

Essential Need for Glycemic Control in the OR and ICU

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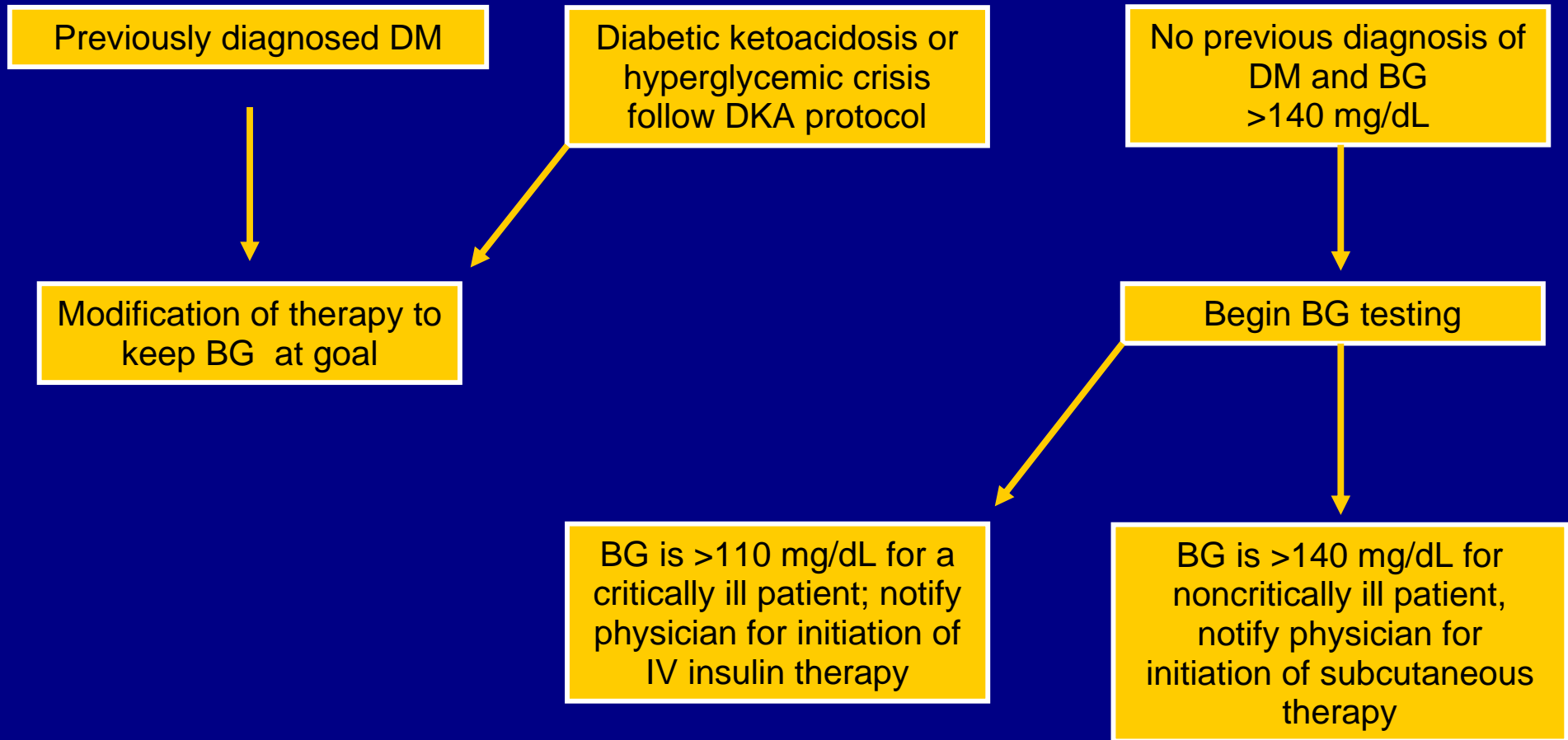
Atlanta Diabetes Associates

**Member of the Diabetes Special Interest Group
of the Georgia Hospital Association**

Objectives

- Present the evidence for tight glycemic control in the ICU
- Understand the need for protocols for identifying and managing hyperglycemia and diabetes in the hospital
- Present what the Georgia Hospital Association (GHA) has done to date and what tools we are using to accomplish this task

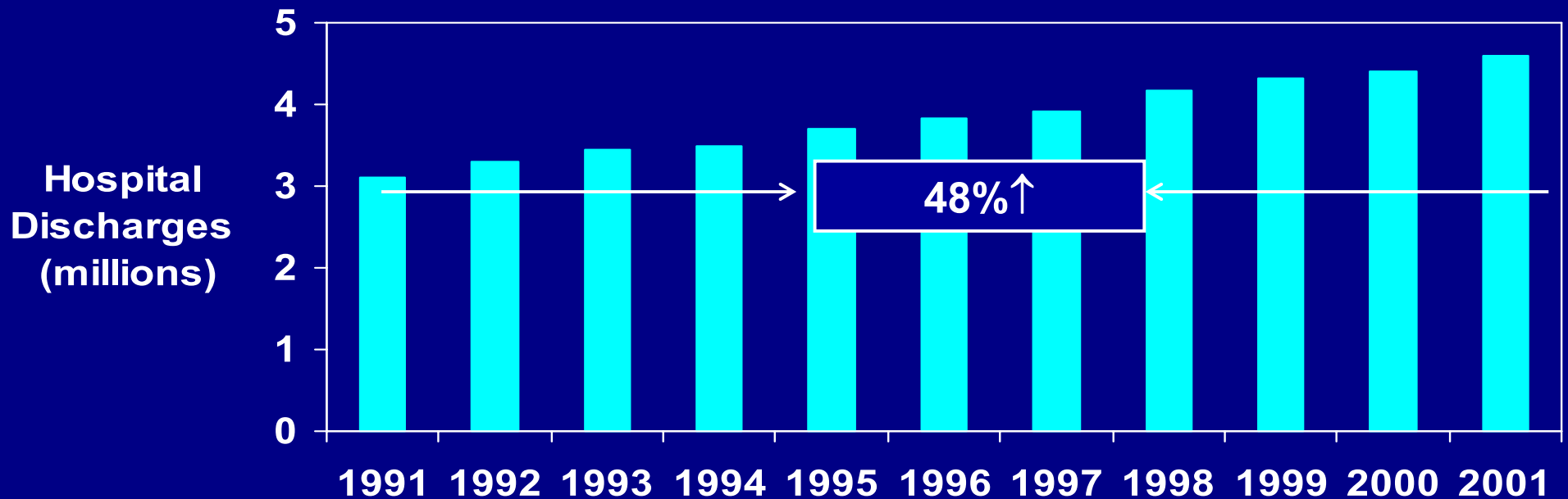
Patient Presents With Hyperglycemia



All patients with hyperglycemia should have an A1C drawn to aid in transition and discharge therapy

The Increasing Rate of Diabetes Among Hospitalized Patients

Hospitalizations for Diabetes as a Listed Diagnosis

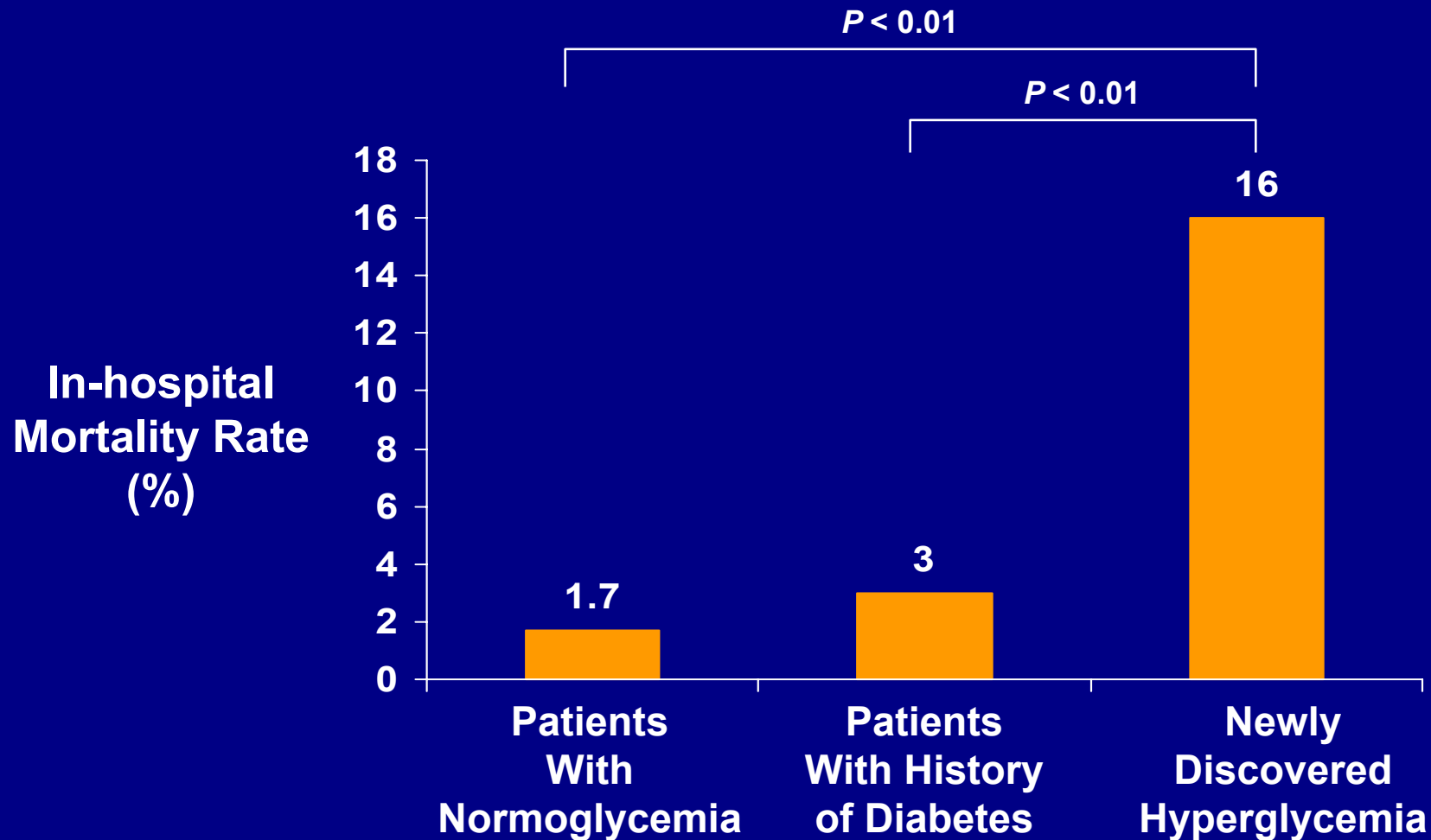


Available at: <http://www.cdc.gov/diabetes/statistics/dmany/fig1.htm>.
Accessed June 15, 2004.

Hyperglycemia in Hospitalized Patients

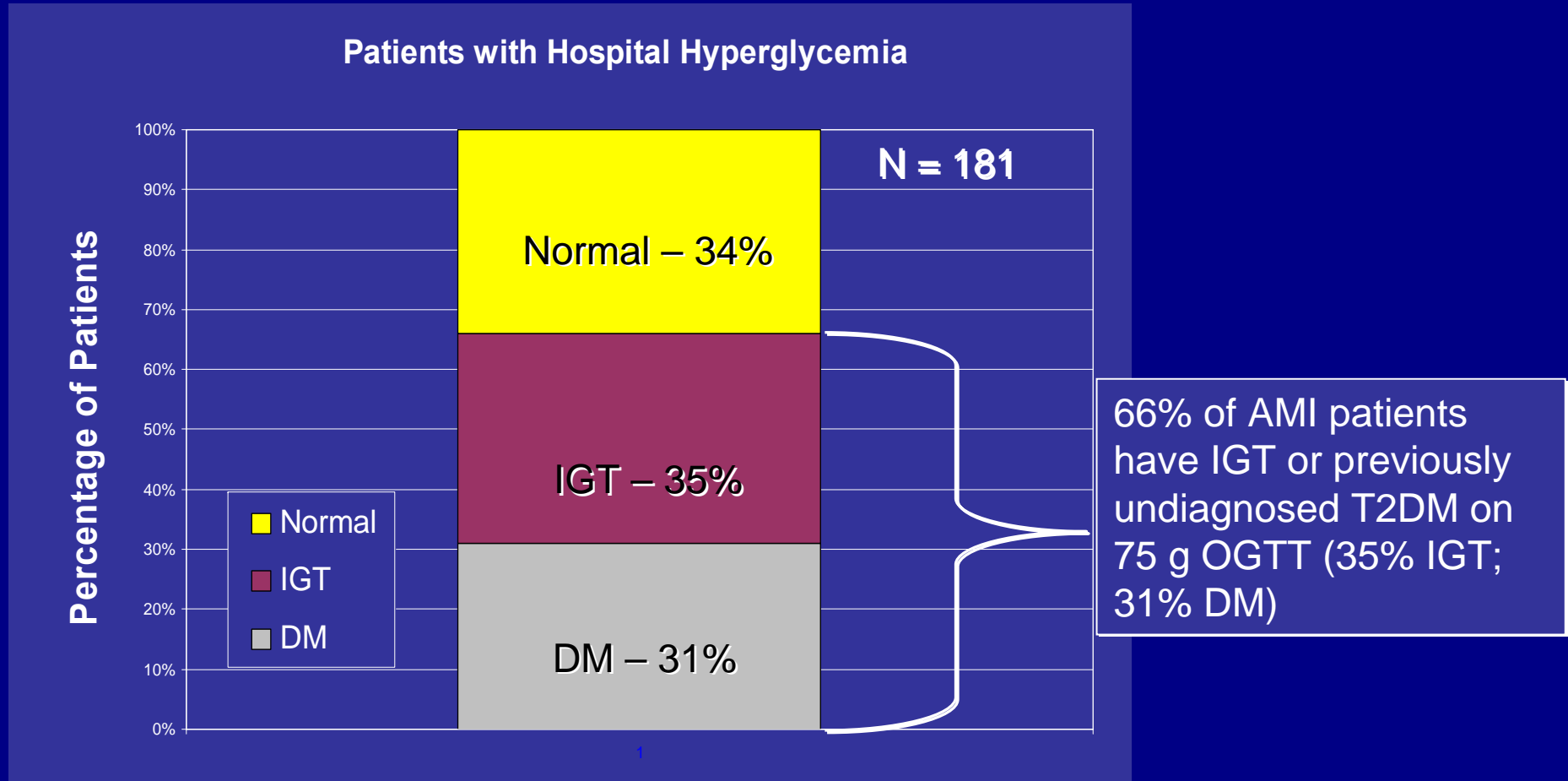
- Hyperglycemia (Fasting >126 or Random >200 mg/dL x 2) occurred in 38% of hospitalized patients
 - 26% had known history of diabetes
 - 12% had *no* history of diabetes
- Newly discovered hyperglycemia was associated with:
 - Longer hospital stays
 - Higher admission rates to the ICUs
 - Less chance to be discharged to home (required more transitional or nursing home care)

Hyperglycemia Is an Independent Marker of Inpatient Mortality in Patients With Undiagnosed Diabetes



Adapted from Umpierrez GE, et al. *J Clin Endocrinol Metab.* 2002;87:978–982.

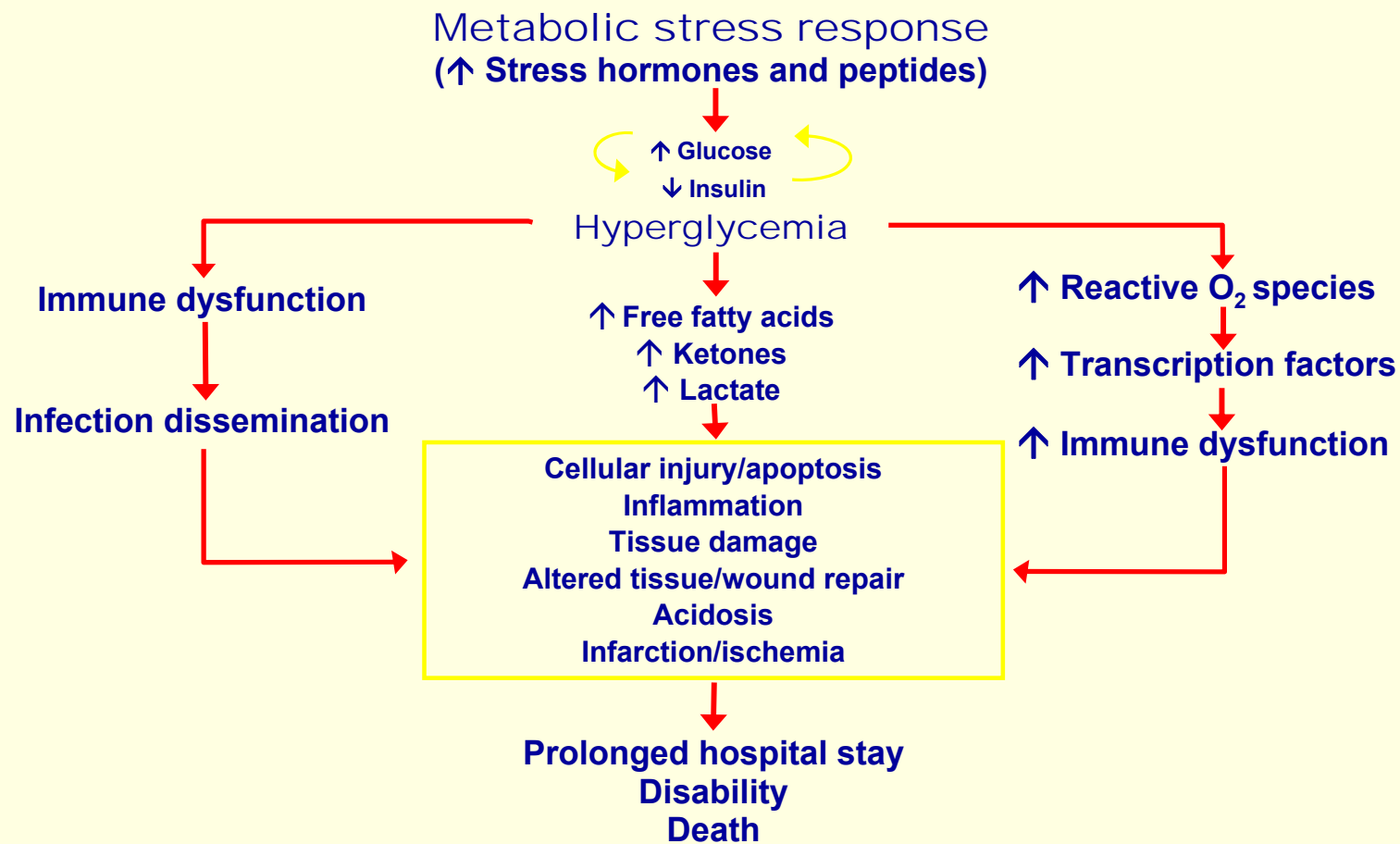
Prevalence of Hyperglycemia in 181 Cardiac Patients Without Known Diabetes



Hyperglycemia in Hospitalized Patients

- **High-risk for bacterial infection**
 - Surgery
 - Catheters
 - Intravenous Access
- **Problems with wound healing**
- **Problems with tissue and organ perfusion**

Hyperglycemia and Poor Hospital Outcomes: A Hypothesis

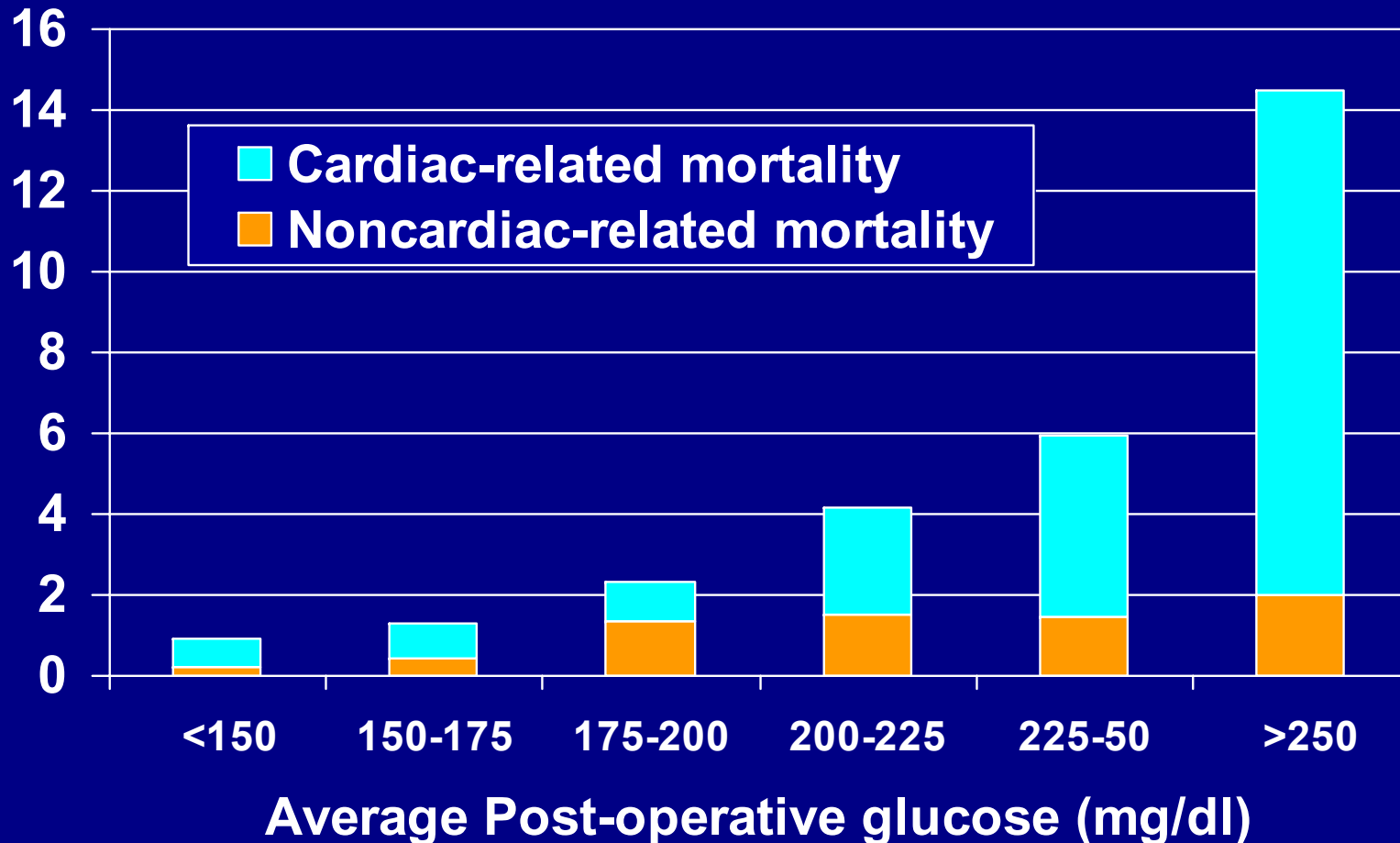


Benefits of Improved Glucose Control in the Hospital

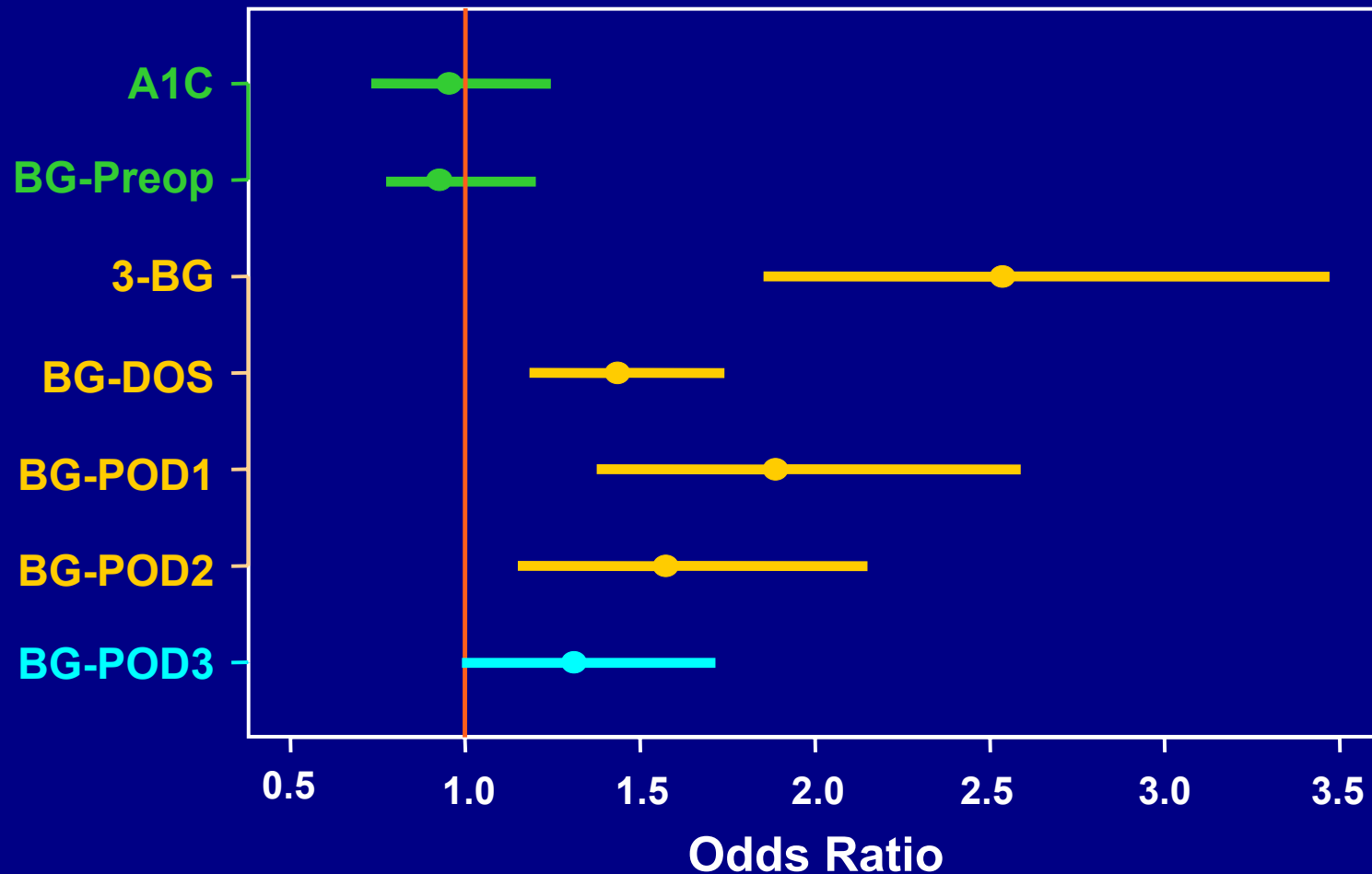
- Aggressive insulin treatment improves
 - ICU outcomes
 - Outcomes post-MI
 - Cardiac surgery outcomes
 - Infections in the hospital
 - CVA outcomes

Mortality of DM Patients Undergoing CABG

Mortality%



Independent Association of Isolated BG Measurements on Mortality



Costs of Hyperglycemia in the Hospital

For each 50 mg/dL rise in glucose:

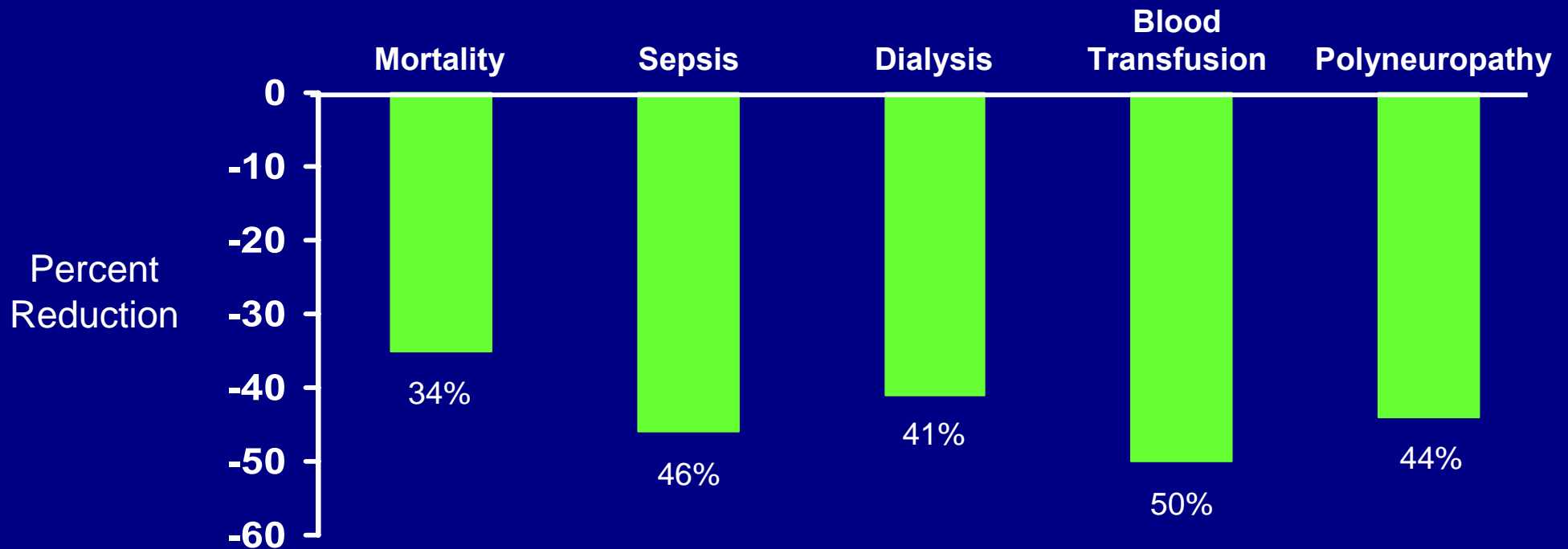
Length of Stay increases by 0.76 days

Hospital Charges increase by \$2824

Hospital Costs increase by \$1769

Intensive Insulin Therapy in Critically Ill Patients—Morbidity and Mortality Benefits

1548 patients: 153 vs 103 mg/dL



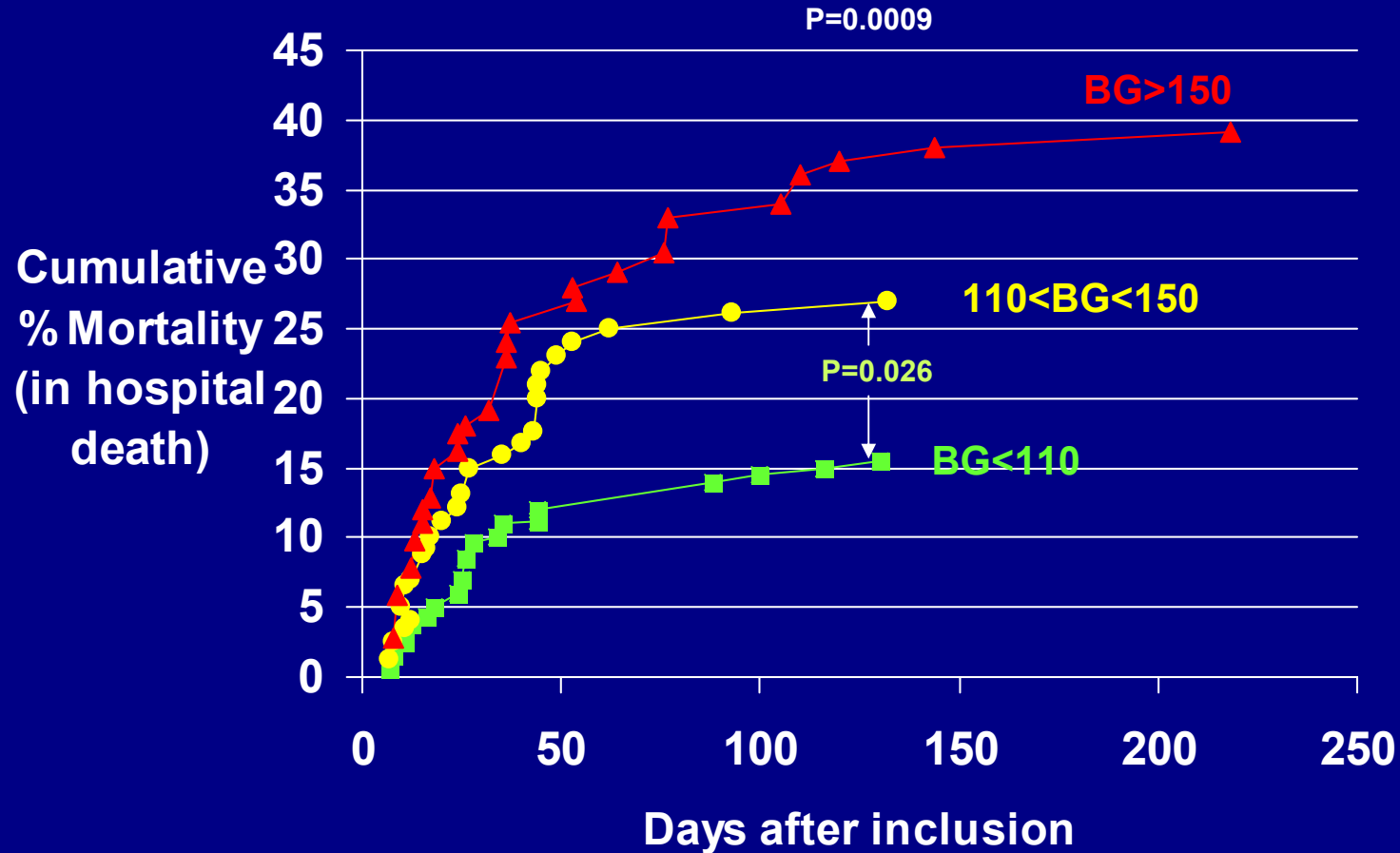
*Net Savings 2638 Euros per patient

Van den Berghe G, et al. N Engl J Med. 2001;345:1359–1367

* Van den Berghe G, et al. Abstract #73 CPOCT Quebec 2006

Surgical ICU Mortality

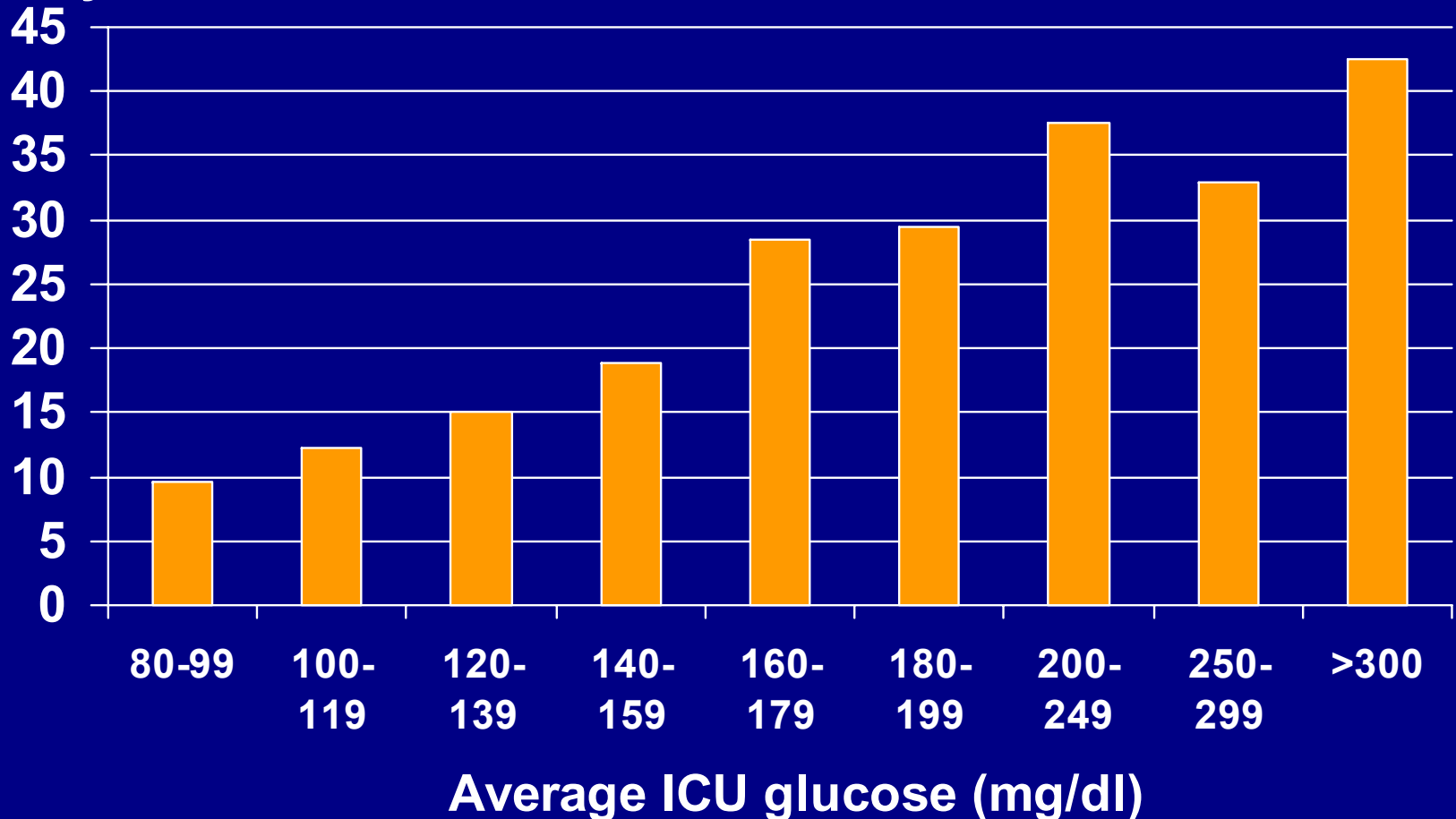
Effect of Average BG



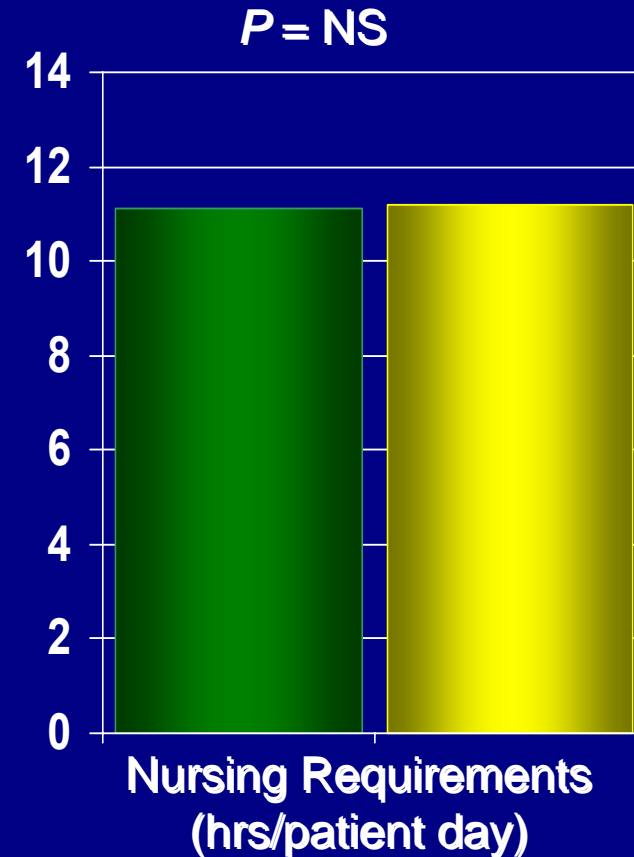
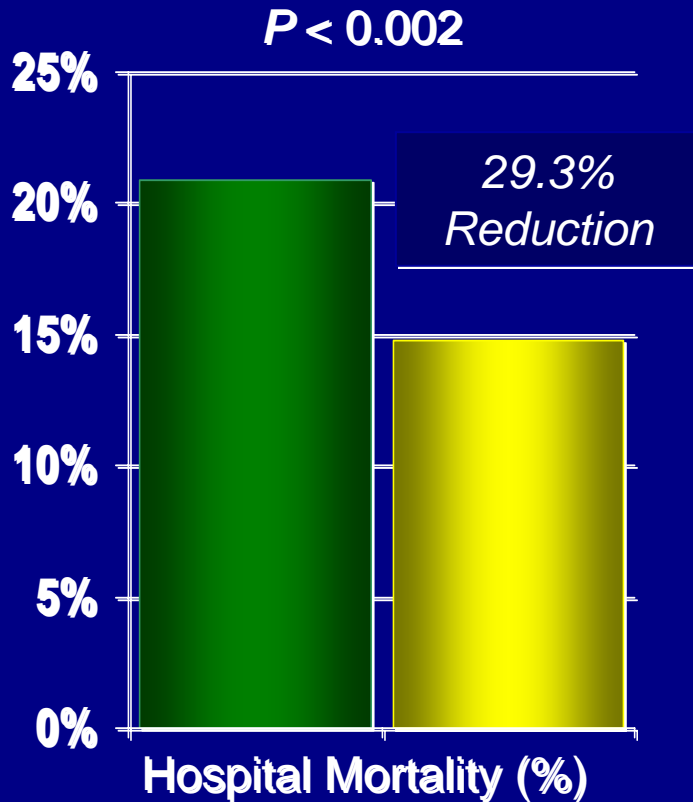
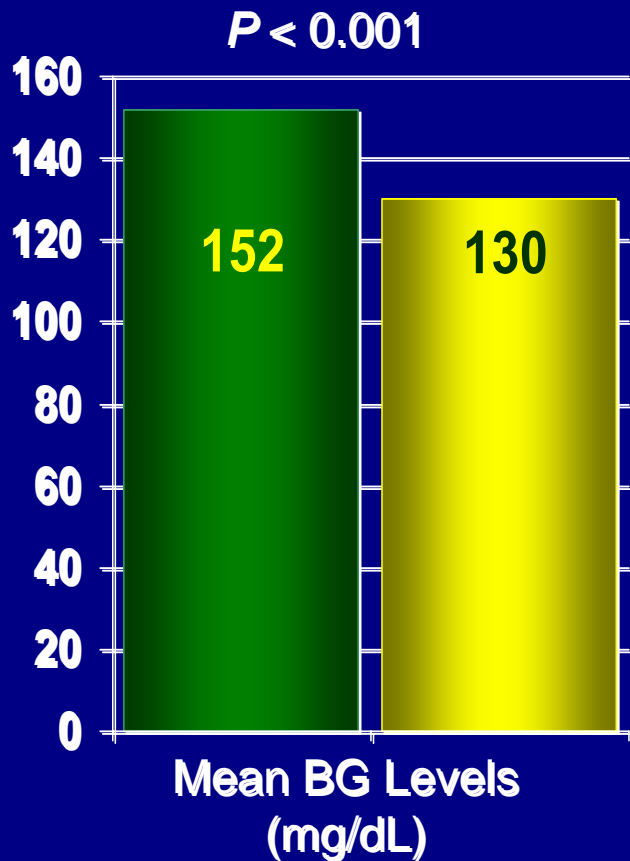
Hyperglycemia and Hospital Mortality

1826 consecutive ICU patients 10/99 thru 4/02, Stamford CT

Mortality %



Intensive Insulin Management in Medical-Surgical ICU (n = 1600)



van den Berghe: Medical ICU

- Target population: in medical ICU for at least a third day
 - 1200 to achieve the required number of patients in ICU for at least a third day
 - Study protocol: similar to surgical study
 - Insulin infusions in the ICU ONLY

Medical ICU Study Results

- In-hospital mortality for patients who were in the ICU and on CII for >3 days was lower (52.5% to 43.0%)
- RRR=18.1%
- $P=0.009$

Glycemic threshold in ICU Patients

- **BG < 110 mg/dL (< 6 mmol/L)**

Van den Berghe et al *Crit Care Med* 2003; 31(2):359-66

Finney SJ et al *JAMA* 2003;290(15):2041-47

Krinsley SK. *Mayo Clin Proc.* 2004;79(8):992-1000

Other Medical Conditions

- Infection data supports BG < 130 mg/dL

Hartford Surgical Study

125 mg/dL vs 179 mg/dL

10X decrease in infections

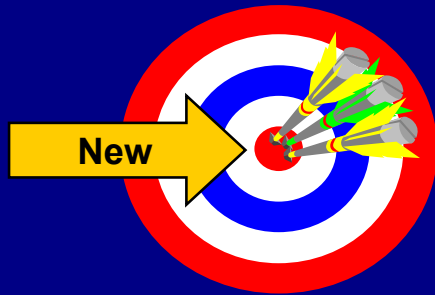
- Stroke data supports BG < 130 mg/dL
- Pregnancy data supports BG < 100 mg/dL

Target blood glucose in mg/dL

- 80 – 110 in ICU patients
- 80 – 140 in other Surgical and Medical Patients
- 70 – 100 in Pregnancy

Hospital Targets for Glucose

AACE and ADA Guidelines: 2006



ADA

- FPG 90-130 mg/dL
- Peak postprandial glucose <180 mg/dl

AACE

- FPG \leq 110 mg/dL
- 2-h postprandial glucose \leq 180 mg/dL

ADA & AACE

- **Critically ill patients: \leq 110 mg/dL**

Modify if:

- Cardiac disease (unstable)
- Hypoglycemic unawareness
- Recurrent hypoglycemia

Conclusion

**All hospital patients should
have normal glucose**

Insulin

only

The most powerful agent we
have
to control glucose

Methods For Managing Hospitalized Persons with Diabetes

- Continuous Variable Rate IV Insulin Drip

Major Surgery, NPO, Unstable, MI, DKA, Hyperglycemia, Steroids, Gastroparesis, Delivery, etc

- Basal / Bolus Therapy (MDI) when eating

Threshold blood glucose in mg/dL for starting IV insulin infusion

- Peri-operative care: > 110 - 140
- ICU care: > 110 - 140 *
- Non-surgical illness: > 140 - 180 **
- Pregnancy > 100

* Van den Berghe's study supports 110;
Finney's study supports 145

** If drip indication is failure of SQ therapy, use 180 ;
if indication is specific condition (DM 1/ NPO, MI, etc), use 140

The Ideal IV Insulin Protocol

- Easily ordered (signature only)
- Effective (Gets to goal quickly)
- Safe (Minimal risk of hypoglycemia)
- Easily implemented
- Able to be used hospital wide

Essentials of a good IV Insulin Algorithm

- Easily implemented by nursing staff
- Able to seek BG range via:
 - Hourly BG monitoring
 - Adjusts to the insulin sensitivity of the patient

Various Protocols Exist

- **Atlanta Multiplier Method**
- **Van den Berghe (studied in critical care setting)**
- **Portland Protocol (used in surgical setting)**
- **Markovitz (studied in postoperative heart surgery patients)**
- **Yale Protocol (studied in medical intensive care setting)**

Portland Protocol

Furnary et al J Thorac Cardiovasc Surg 2003;123:1007-21

1. Start Portland protocol during surgery and continue through 7 AM of the third POD. Patients who are not receiving enteral nutrition on the third POD should remain on this protocol until receiving at least 50% of a full liquid or soft American Diabetes Association diet.
2. For patients with previously undiagnosed DM who have hyperglycemia, start Portland protocol if blood glucose is greater than 200 mg/dL. Consult endocrinologist on POD 2 for DM workup and follow-up orders.
3. Start infusion by pump piggyback to maintenance intravenous line as shown in Appendix Table 1.
4. Test blood glucose level by finger stick method or arterial line drop sample. Frequency of blood glucose testing is as follows:
 - a. When blood glucose level greater than 200 mg/dL, check every 30 minutes.
 - b. When blood glucose level is less than 200 mg/dL, check every hour.
 - c. When titrating vasopressors, (eg, epinephrine) check every 30 minutes.
 - d. When blood glucose level is 100 to 150 mg/dL with less than 15 mg/dL change and insulin rate remains unchanged for 4 hours ("stable infusion rate"), then you may test every 2 hours.
 - e. You may stop testing every 2 hours on POD 3 (see items 1 and 8).
 - f. At night on telemetry unit, test every 2 hours if blood glucose level is 150 to 200 mg/dL; test every 4 hours if blood glucose level is less than 150 mg/dL and "stable infusion rate" exists.
5. Insulin titration according to blood glucose level is performed as follows
 - a. When blood glucose level is less than 50 mg/dL, stop insulin and give 25 mL 50% dextrose in water. Recheck blood glucose level in 30 minutes. When blood glucose level is greater than 75 mg/dL, restart with rate 50% of previous rate.
 - b. When blood glucose level is 50 to 75 mg/dL, stop insulin. Recheck blood glucose level in 30 minutes; if previous blood glucose level was greater than 100 then give 25 mL 50% dextrose in water. When blood glucose level is greater than 75 mg/dL, restart with rate 50% of previous rate.
 - c. When blood glucose level is 75 to 100 mg/dL and less than 10 mg/dL lower than last test, decrease rate by 0.5 U/h. If blood glucose level is more than 10 mg/dL lower than last test, decrease rate by 50%. If blood glucose level is the same or greater than last test, maintain same rate.
 - d. When blood glucose level is 101 to 150 mg/dL, maintain rate.
 - e. When blood glucose level is 151 to 200 mg/dL and 20 mg/dL lower than last test, maintain rate. Otherwise increase rate by 0.5 U/h.
 - f. When blood glucose level is greater than 200 mg/dL and at least 30 mg/dL lower than last test, maintain rate. If blood glucose level is less than 30 mg/dL lower than last test (or is higher than last test), increase rate by 1 U/h and, if greater than 240 mg/dL, administer intravenous bolus of regular insulin per initial intravenous insulin bolus dosage scale (see item 3). Recheck blood glucose level in 30 minutes.
 - g. If blood glucose level is greater than 200 mg/dL and has not decreased after three consecutive increases in insulin, then double insulin rate.
 - h. If blood glucose level is greater than 300 mg/dL for four consecutive readings, call physician for additional intravenous bolus orders.
6. American Diabetes Association 1800-kcal diabetic diet starts with any intake by mouth.
7. Postmeal subcutaneous Humalog insulin supplement is given in addition to insulin infusion when oral intake has advanced beyond clear liquids.
 - a. If patient eats 50% or less of servings on breakfast, lunch, or dinner tray, then give 3 units of Humalog insulin subcutaneously immediately after that meal.
 - b. If patient eats more than 50% of servings on breakfast, lunch, or supper tray, then give 6 units of Humalog insulin subcutaneously immediately after that meal.
8. On third POD, restart preadmission glycemic control medication unless patient is not tolerating enteral nutrition and is still receiving an insulin drip.

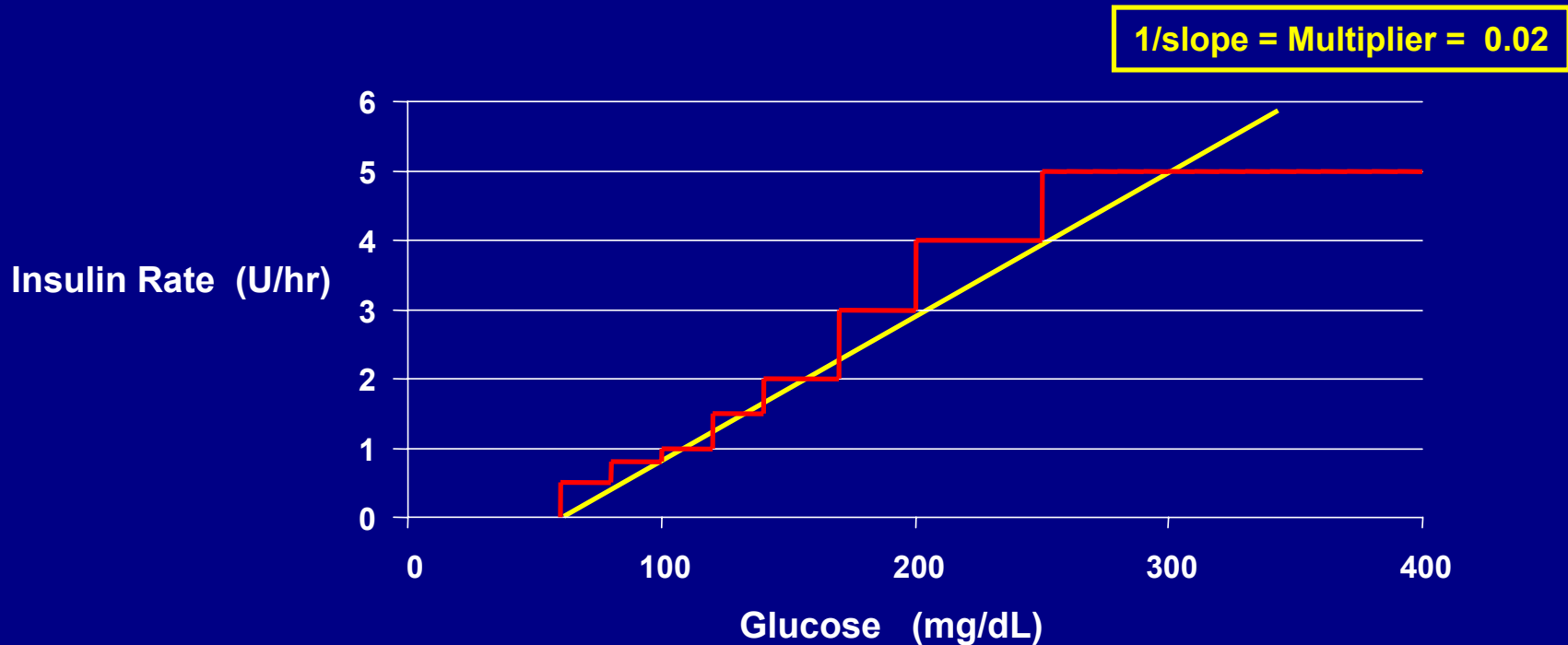
Leuven Protocol

- Arterial BG q 1-2 hours, then q 4 hours if stable
- If BG >220 give 4 units/hr
- If BG >110 mg/dl give 2 units/hr.
- If F/U BG in 1-2 hours >140 mg/dl Increase insulin 1-2 units/hr.
- If F/U BG in 1-2 hours 121-140 mg/dl increase insulin 0.5-1 unit/hr.
- If F/U BG 110-120 mg/dl increase insulin 0.1-0.15 units/hr.
- If BG 81-110 mg/dl then do not change.
- If BG decreases >50% decrease insulin 50%.
- If BG 61-80 mg/dl decrease insulin “reduced as dictated by previous BG level.
- Repeat BG in one hour.
- If B 41-60 mg/dl discontinue insulin.
- If BG >40 mg/dl give 10 Gm glucose IV. Repeat q 1 hr until BG 81-110 mg/dl.
- If BGT decreases >20% in 81-110 mg/dl range decrease insulin 20%.
- If patient transferred from ICU and insulin <2 units/hr, DC insulin.
- If patient transferred from ICU and insulin >2 units/hr get endocrine consult.

Requires ICU nurses trained in protocol and study physician

Practical Closed Loop Insulin Delivery: Multiplier Method

A System for the Maintenance of Overnight Euglycemia and the Calculation of Basal Insulin Requirements in Insulin-Dependent Diabetics



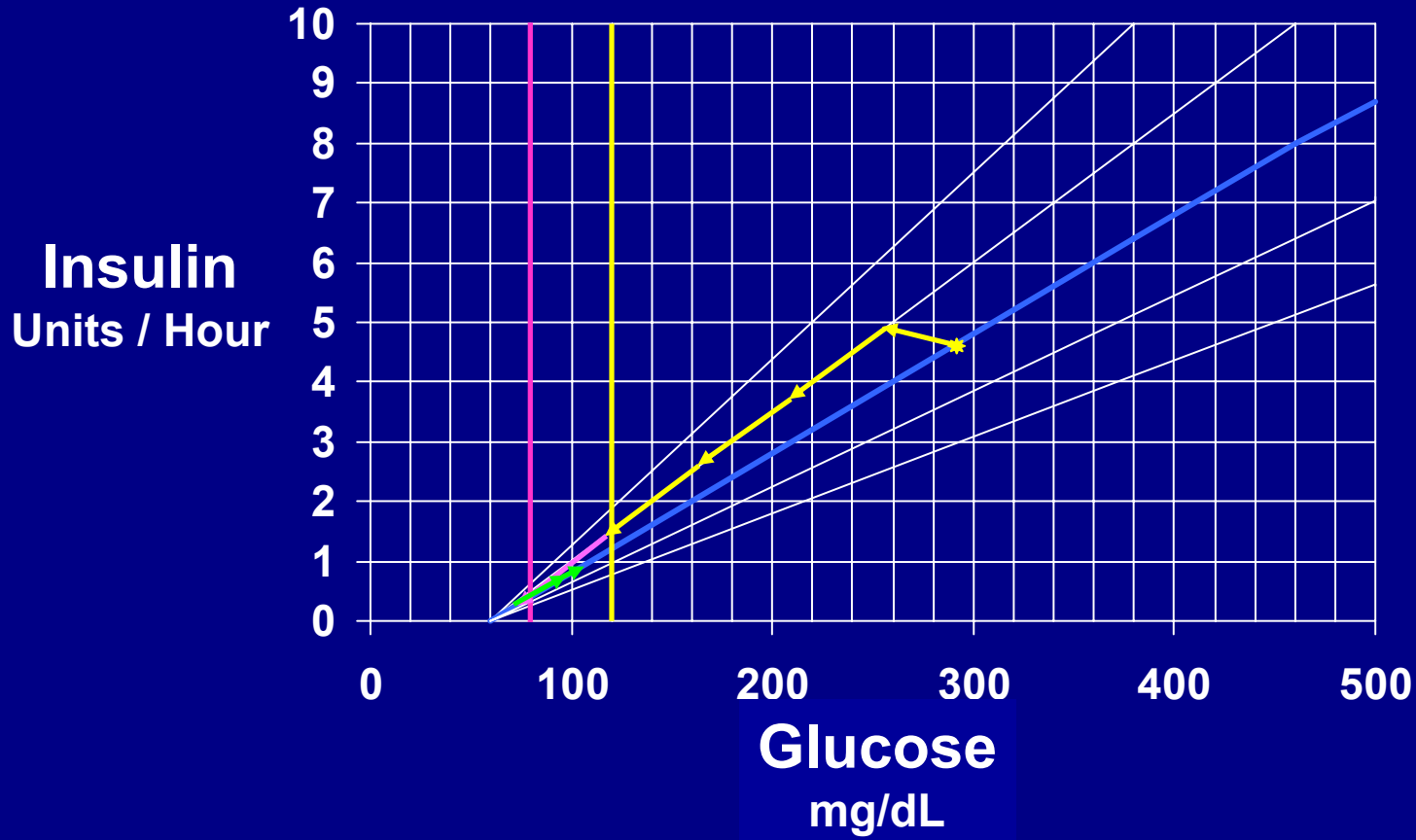
NEIL H. WHITE, M.D., DONALD SKOR, M.D., JULIO V. SANTIAGO, M.D.;
Ann Int Med 1982 ;97:210-214

Continuous Variable Rate IV Insulin Drip

Atlanta Multiplier Method

- Starting Rate **Units / hour = (BG – 60) x 0.02**
where BG is current Blood Glucose
and 0.02 is the multiplier
- Check glucose every hour and adjust drip
- Adjust Multiplier to keep in desired glucose target range (mg/dL): 80 to 110 in ICU;
100 to 140 on floor

Multiplier Principles



**INSULIN IV INFUSION FOR TARGET 80-110MG/DL
(Nurse Calculated)**

1) Initial Orders

- a) Discontinue all previous diabetes medication orders
- b) Obtain Basic Metabolic profile now, in 6 hours, then daily
- c) IV fluid: () Normal Saline () D5¹/₂ Normal Saline () D5¹/₂ Normal Saline/20meq Potassium (K⁺)
() Other _____

If patient is "NPO" and not receiving TPN or continuous enteral feedings and Blood Glucose (BG) less than 250, then the IV fluid selected and the rate of infusion should reflect a glucose source of not less than 5g per hour.

- d) Rate of fluid infusion _____ ml/hr (_____ rate at a minimum)
- e) _____ meq KCl (If K⁺ level is less than 4, order the above listed IV fluid with 20meq K⁺)
- f) Diet: () NPO () Continuous enteral feeding () TPN mixed without insulin
() Other _____

(Do not feed calorie-containing foods unless additional mealtime insulin is ordered).

2) IV Insulin Administration

- a) Mix 250 units of Human Regular insulin in 250ml Normal Saline (1 unit/ml)
- b) Flush approximately 30ml through line prior to administration
- c) Do not use filter or filtered set with insulin
- d) Piggyback insulin drip into IV fluid using an IV infusion pump with capability of 0.1ml/h

3) Initiate IV insulin flow sheet

4) Blood glucose testing

- a) Check BG now and every hour by finger stick using hospital certified BG meter
- b) Do not alternate sites without physician approval
- c) After hourly BGs remain in the desired range for 4 consecutive hours, may begin BG testing every 2 hours
- d) Have laboratory verify "stat" all BGs less than 40 or greater than 500

5) Determination of IV insulin infusion rate (units of insulin/hour) = (BG-60) x (Multiplier)

- a) Initiate drip by applying the current BG and the multiplier 0.02 to the above formula
- b) When BG is greater than 110, but has not dropped by at least 15%, increase multiplier by 0.01
(Refer to Figure 1)
- c) When hourly BG is 80-110, do not change the multiplier and adjust the rate according to formula
- d) When hourly BG is less than 80, decrease multiplier by 0.01 to calculate new drip rate and refer to Figure 2

6) Treatment for hypoglycemia (BG less than 80)

- a) Decrease the multiplier by 0.01 as stated in 5-d above
- b) Give D50W by IV push (refer to the Hypoglycemia Dosing Algorithm)
- c) Recheck BG in 15 minutes (repeat steps a & b if BG is still less than 80)
- d) Resume hourly BG monitoring and insulin drip adjustments

7) Notify physician if:

- a) BG is less than 60 for 2 consecutive BG measurements
- b) BG reverts back to levels greater than 200 for 2 consecutive BG measurements
- c) Insulin requirements exceed 24 units per hour
- d) Patient's K⁺ level drops to less than 4
- e) Continuous enteral feedings, TPN, or IV insulin infusion is stopped or interrupted

8) Transition to subcutaneous insulin

(FIGURE No. 1)

The Column Dosing Chart is the property of the Georgia Hospital Association's Diabetes SIG: All Rights Reserved; Copyright Pending

DIRECTIONS:

TARGET BG 80-110 (1 ml = 1 unit)

Start infusion using the drip rate (ml/hr) in COLUMN No.2 for the current Blood Glucose Tier	Blood Glucose Tiers (mg/dl)	column 1 (ml/hr)	column 2 (ml/hr)	column 3 (ml/hr)	column 4 (ml/hr)	column 5 (ml/hr)	column 6 (ml/hr)	column 7 (ml/hr)	column 8 (ml/hr)	column 9 (ml/hr)	column 10 (ml/hr)	column 11 (ml/hr)	column 12 (ml/hr)	column 13 (ml/hr)	column 14 (ml/hr)	column 15 (ml/hr)	column 16 (ml/hr)
To determine the new drip rate, compare the current BG Tier to the previous BG Tier.	Over 450	4.4	8.8	13.2	17.6	22	26.4	30.8	35.2	39.6	44	48.4	52.8	57.2	61.6	66	70.4
	385-450	3.6	7.2	10.8	14.4	18	21.6	25.2	28.8	32.4	36	39.6	43.2	46.8	50.4	54	57.6
If current BG Tier is lower than the previous BG Tier, STAY IN THE SAME COLUMN	334-384	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
	290-333	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
	251-289	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21	23.1	25.2	27.3	29.4	31.5	33.6
	217-250	1.7	3.4	5.1	7.2	8.5	10.2	11.9	13.6	15.3	17	18.7	20.4	22.1	23.8	25.5	27.2
If current BG Tier has not dropped (is the same or higher), MOVE 1 COLUMN TO THE RIGHT	188-216	1.4	2.8	4.2	5.6	7	8.4	9.8	11.2	12.6	14	15.4	16.8	18.2	19.6	21	22.4
	163-187	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	10.8	12	13.2	14.4	15.6	16.8	18	19.2
	141-162	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
If more than 16 columns are needed: Refer to page No. 2	121-140	0.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	8.8	9.6	10.4	11.2	12	12.8
	111-120	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	6.6	7.2	7.8	8.4	9	9.6
When hourly BG is 80-110, stay in the same column to determine the new drip rate. Do Not Change Columns	106-110	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
	101-105	0.4	0.9	1.3	1.8	2.2	2.7	3.1	3.6	4	4.5	5	5.4	5.8	6.3	6.7	7.2
	96-100	0.4	0.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4	4.4	4.8	5.2	5.6	6	6.4
	91-95	0.3	0.7	1	1.4	1.7	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	4.9	5.3	5.6
	86-90	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3	3.3	3.6	3.9	4.2	4.5	4.8
	80-85	0.2	0.5	0.7	1	1.2	1.5	1.7	2	2.3	2.5	2.7	3	3.2	3.5	3.7	4
When new BG is less than 80, Move 1 Column To The Left and refer to Figure no. 2 for D50 treatment.	75-79	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	3.2
	71-74	0.1	0.3	0.4	0.6	0.7	0.9	1	1.2	1.3	1.5	1.7	1.8	1.9	2.1	2.2	2.4
	60-70	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
	Under 60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(Figure No.2)

BG	D50W	ACTION
70-79	10 ml IV Push	* If you have not moved 1 column to the left as directed above, do so now * Recheck BG in 15 minutes * Repeat as necessary
60-69	15 ml IV Push	
50-59	20 ml IV Push	* If you have not moved 1 column to the left as directed above, do so now * Recheck BG in 15 minutes * Repeat as necessary
30-49	25 ml IV Push	
Under 30	30 ml IV Push	* Contact physician if BG is under 60 for 2 consecutive BG measurements

(Figure No. 3)

NOTIFY PHYSICIAN IF:
* BG is less than 60 for 2 consecutive BG measurements
* BG reverts to greater than 200 for 2 consecutive BG measurements
* If an insulin requirement exceeding 24 units/hour does not result in a lower BG Level or if the drip rate (ml/hr) drops to less than 0.5 units/hr
* If the K+ level drops to less than 4
* If continuous enteral feeding, TPN, or IV insulin infusion is stopped

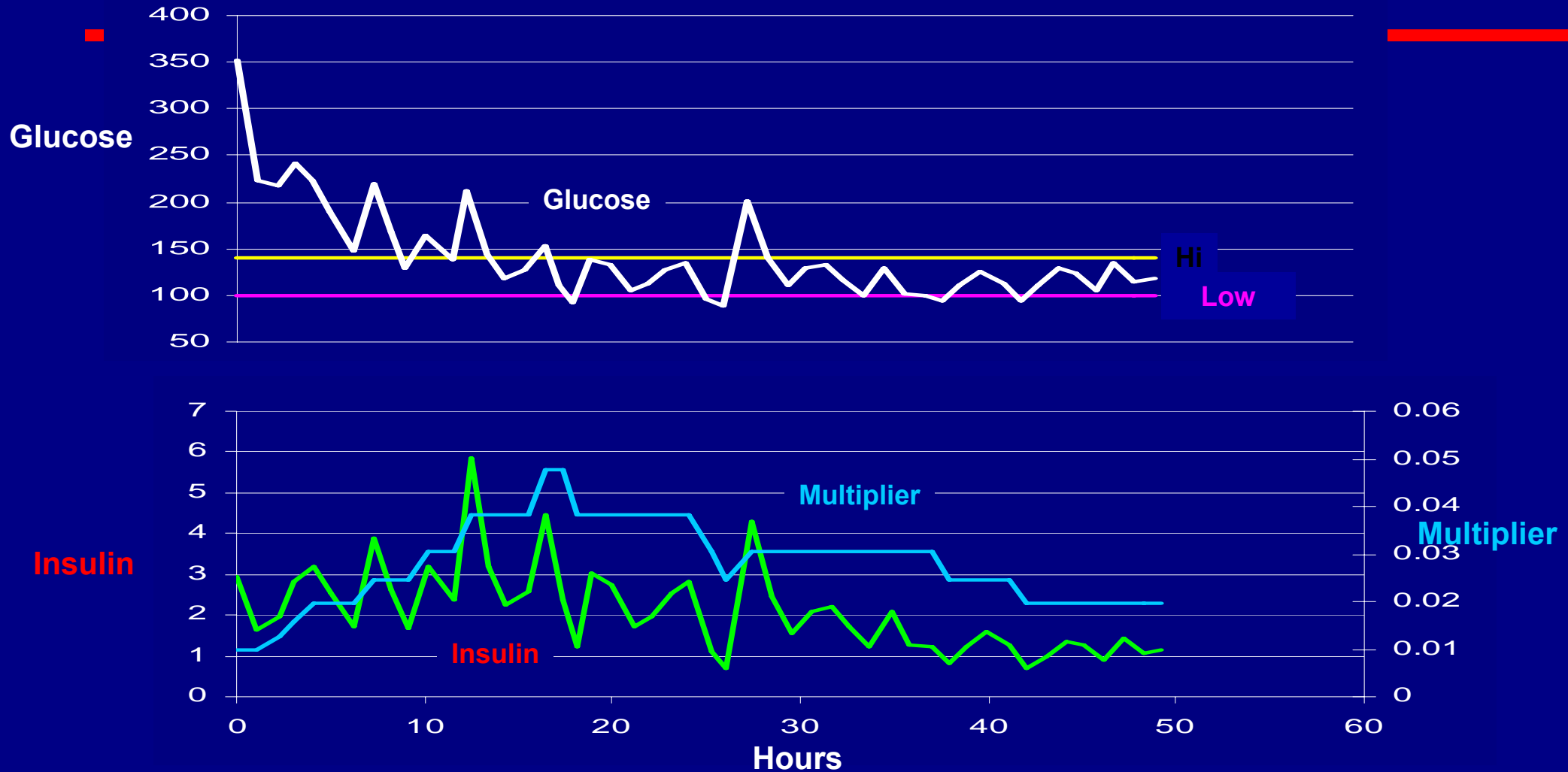
Ideal Solution

- **Computer directed insulin infusion**
 - **Complexity is moved to the computer**
 - **Standardization is achieved**

Computerized Insulin Delivery

- **In 1984, R Dennis Steed computerized our insulin drip orders into “Glucommander”**
- **Glucommander used extensively since 1985 in our hospitals as well as 40 plus DTCA hospitals**
- **Product never marketed because IV insulin had not been FDA approved**
- **On October 2005, FDA approved Novolin R and Novolog for IV use**
- **Glucommander followed by EndoTool have received FDA approval**

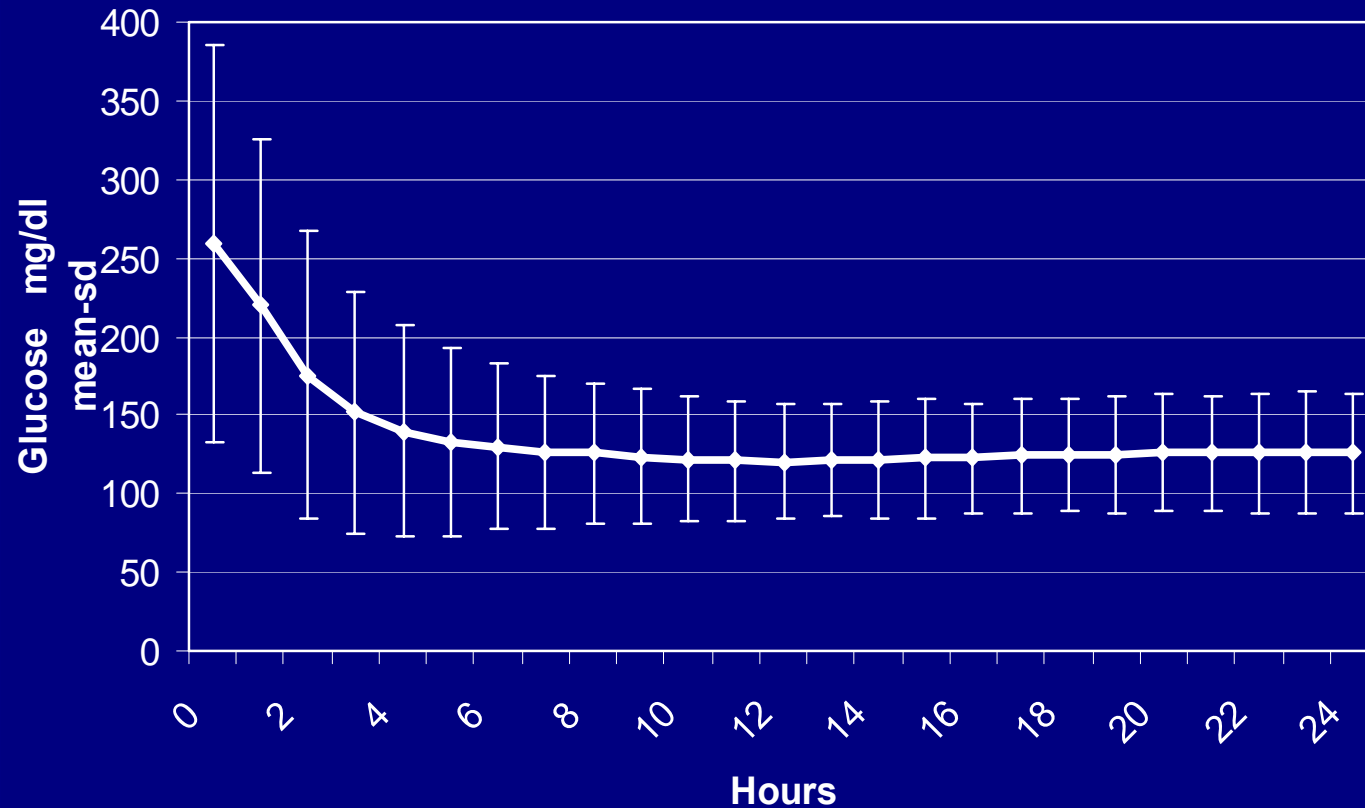
Typical Glucommander Run



Computerized IV Insulin Delivery (Glucommander)

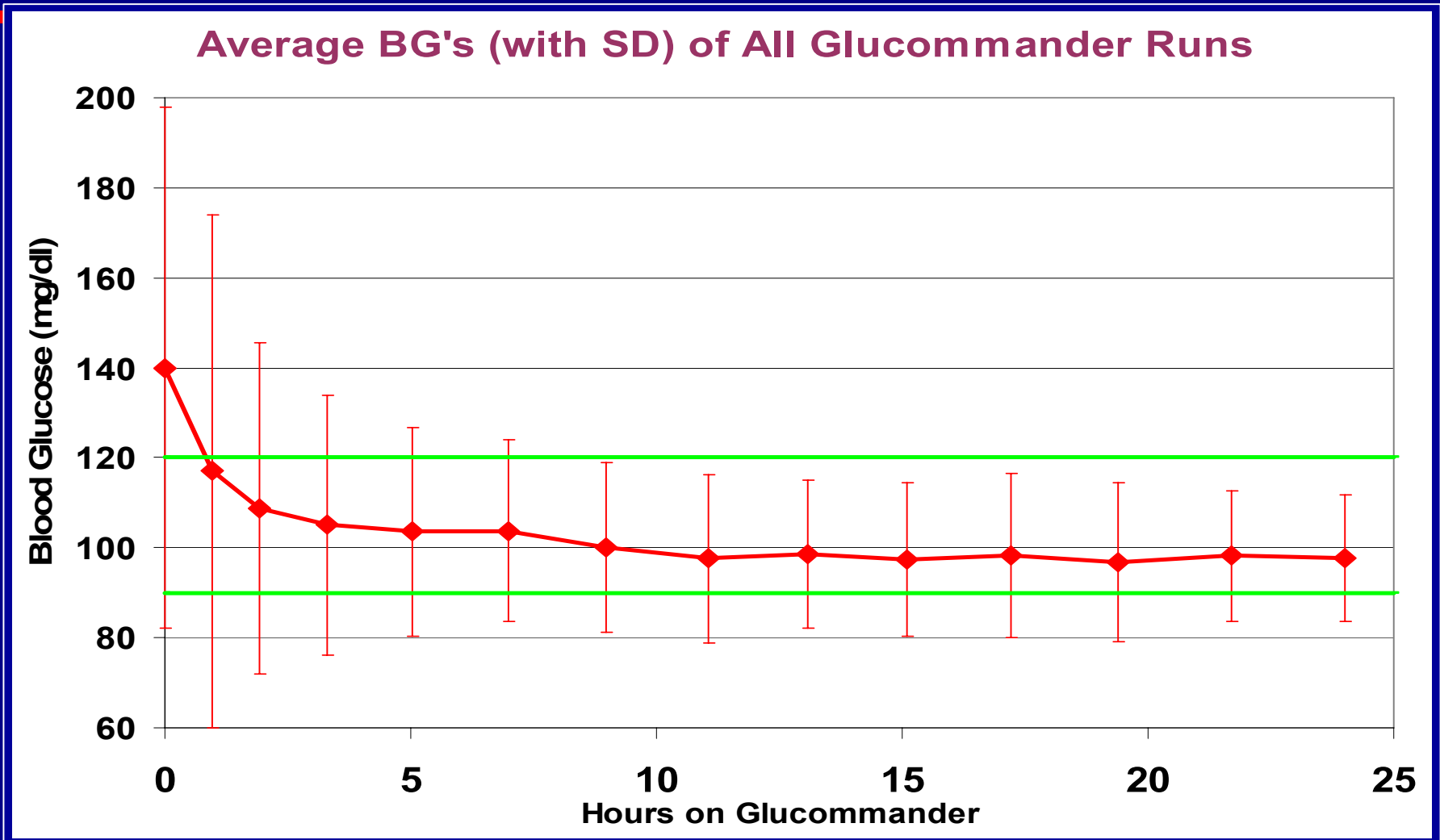
Average and Standard Deviation of of All Runs

1985 to 1998; 5808 runs, 120,618 BG's



Average BG's of All Glycemic CV Surgery Protocol Runs

With Standard Deviation (n = 470 patients; Target 90 to 110 mg/dl)



Physician View – Writing orders

- High Target Glucose (110 mg/dl)
- Low Target Glucose (90 mg/dl)
- Multiplier (0.02 unless post CABG, then 0.06)
- Maximum interval (120 minutes)
- Insulin concentration (1 unit per ml)

Nurse View of Computerized Delivery

- **Computer periodically alarms**
- **Check blood glucose**
- **Enter glucose into computer**
- **Set insulin drip to rate from computer**
- **Eliminates calls to the physician**



Glucommander

Glucommander is a computer expert system for managing insulin drips.

To start the Glucommander, click on the button below and enter parameters as ordered by the physician.

Start new run

Copyright 1984-2005 R. Dennis Steed
Days until expiration: 7



Palm OS™ Emulator



Initial Parameters

Name

ID

Low Target

High Target

Max Interval

Multiplier

Concentration

Keybd

Done

Cancel



Palm OS™ Emulator



Initial Parameters

Name Bruce Bode
ID 123456
Low Target 80
High Target 120
Max Interval 120
Multiplier 0.02
Concentration 0.5

Keybd

Done

Cancel



Palm OS™ Emulator



Enter glucose

210

7	8	9
4	5	6
1	2	3
Clear	0	.
Done		Cancel





Confirm glucose

210

7	8	9
4	5	6
1	2	3
Clear	0	.
Done		Cancel



abcde

12345





Glucommander

Bruce Bode		123456
Low	High	Max Interval
.....80	.....120	.....120

Date	Time	Glucose	Mult
10/23/05	17:23:19	.....210	0.02000
units/hr	ml/hr	Next BG	Remain
.....3.00	.....6.00	18:23:19	00:59:55

Glucose Flow Stop

APPLICATIONS CALCULATOR

MENU FIND

abcde 12345





Glucommander

Bruce Bode		123456
Low	High	Max Interval
.....80	.....120	.....120

Date	Time	Glucose	Mult
10/23/05	17:23:19	210	0.02000
units/hr	ml/hr	Next BG	Remain
.....3.00	.....6.00	18:23:19	00:01:40

Glucose

Flow

Stop





Glucommander

Bruce Bode		123456
Low	High	Max Interval
.....80	.....120	.....120

Date	Time	Glucose	Mult
------	------	---------	------

Information



Check glucose!

OK



Palm OS™ Emulator



Flowsheet

#	Day	Time	Glucose	Mult	Insulin
1	23	17:23	210	0.0200	3.00
2	23	18:24	115	0.0200	1.10
3	23	18:50	105	0.0200	0.90

Return





Glucommander

Bruce Bode		123456
Low	High	Max Interval
.....80	.....120	.....120

Date	Time	Glucose	Mult
10/23/05	18:50:07	.....105	0.02000
units/hr	ml/hr	Next BG	Remain
.....0.90	.....1.80	19:50:07	00:56:38



1 Center Experience with Computerized Algorithm over a 1 year period (2004 to 2005)

- **East Carolina University – 750 bed hospital with 7 ICU's**
- **Glucommander initiated in all ICU patients with BG >140 mg/dL**
- **7 FTE's hired to implement the program**
- **Average BG went from 167 to 126 mg/dl**
- **LOS decreased in ICU by 1 day; in Hospital by 0.3 days**
- **No central line infections**
- **Net savings to hospital 2 million dollars (470% Return on Investment)**

Piedmont Hospital Experience with Glucommander in CV Surgery (n = 470)

- **Mandated use in CV surgery patients since 2-1-06**
- **All CV patients screened for diabetes with BG and A1C**
- **28% of patients had known diabetes (10% insulin treated)**
- **52% had known DM or A1C >6%**
- **Glucommander initiated in all patients with BG >140 mg/dL x1 or BG >110 mg/dL x 2**

Piedmont Hospital Experience with Glucommander in CV Surgery

- **96% of patients needed IV insulin post op**
- **Mean BG <120 mg/dL in 2.7 hours;
average BG 107 mg/dL**
- **55% were transitioned to basal bolus therapy;
23% went home on insulin**
- **LOS decreased in hospital by 1.4 days
(7.3 to 5.9 days)**
- **Net savings to hospital: 2.7 million dollars**

Converting to SC insulin

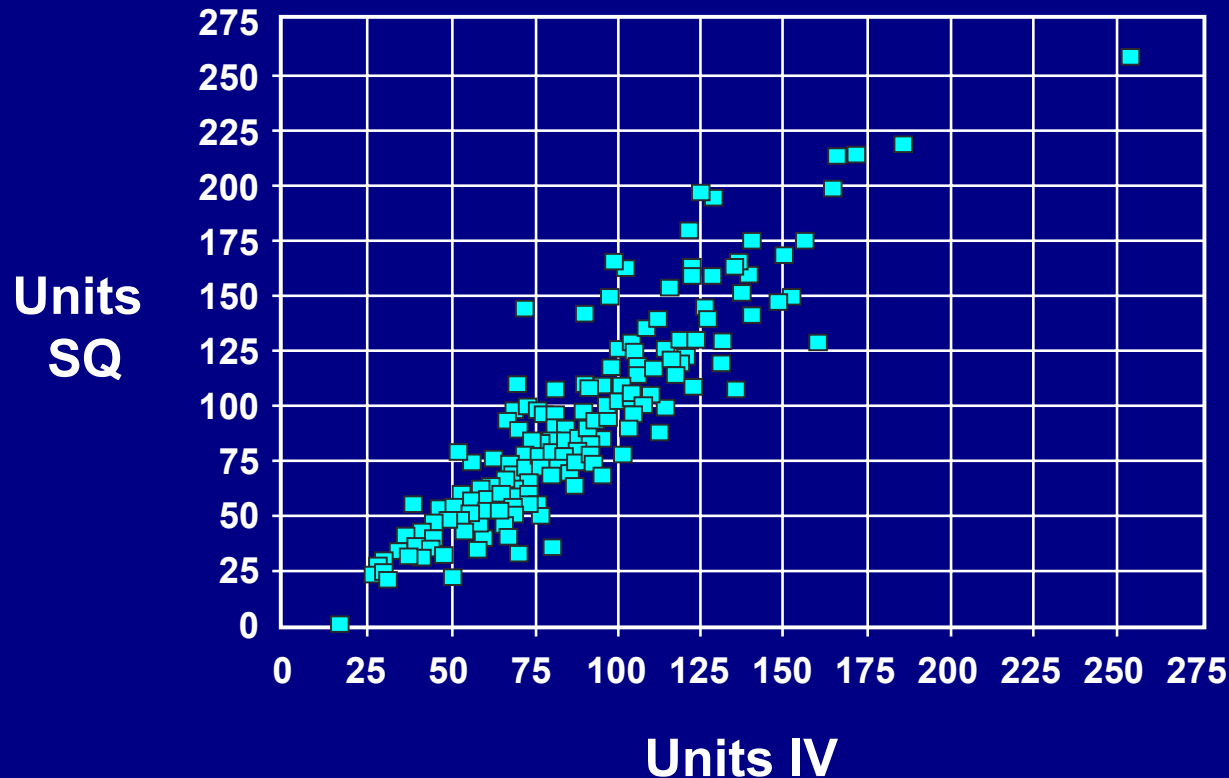
- If More than 0.5 u/hr IV insulin required with normal BG, start long-acting insulin (glargine)

Exception: if no prior DM and normal A1C, may not need SC insulin

- Must start SC insulin at least 1 to 2 hours before stopping IV insulin
- Some centers start long-acting insulin on initiation of IV insulin or the night before stopping the drip

Intravenous Insulin Infusion Under Basal Conditions Correlates Well With Subsequent Subcutaneous Insulin Requirement

Total Intravenous vs. Subcutaneous 24-hour Insulin Requirements, units



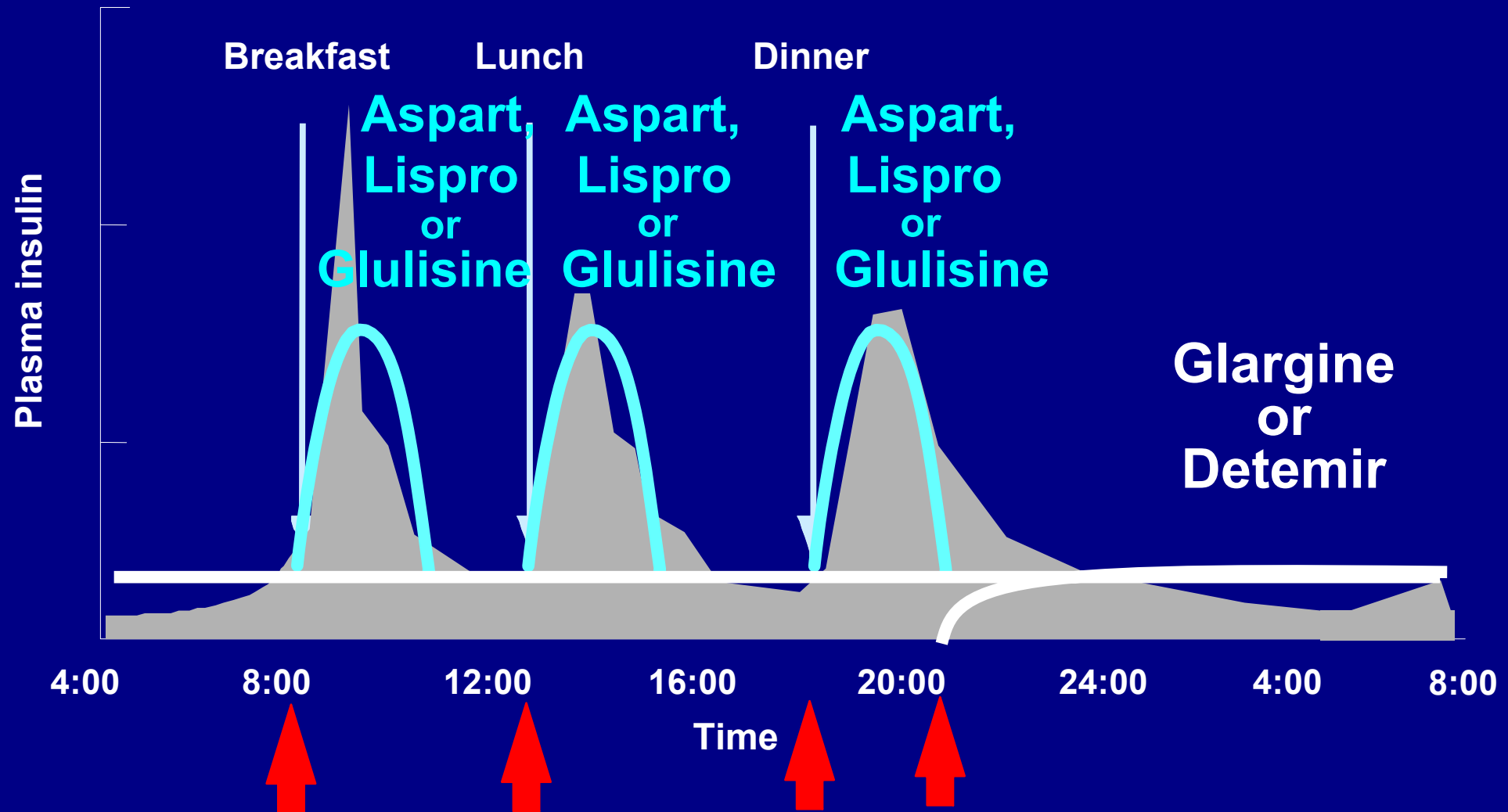
Converting from IV to SC insulin

- Establish 24 hr Insulin Requirement
 - Extrapolate from average over last 4 hr if stable
- Give One-Half Amount As Basal
- Give One-Half Amount As Total Bolus
 - Give post meal based on portion of food consumed or
 - Give 1.5 units Rapid-acting for every CHO consumed
- Monitor a.c. tid, hs, and 3 am
- Correction Bolus for All BG >140 mg/dl

Transition from Multiplier Method to Subcutaneous Insulin

- 24-hour insulin requirement
 - Multiplier X 1000 = TDD
- Give one-half TDD as basal (Glargine)
 - Multiplier X 500 = BI
- Give rapid acting insulin based on CHO consumed
 - $0.5 / \text{multiplier} = \text{CIR (Gms CHO / unit)}$ or
 - $30 \times \text{multiplier} = \text{units / CHO exchange}$
- Monitor BG a.c. t.i.d., h.s., and 3 am
- Correct all BG > 140 mg/dL
 - $(\text{BG} - 100) / (1.7 / \text{multiplier})$

Basal/Bolus Treatment Program with Rapid-acting and Long-acting Analogs



Initiating SC Basal Bolus

- Starting total dose = $0.5 \times \text{wgt. in kg}$
Wt. is 100 kg; $0.5 \times 100 = 50$ units
- Basal dose (glargine) = 50% of starting dose at HS
 $0.5 \times 50 = 25$ units at HS
- Bolus doses (Rapid-acting I) = 50% of starting dose
 $0.5 \times 50 = 25$ divided by 3 = ~ 8 units pc (tid)
- Correction bolus = $(\text{BG} - 100) / \text{CF}$, where
 $\text{CF} = 1700 / \text{total daily dose}$; $\text{CF} = 30$

Protocol for Treatment of Hypoglycemia

- Any BG <60 mg/dl: $D50 = (100 - BG) \times 0.4 \text{ ml IV}$
- Recheck in 15 minutes and retreat if needed
- If eating, may use 15 gm of rapid CHO
- Do Not Hold Insulin When BG Normal

Diabetic Ketoacidosis Adult Guidelines

1. Place patient on DKA Pathway until DKA resolved ($\text{CO}_2 > 18$ or Venous pH > 7.3 or Anion Gap < 14)
2. Diet: NPO
3. Consult Nutritional Services for diet, so when DKA resolves patient specific subcutaneous insulin can begin
4. Strict I & O
5. Vital signs every 2 hr x 4 or until DKA resolved then every 4 hr
6. Continuous cardiac monitoring
7. Initial Labs/Diagnostics
 _____ EKG if over age 40 or as indicated by: (*co-morbid disease state, and/or labs and diagnostics*)
 _____ Complete Metabolic Profile, CBC with differential, lipid profile, venous pH, Hemoglobin A1C, & urinalysis
 _____ If temp is greater than 101°F or greater than 20% Bands present in CBC, obtain blood cultures x 2, urine C&S, and Chest X-ray
 _____ Other Labs/Diagnostics: _____
8. Follow up Lab/Diagnostics until DKA resolved:
 _____ Basic Metabolic Profile every ___ hour
 _____ Phosphorus
 _____ Venous pH every ___ hour
 _____ Anion gap every ___ hour
9. IV Fluids: Administer NS 1 to 2 liters for first 4 hours (may need to adjust type & rate of fluid administration in the elderly and in patients with CHF or renal failure). Normal Na^+ levels are 135-145 meq/L. For subsequent fluid infusion, please refer to the chart below.

Serum Sodium (Na^+) level	IV Fluid	mEq K^+ to add	Rate of Infusion
Low Serum Na^+	0.9% NaCl	See Chart Below	7-14 ml/kg/hr based on hydration status
Normal Serum Na^+	0.45% NaCl	See Chart Below	7-14 ml/kg/hr based on hydration status
High Serum Na^+	0.45% NaCl	See Chart Below	7-14 ml/kg/hr based on hydration status

When plasma BG reaches a level of 250mg/dl or less, begin D5/ ½ NS at 100-200ml/hr (as stated in the IV infusion standing order set)

Initial IV Fluid _____ with _____ mEq K^+ at _____ ml/hr
 (see No. 9 above) (see No. 10 below) (see No. 9 above)

10. Serum Potassium (K^+) (If there is persistent acidosis due to hyperchloremia, consider using Potassium Phosphate instead of Potassium Chloride)

Serum K^+	mEq K^+ To Administer
Greater than 5.4 mEq/L	DO NOT GIVE K^+ but check level every 2 hours
Between 4.3 and 5.4 mEq/L	30 mEq K^+ in each liter of IV fluid to keep level 4.0-5.0 mEq/L
Between 3.3 and 4.2 mEq/L	40 mEq K^+ in each liter of IV fluid to keep level 4.0-5.0 mEq/L
Less than 3.2 mEq/L	HOLD INSULIN and give 40 mEq of K^+ in 1 liter of fluid over 1 hour (smaller volume can be used only if fluid compromised).. Retest and repeat until $\text{K}^+ > 3.2$

Notify physician if corrective measures still result in serum K^+ greater than 5.4 or less than 3.2

11. Insulin Insulin: Follow IV Insulin Protocol
12. BICARBONATE (for adult use only)
 - * If arterial pH is less than 7, may consider administration of 100ml NaHCO_3
 - * Check acid-base 30 minutes later & may repeat if pH is still less than 7
 - * Bicarbonate should not be administered if K^+ is less than 3.6
13. Continue with Insulin IV infusion standing orders inclusive of the subcutaneous insulin transition process.
14. Notify diabetes educator of admission.

Time: _____ Date: _____ MD Signature _____

GLYCEMIC CONTROL FOR THE WOMAN IN LABOR AND DELIVERY

Column Chart

- Check Blood Glucose (BG) every one (1) hour for those patients on insulin and for those patients with BG levels greater than 120mg/dl. All other patients should have their BG monitored every 2 hours.**

Blood Glucose	Action To Be Taken	Calculations
70 mg/dl or less	Administer D50 IV Push	Refer to Figure 2 on Columnar Chart
70 – 100 mg/dl	No Action Necessary	None Necessary
101 – 120 mg/dl	Supplement with either: 1) Regular insulin if administering IV 2) Rapid acting analog for Subcutaneous.	Units of Insulin = $\frac{BG - 80}{30}$
120 mg/dl or more or if nausea, vomiting or illness is present.	Begin insulin drip with target range of 70-100	Refer to Columnar Chart Figure 1 beginning with column 3

IV Fluids:

- D5 / ½ NS with 20mEq of K+ /Liter at 100ml/hour
- D5 / _____ with _____ mEq K+/Liter at 100ml/hour

Alert Surgical Suite for potential Caesarian Birth

At Delivery and Cut of Cord:

- Discontinue insulin drip
- Begin IV Fluid:
 - D5 / ½ NS with 20mEq of K+ /Liter at 100ml/hour
 - D5 / _____ with _____ mEq K+/Liter at 100ml/hour
- Call physician with Blood Glucose levels one hour post delivery

Resuming Insulin

- Resume insulin at pre-pregnancy rate when glucose is greater than 100mg/dl, If rate is not known, calculate amount based on weight (Refer to subcutaneous insulin guideline)
- For those patients who were not on insulin prior to pregnancy, use supplemental rapid-acting insulin subcutaneously if Blood Glucose exceeds 140mg/dl using formulae $(BG-100)/40$
- Check Blood Glucose every 4 hours until patient is eating
- Refer to Nutrition Services to determine kcal/day
- Once patient is eating: Check Blood Glucose before each meal time, bedtime and at 3AM and refer to subcutaneous insulin guideline

See Back for Special Considerations

DIRECTIONS:

IV Insulin Dosing for Labor and Delivery Patients With Diabetes

Start infusion using the drip rate (ml/hr) in COLUMN No. 3 for the current Blood Glucose Level	Blood Glucose Levels	column 1 (ml/hr)	column 2 (ml/hr)	column 3 (ml/hr)	column 4 (ml/hr)	column 5 (ml/hr)	column 6 (ml/hr)	column 7 (ml/hr)	column 8 (ml/hr)	column 9 (ml/hr)	column 10 (ml/hr)	column 11 (ml/hr)	column 12 (ml/hr)	column 13 (ml/hr)	column 14 (ml/hr)	column 15 (ml/hr)	column 16 (ml/hr)
To determine the new drip rate, compare the current BG Level to the previous BG Level.	Over 450	4.4	8.8	13.2	17.6	22	26.4	30.8	35.2	39.6	44	48.4	52.8	57.2	61.6	66	70.4
	385-450	3.6	7.2	10.8	14.4	18	21.6	25.2	28.8	32.4	36	39.6	43.2	46.8	50.4	54	57.6
	326-384	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
	290-333	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40
If current BG level is lower than the previous BG level, STAY IN THE SAME COLUMN	251-289	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21	23.1	25.2	27.3	29.4	31.5	33.6
	217-250	1.7	3.4	5.1	7.2	8.5	10.2	11.9	13.6	15.3	17	18.7	20.4	22.1	23.8	25.5	27.2
	188-216	1.4	2.8	4.2	5.6	7	8.4	9.8	11.2	12.6	14	15.4	16.8	18.2	19.6	21	22.4
	163-187	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	10.8	12	13.2	14.4	15.6	16.8	18	19.2
If current BG level has not dropped (is the same or higher), MOVE 1 COLUMN TO THE RIGHT	141-162	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	121-140	0.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	8.8	9.6	10.4	11.2	12	12.8
	111-120	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	6.6	7.2	7.8	8.4	9	9.6
If more than 16 columns are needed: column 17 = 16+1, etc.	106-110	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
	101-105	0.4	0.9	1.3	1.8	2.2	2.7	3.1	3.6	4	4.5	5	5.4	5.8	6.3	6.7	7.2
When hourly BG is 70-100, stay in the same column to determine the new drip rate. Do Not Change Columns	96-100	0.4	0.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4	4.4	4.8	5.2	5.6	6	6.4
	91-95	0.3	0.7	1	1.4	1.7	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	4.9	5.3	5.6
	86-90	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3	3.3	3.6	3.9	4.2	4.5	4.8
	80-85	0.2	0.5	0.7	1	1.2	1.5	1.7	2	2.3	2.5	2.7	3	3.2	3.5	3.7	4
	75-79	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	3.2
	70-74	0.1	0.3	0.4	0.6	0.7	0.9	1	1.2	1.3	1.5	1.7	1.8	1.9	2.1	2.2	2.4
If BG is less than 70 Move 1 Column To The Left and refer to Figure no. 2 for D50 treatment.	65-69	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6
	60-64	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
	Under 60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

(Figure No. 2)

BG	D50W	ACTION
66-69	10 ml IV push	* If you have not moved 1 column to the left as directed above, do so now * Recheck BG in 15 minutes * Repeat as necessary
53-65	15ml IV push	
42-52	20ml IV push	
30-41	25ml IV push	
Under 30	30ml IV push	

Hospital Diabetes Plan

What Can We Do For Patients Admitted To Hospital?

- Pathway Protocols For All Hyperglycemia and Diabetes Patients
- Finger Stick BG ac qid on ALL Admissions with BG >140 mg/dL or history of DM or high risk (ICU, Cardiac, Vascular, CVA, Steroids, etc)
- Check Hemoglobin A1C in all hyperglycemic patients

Hospital Diabetes Plan

Protocol for Insulin in Hospitalized Patient

- Treat Any Patient With BG >140 mg/dL With Insulin
 - Treat Any BG >140 mg/dL with Rapid-acting Insulin (BG-100) / (3000 / wt kg) or 1700 / total daily insulin
 - Treat Any Recurrent BG >180 mg/dL with IV Insulin if failing SC therapy or >110 to 140 mg/dL if NPO, acute MI, perioperative, ICU, or >100 mg/dL if pregnant
- If More than 0.5 u/hr IV Insulin Required with Normal BG Start Long Acting Insulin

Hospital Diabetes Plan

Protocol for Insulin in Hospitalized Patient

- Daily Total: Pre-Admission or Weight (kg) x 0.5 u
 - 50% as Glargine (Basal)
 - 50% as Total Rapid-acting insulin (Bolus)
 - Give in Proportion to Meal's CHO Eaten
- BG >140 mg/dl: (BG-100) / CF
 - CF = 1700 / Total Daily Insulin or 3000 / Wt (kg)

Do Not Use Sliding Scale As Only Diabetes Management

Diabetes Education and Discharge Planning

- Diabetes service is contacted for all patients new to SC insulin.
- Discharge planning is initiated.
- Instruct Patient in Monitoring and Recording
See That Patient Has Meter on Discharge
- Decide on Case Specific Program for Discharge
- Arrange Early F/U with PCP

Conclusion

- Our journey is not over, it has only begun
- We must normalize glucose in all hospital patients
- By implementing, assessing and revising protocols/pathways for hyperglycemic management, we can achieve this ultimate goal of normal glycemia

For Further Information

- Guidelines

- American Academy of Clinical Endocrinology: www.aace.com/pub/ICC/inpatientStatement

- Protocols

- Georgia Hospital Association: www.gha.org/pha/health/diabetes/index.asp
- Atlanta Diabetes Associates: www.adaendo.com
- Glucommander: www.glucommander.com