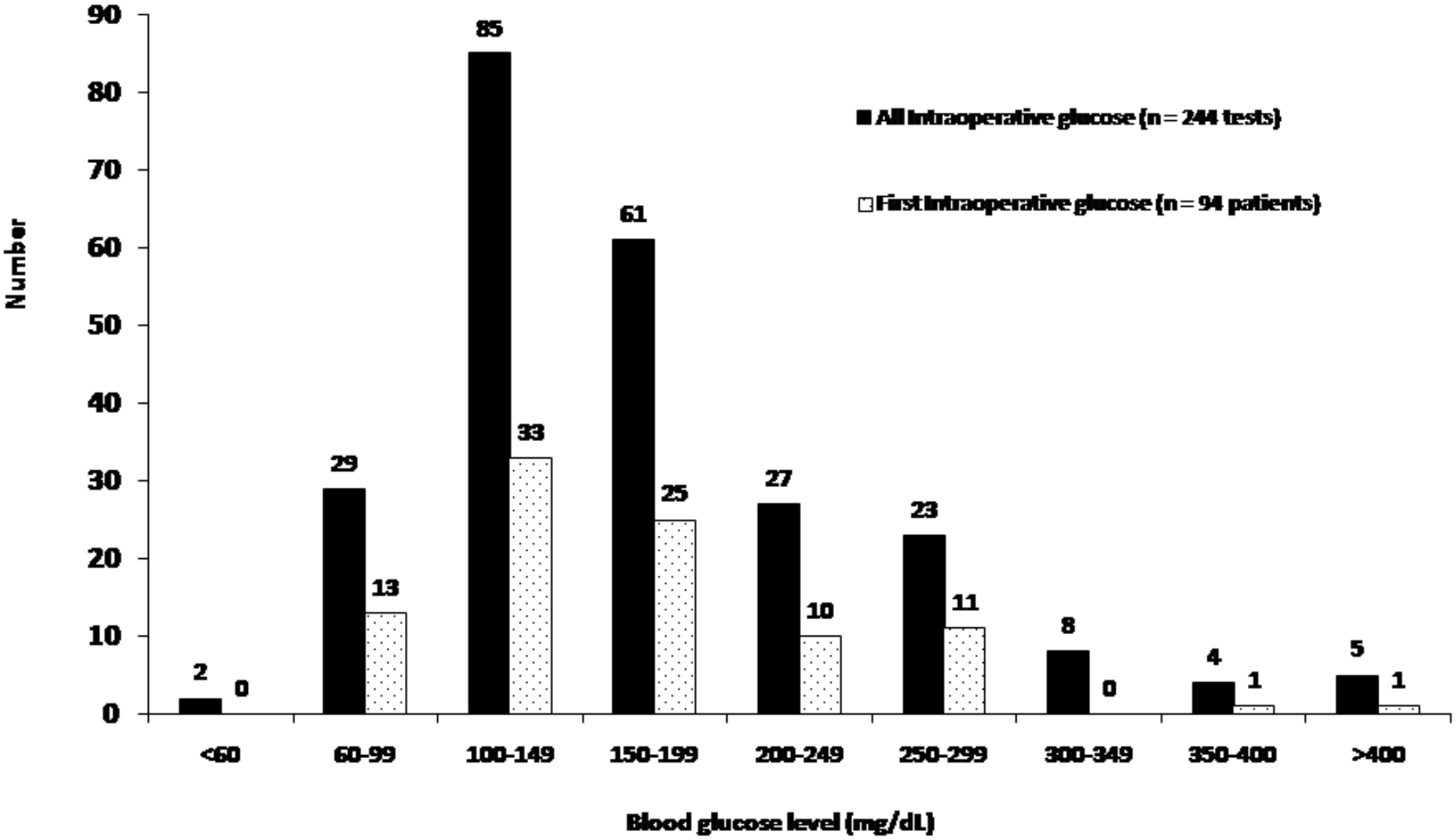
- Hypoglycemia was an independent risk factor for death

Berghe, *NEJM*, 2006.

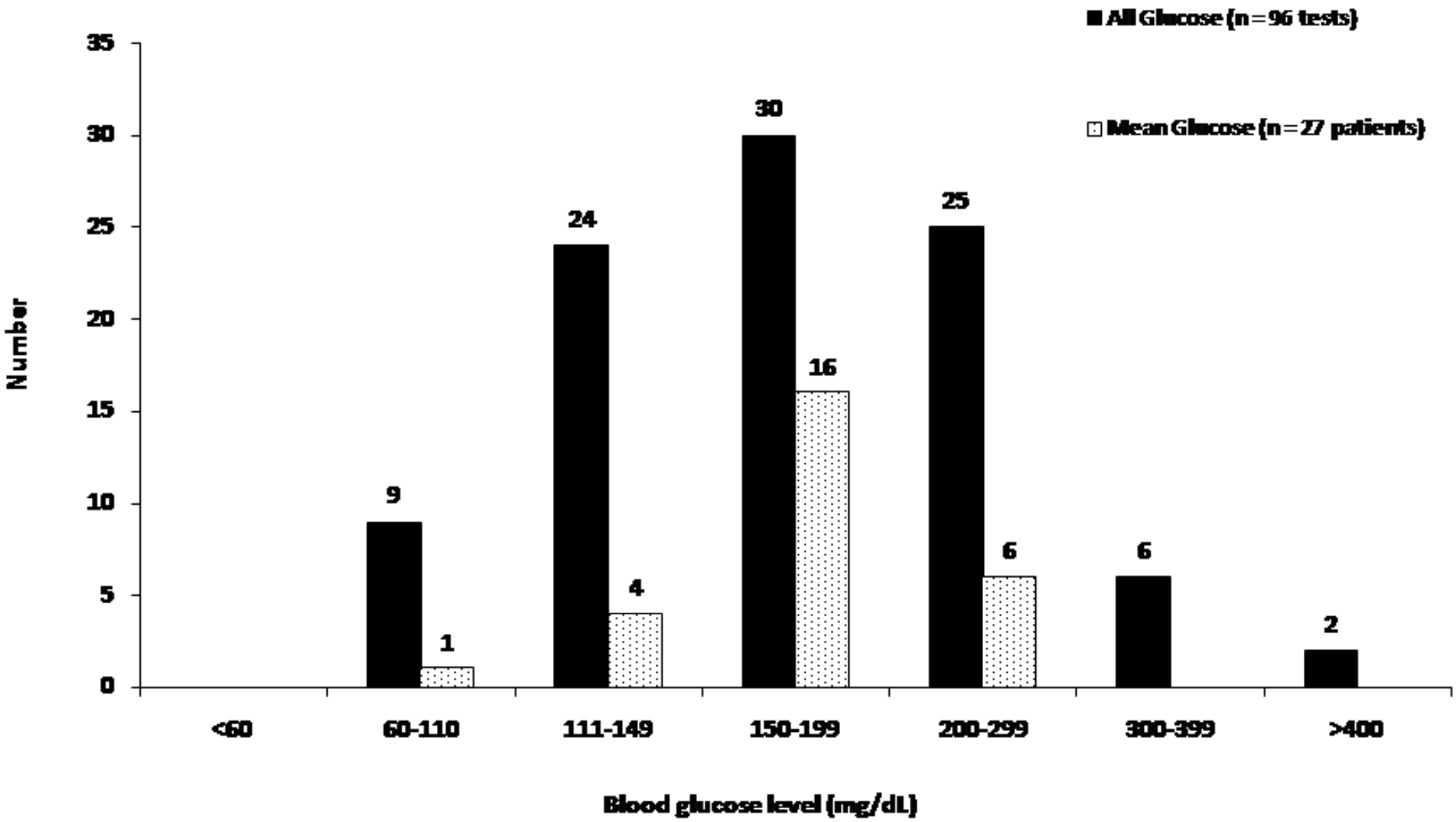
TABLE 3. MORTALITY.

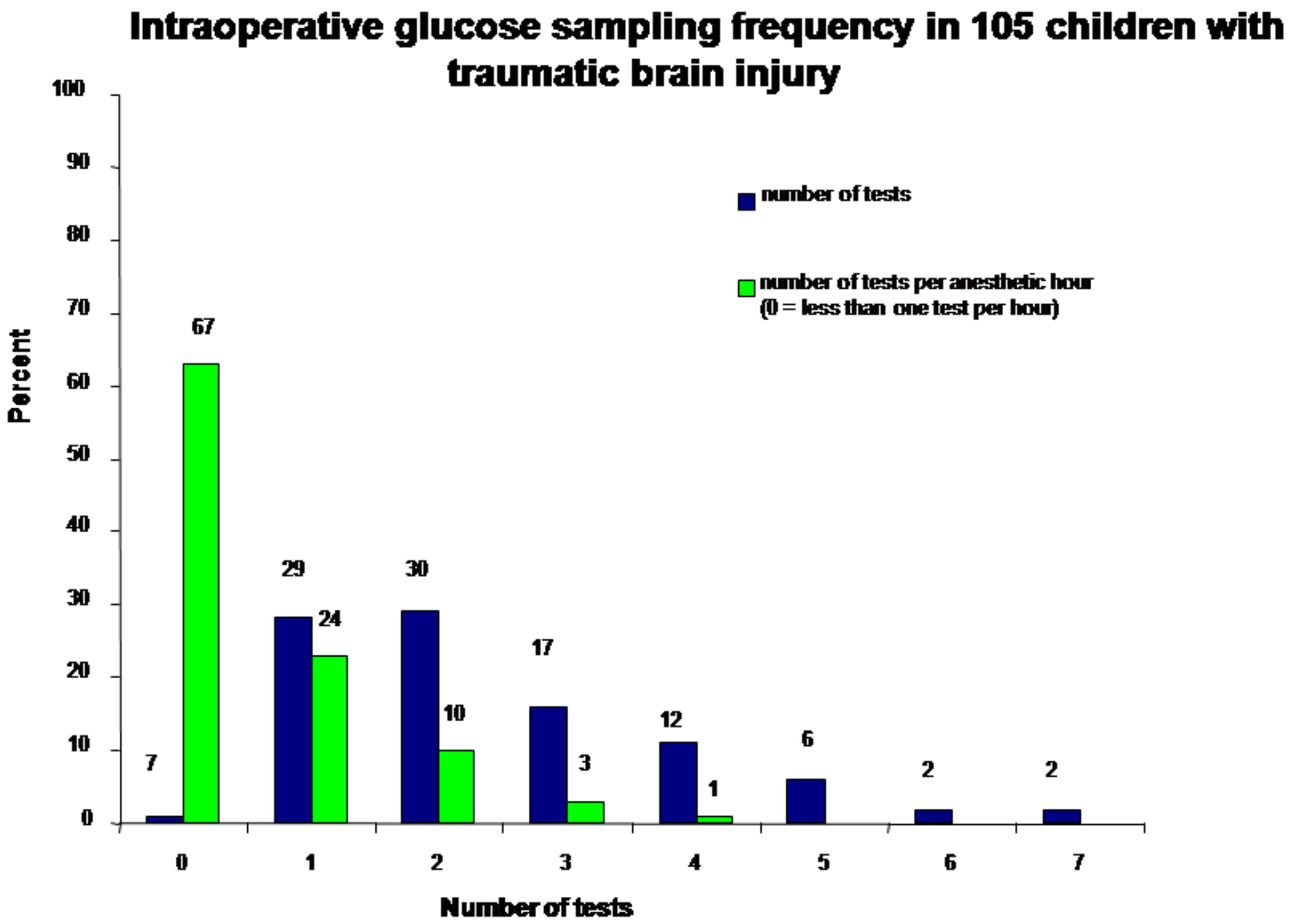
VARIABLE	CONVENTIONAL TREATMENT (N=783)	INTENSIVE TREATMENT (N=765)	P VALUE*
Death during intensive care — no./total no. (%)	63/783 (8.0)	35/765 (4.6)	<0.04 (adjusted)
During first 5 days of intensive care	14/783 (1.8)	13/765 (1.7)	0.9
Among patients receiving intensive care for >5 days	49/243 (20.2)	22/208 (10.6)	0.005
Reason for intensive care			
Cardiac surgery	25/493 (5.1)	10/477 (2.1)	
Neurologic disease, cerebral trauma, or brain surgery	7/30 (23.3)	6/33 (18.2)	
Thoracic surgery, respiratory insufficiency, or both	10/56 (17.9)	5/66 (7.6)	
Abdominal surgery or peritonitis	9/58 (15.5)	6/45 (13.3)	
Vascular surgery	2/32 (6.2)	2/30 (6.7)	
Multiple trauma or severe burns	3/35 (8.6)	4/33 (12.1)	
Transplantation	1/44 (2.3)	2/46 (4.4)	
Other	6/35 (17.1)	0/35	
No history of diabetes	57/680 (8.4)	31/664 (4.7)	
No history of diabetes and >5 days of intensive care	45/218 (20.6)	20/187 (10.7)	
History of diabetes	6/103 (5.8)	4/101 (4.0)	
History of diabetes and >5 days of intensive care	4/25 (16.0)	2/21 (9.5)	
Cause of death — no.			0.02
Multiple-organ failure with proven septic focus	33	8	
Multiple-organ failure without detectable septic focus	18	14	
Severe brain damage	5	3	
Acute cardiovascular collapse	7	10	
In-hospital death — no./total no. (%)			
All patients	85/783 (10.9)	55/765 (7.2)	0.01
Patients receiving intensive care for >5 days	64/243 (26.3)	35/208 (16.8)	0.01

Distribution of intraoperative glucose values in 94/105 children with traumatic brain injury



Distribution of immediate postoperative (first 24 hours after surgery) glucose values in 27/30 children with intraoperative hyperglycemia




Intraoperative glucose sampling frequency in 105 children with traumatic brain injury
Percent
100
90
80
70
60
50
40
30
20
10
0
number of tests
number of tests per anesthetic hour
(0 = less than one test per hour)
67
7
29
24
30
10
17
3
12
1
6
2
2
0
1
2
3
4
5
6
7
Number of tests

Statistical Analysis

- Descriptive statistics
- Pearsons' correlation coefficient
  - Preoperative vs. intraoperative glucose
  - Intraoperative vs. postoperative glucose
- Student's T and Chi square tests to examine HG by Age, GCS, CT lesion type
- Multivariate regression analyses to determine independent predictors of perioperative HG
- Data as mean ± SD, AOR (95% CI), $p < 0.05$ significant

Glucose Monitoring Techniques

- Intermittent or continuous

Gaps in Knowledge

- Incidence & treatment of intraoperative hyperglycemia
- Incidence and risk factors for perioperative hyperglycemia
- Incidence of perioperative hypoglycemia

Intravenous Fluids

- 1900s: Karelitz and Schick reported that the addition of glucose to IV fluids in dehydrated children allowed them “to fall into a restful sleep.” Used D5w to render the IV fluid isosmolar and to prevent hypoglycemia.
- Estimated incidence of preoperative hypoglycemia is 0-2.5 and associated with 8 to 19 h NPO times, beyond ASA recommendation.23
- Most common maintenance IVF in USA D5W 0.2 NS.
- Routine dextrose administration is no longer advised for otherwise healthy children receiving anesthesia.
- High risk populations include neonates, children receiving hyperalimentation, and those with endocrinopathies.

Which IVF Should I Choose ?

- 1986: Welborn randomized patients to intraoperatively receive LR or D5LR. Both groups had increases in glucose but the D5LR group had a much larger increase in blood glucose (83 ± 14 mg/dL preoperatively to 244 ± 60 mg/dL postoperatively) vs. (85 ± 14 mg/dL preoperatively to 111 ± 22 mg/dL postoperatively).22

- Routine dextrose administration is no longer advised for otherwise healthy children receiving anesthesia.

- The populations at highest risk of hypoglycemia include neonates, children receiving hyperalimentation, and those with endocrinopathies, in whom monitoring blood glucose levels and adjusting the rate of infusion is also recommended.24,25,30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