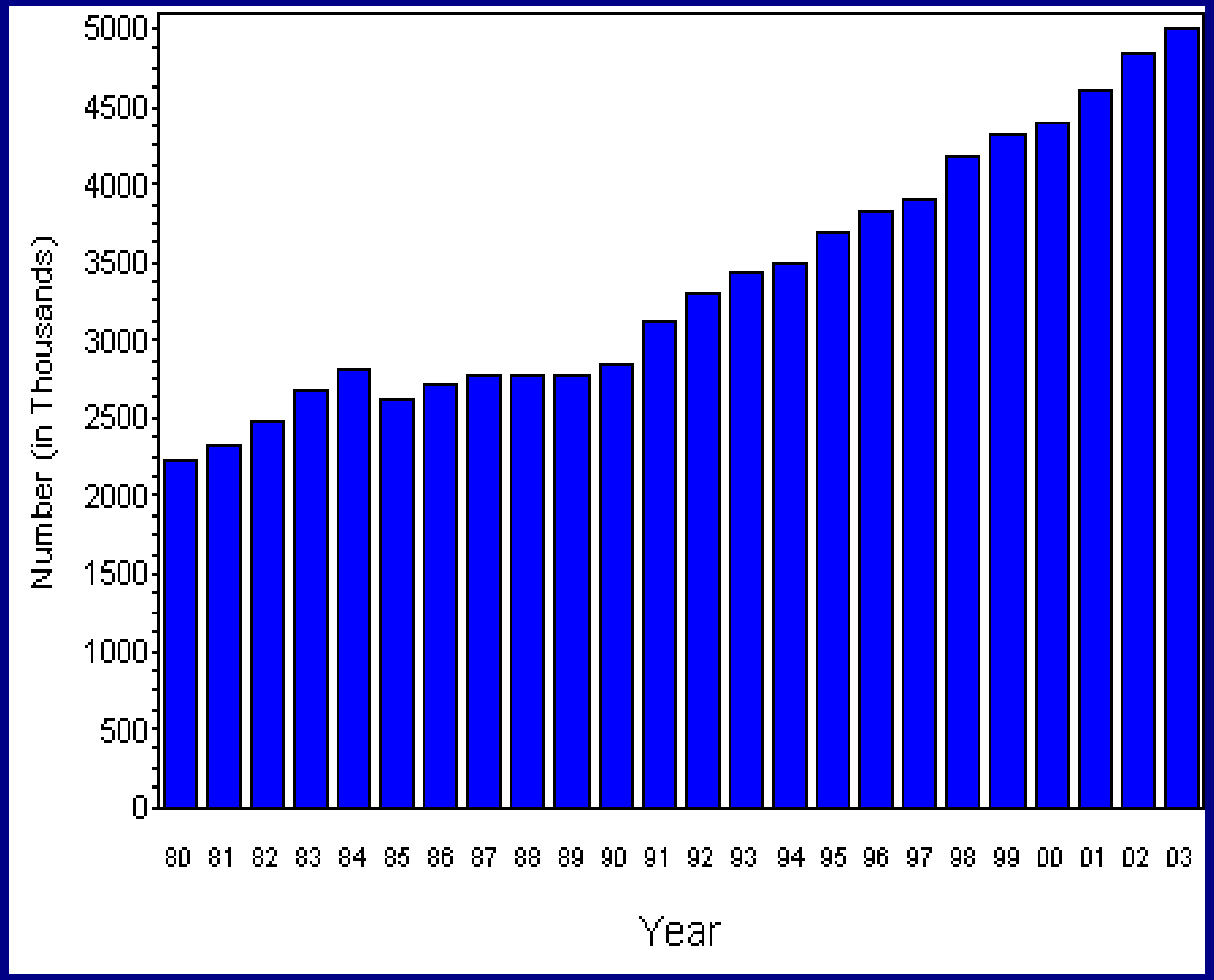
In - Hospital Diabetes Care

A review and personal experience

Hyperglycemia in the Hospital

The Problem

Hospitalizations with Diabetes



http://www.cdc.gov/diabetes/statistics/dmany/fig1.htm

Prevalence of Hyperglycemia

- Umpierrez et al (1998) examined the prevalence of hyperglycemia (fbg > 126 or rbg > 200 X 2) in 2030 patients

	Prevalence	Hosp Mortality
Known diabetes	26%	3%
New hyperglycemia	12%	16%
Not hyperglycemic	62%	1.7%

Associated morbidities

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

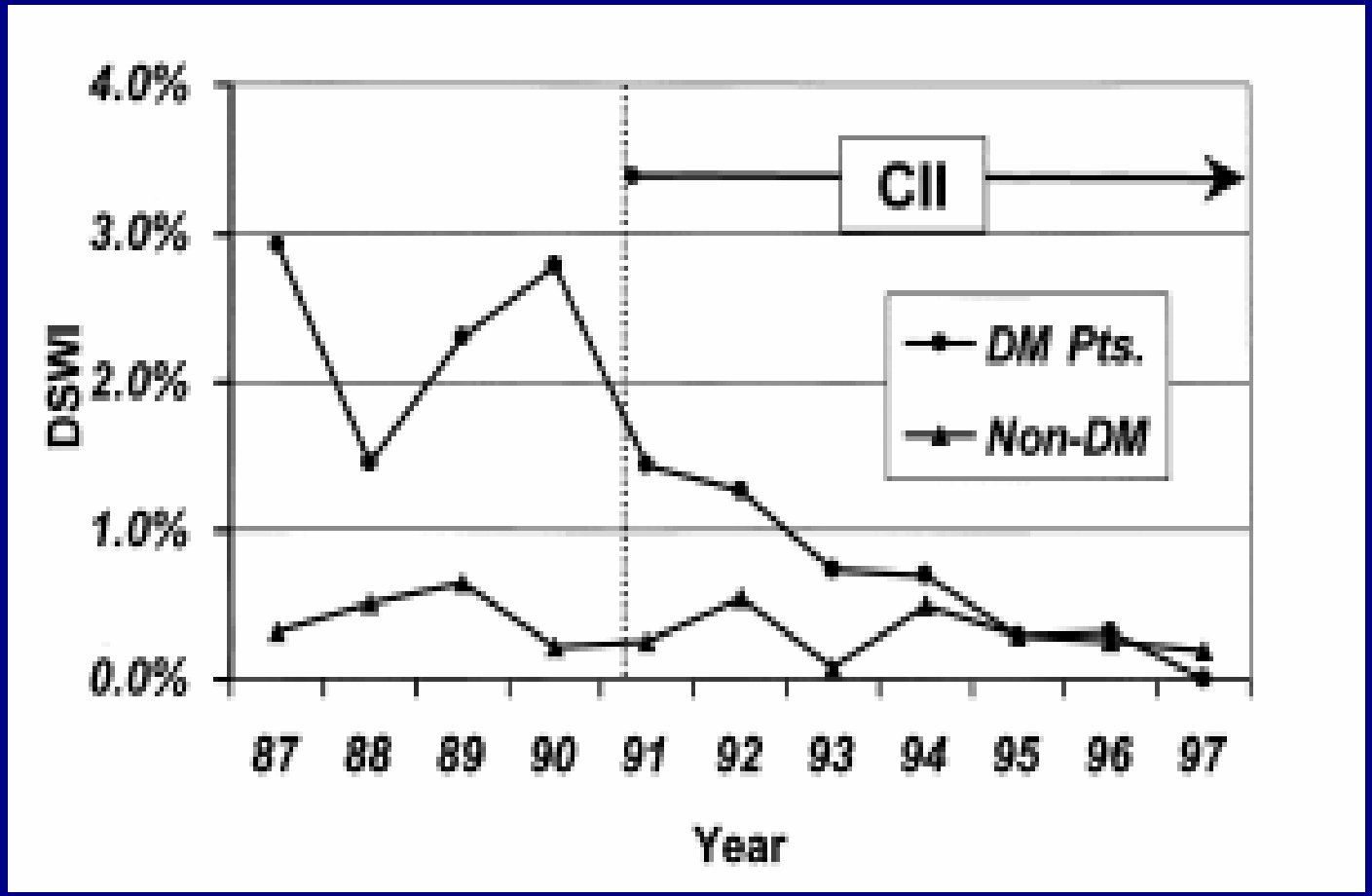
Associated Costs

- Integris Baptist Medical Center Oklahoma City 1997
  - No diabetes – 3.4 days
  - Uncoded diabetes – 10.6 days
  - Primary diabetes – 6.4 days
  - Secondary diabetes – 5.9 days

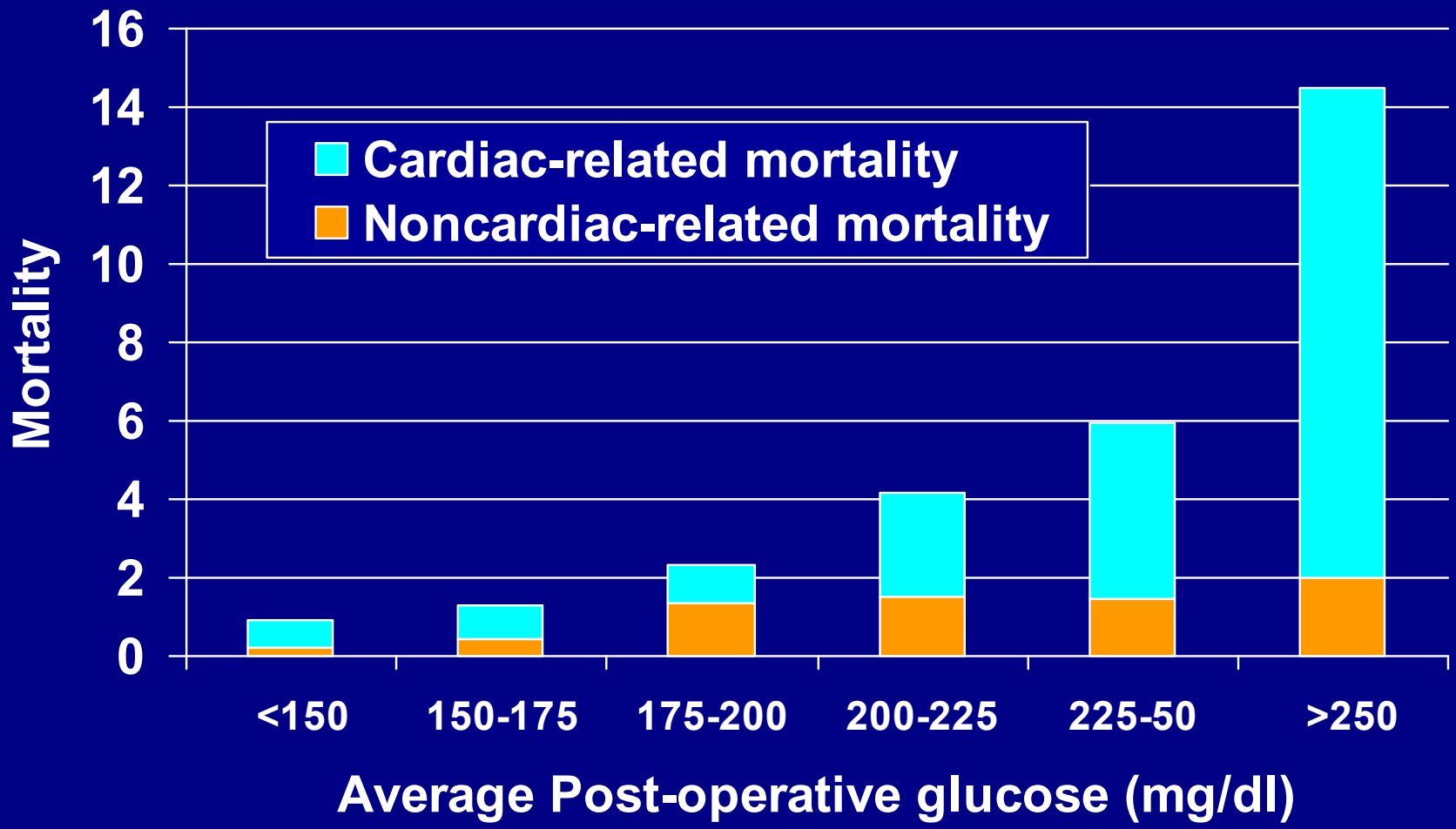
The Value of Intervention

Recently Recognized

Sternal Wound Infection



Mortality of DM Patients Undergoing CABG



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

Costs of Hyperglycemia in the Hospital

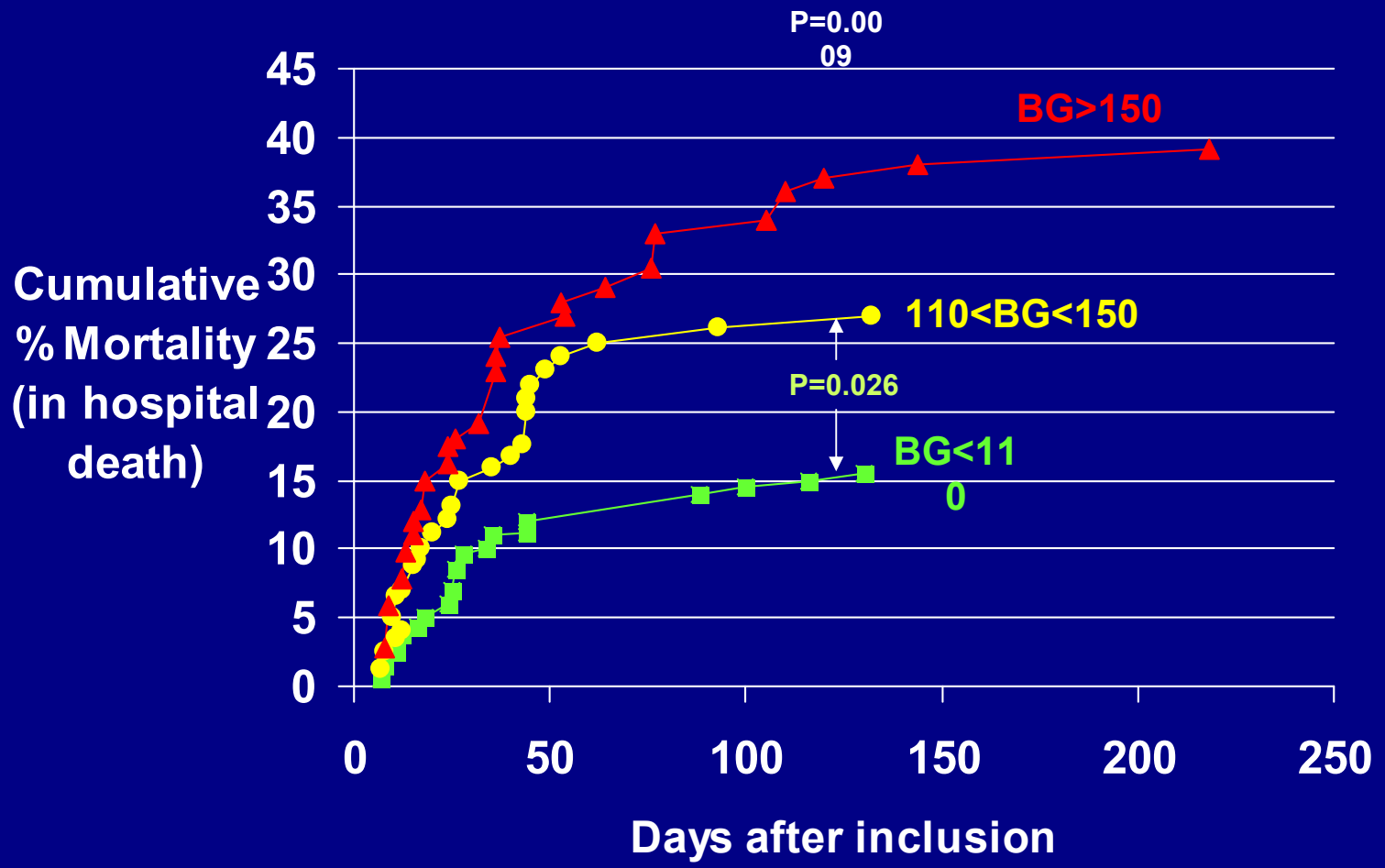
For each 50 mg/dL rise in glucose:

- **Length of Stay increases by 0.76 days**
- **Hospital Charges increase by $2824**
- **Hospital Costs increase by $1769**

Furnary et al Am Thorac Surg 2003;75:1392-9

Surgical ICU Mortality

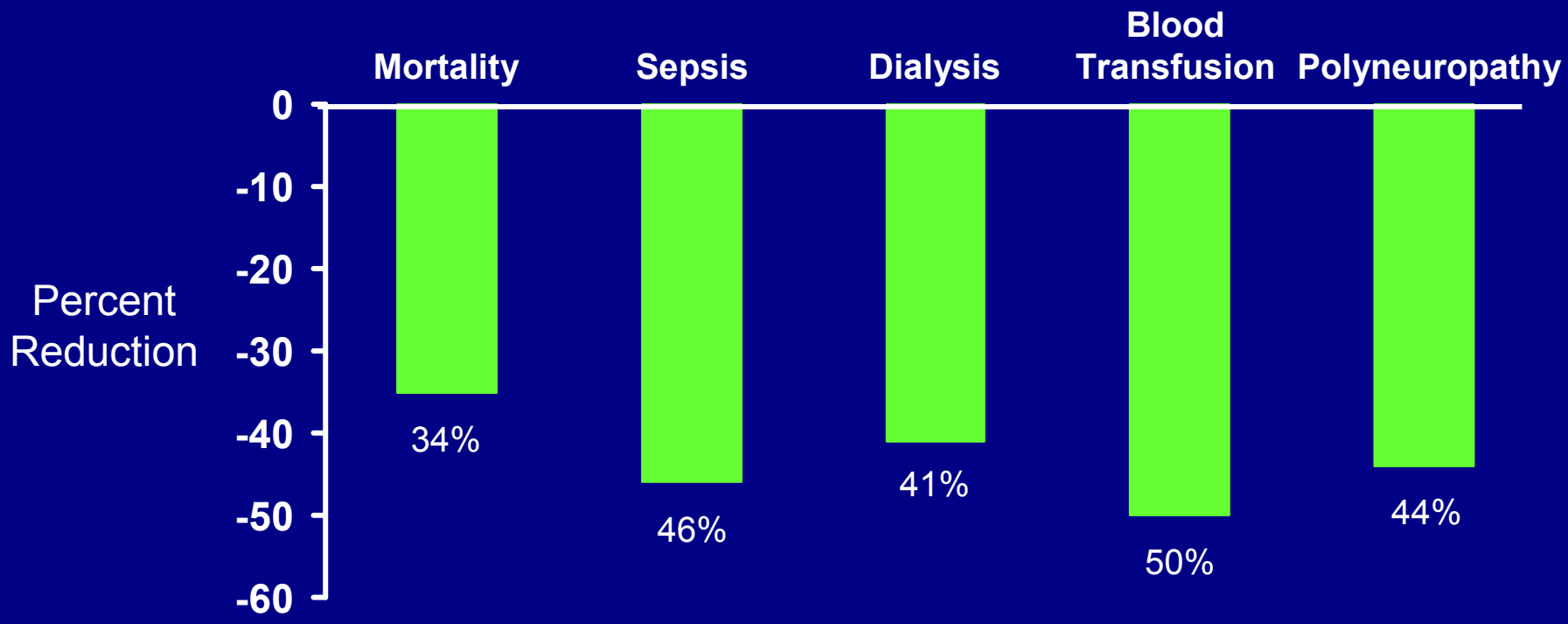
Effect of Average BG



Van den Berghe et al (Crit Care Med 2003; 31:359-366)

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

1548 patients: 153 vs 103 mg/dl



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

Goals of Management - AACE

	Premeal	Postmeal	L&D
Critical	110	110	
Non Critical	110	180	
Pregnancy	100	120	100

Reaching Goal

Treatment Options

- Medications – levels of care
  - Intravenous insulin (for the very sick)
  - Subcutaneous insulin (most patients)
  - Oral Agents (transitioning to home?)

Intravenous Insulin

- Indications
  - Hyperglycemic emergencies DKA / HHNK
  - Perioperative
  - Critical care
  - Dose finding

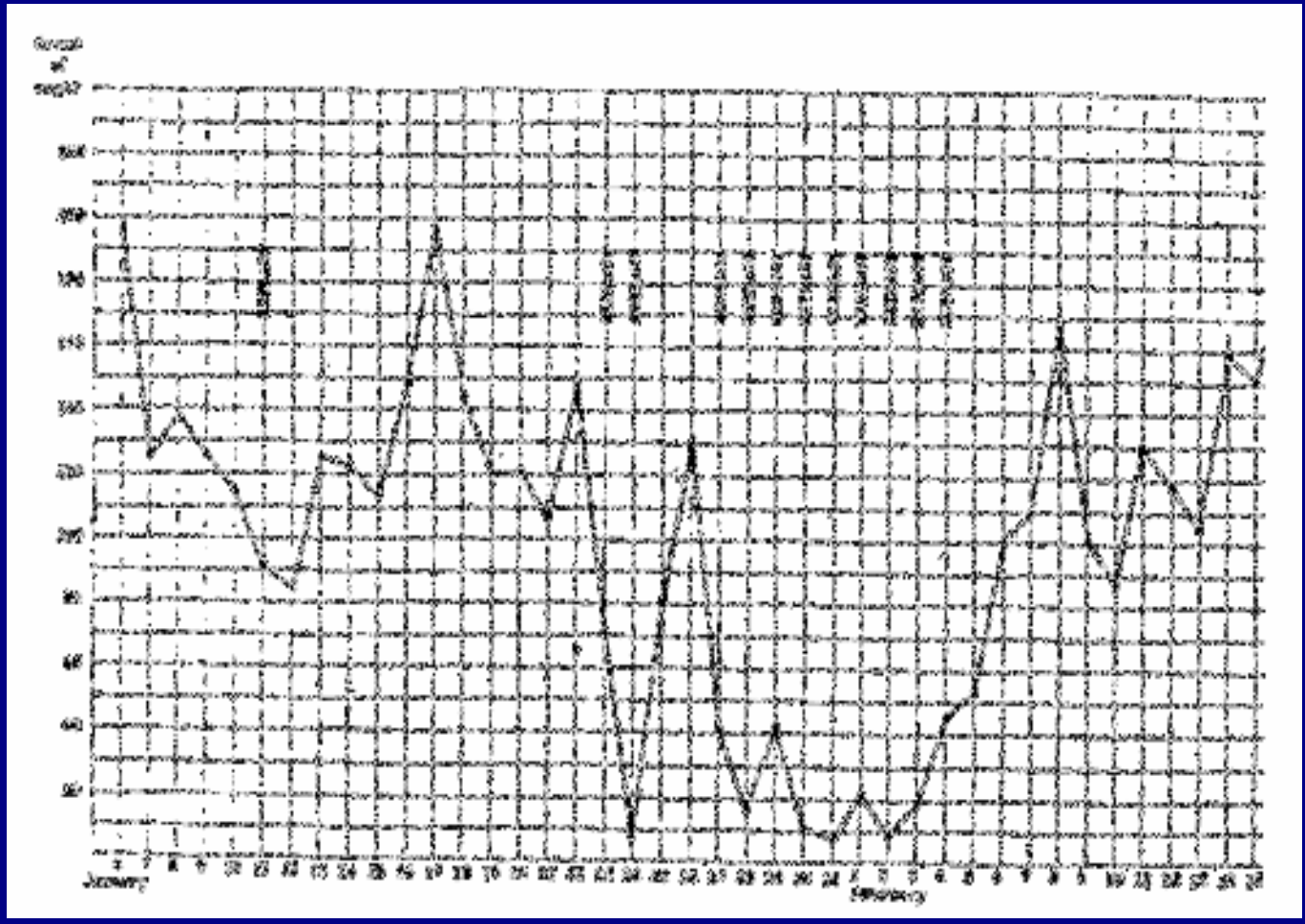
Subcutaneous Insulin

- Majority of hospitalized patients
- Programmed doses
  - Fixed doses
  - Basal / bolus with carbohydrate counting
- Corrective doses
  - Based on deviation from target

Sliding Scale

- Intermittent use of insulin only in reaction to hyperglycemia
- Frequently used
- Not effective

Early Demonstration Failure to Control Hyperglycemia with Intermittent Injection



Oral Agents

- Often contraindicated and problematic in acute care patients
- May have a role in relatively minor illness or as a transition to home therapy

Nutrition

- Good nutrition is important for healing and recovery from illness
- Feeding, particularly carbohydrates, aggravates hyperglycemia
- Critical to balance nutrition and insulin

Intravenous Insulin Algorithms

Personal Experience

Insulin Drips in the Hospital

- The need

  Safe, standardized methods of achieving tight glycemic control

- The problem

  Balancing safety, practicality and efficacy

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.

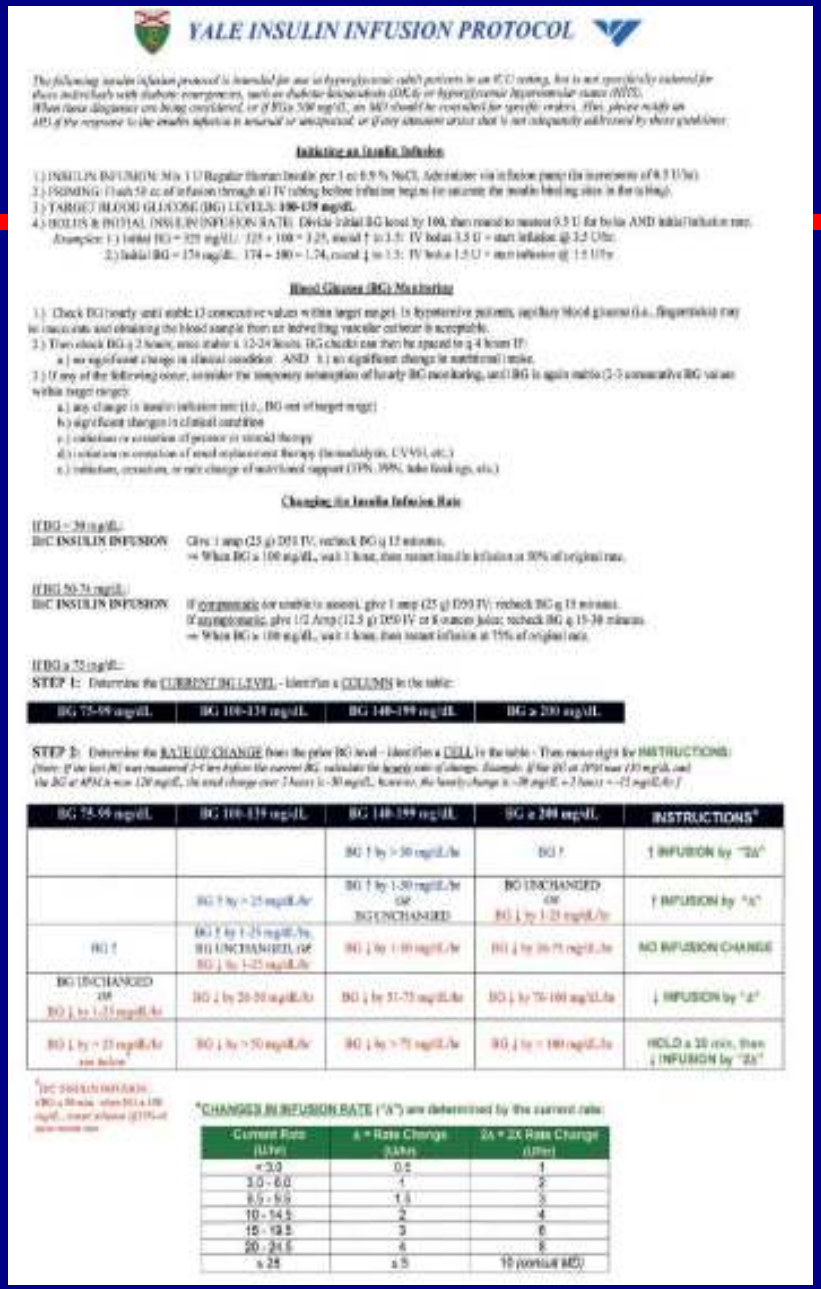
3. Start infusion by pump piggyback to maintenance intravenous line as shown in Appendix Table 1.
4. Test blood glucose level by finger stick method or arterial line drop sample. Frequency of blood glucose testing is as follows:
   a. When blood glucose level greater than 200 mg/dL, check every 30 minutes.
   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

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

Yale Protocol



YALE INSULIN INFUSION PROTOCOL

The following insulin infusion protocol is intended for use in hyperglycemic adult patients in an ICU setting. It is not specifically indicated for those individuals with diabetic emergencies, such as diabetic ketoacidosis (DKA) or hyperglycemic hyperosmolar states (HHS). When these diagnoses are being considered, or if BGs > 500 mg/dL, an MD should be consulted for specific orders. Also, please notify an MD if the response to the insulin infusion is unusual or unexpected, or if any situation arises that is not adequately addressed by these guidelines.

Initiating an Insulin Infusion

1.) INSULIN INFUSION: Mix 1 U Regular (human) insulin per 1 cc 0.9 % NaCl. Administer via infusion pump (to increments of 0.1 U/hr).
2.) PRIMING: Flush 50 cc of infusion through all IV tubing before infusion begins (to saturate the insulin binding sites in the tubing).
3.) TARGET BLOOD GLUCOSE (BG) LEVELS: **100-139 mg/dL**
4.) BOLUS & INITIAL INSULIN INFUSION RATE: Divide initial BG level by 100, then round to nearest 0.5 U for bolus AND initial infusion rate.
Examples: 1.) Initial BG = 325 mg/dL: 325 ÷ 100 = 3.25, round ↑ to 3.5: IV bolus 3.5 U + start infusion @ 3.5 U/hr;
2.) Initial BG = 174 mg/dL: 174 ÷ 100 = 1.74, round ↓ to 1.5: IV bolus 1.5 U + start infusion @ 1.5 U/hr

Blood Glucose (BG) Monitoring

1.) Check BG hourly until stable (3 consecutive values within target range). In hypotensive patients, capillary blood glucose (i.e., fingerstick) may be inaccurate and obtaining the blood sample from an indwelling vascular catheter is acceptable.
2.) Then check BG q 2 hours, once stable x 12-24 hours, BG checks can then be spaced to q 4 hours IF:
a.) no significant change in clinical condition AND b.) no significant change in nutritional intake.
3.) If any of the following occur, consider the temporary resumption of hourly BG monitoring, until BG is again stable (3-5 consecutive BG values within target range):
a.) any change in insulin infusion rate (i.e., BG out of target range)
b.) significant changes in clinical condition
c.) initiation or cessation of pressor or steroid therapy
d.) initiation or cessation of renal replacement therapy (hemodialysis, CVVH, etc.)
e.) initiation, cessation, or rate change of nutritional support (TPN, PPN, tube feedings, etc.)

Changing the Insulin Infusion Rate

IF BG < 50 mg/dL:
D50 INSULIN INFUSION — Give 1 amp (25 g) D50 IV, recheck BG q 15 minutes.
⇒ When BG ≥ 100 mg/dL, wait 1 hour, then restart insulin infusion at 50% of original rate.

IF BG 50-74 mg/dL:
D50 INSULIN INFUSION — If symptomatic (or unable to assess), give 1 amp (25 g) D50 IV; recheck BG q 15 minutes.
If asymptomatic, give 1/2 Amp (12.5 g) D50 IV or 8 ounces juice; recheck BG q 15-30 minutes.
⇒ When BG ≥ 100 mg/dL, wait 1 hour, then restart infusion at 75% of original rate.

IF BG ≥ 75 mg/dL:
STEP 1: Determine the CURRENT BG LEVEL - Identify a COLUMN in the table:

BG 75-99 mg/dL	BG 100-139 mg/dL	BG 140-199 mg/dL	BG ≥ 200 mg/dL

STEP 2: Determine the RATE OF CHANGE from the prior BG level - Identify a CELL in the table - Then move right for INSTRUCTIONS:
(Note: If the last BG was measured 2-3 hrs before the current BG, calculate the hourly rate of change. Example: If the BG at 0930 was 130 mg/dL and the BG at 0NOON was 120 mg/dL, the total change over 3 hours is -10 mg/dL, however, the hourly change is -10 mg/dL ÷ 3 hours = ~3 mg/dL/hr.)

BG 75-99 mg/dL	BG 100-139 mg/dL	BG 140-199 mg/dL	BG ≥ 200 mg/dL	INSTRUCTIONS*
		BG ↑ by > 30 mg/dL/hr	BG ↑	↑ INFUSION by "2Δ"
	BG ↑ by > 25 mg/dL/hr	BG ↑ by 1-30 mg/dL/hr OR BG UNCHANGED	BG UNCHANGED OR BG ↓ by 1-25 mg/dL/hr	↑ INFUSION by "Δ"
BG ↑	BG ↑ by 1-25 mg/dL/hr, BG UNCHANGED, OR BG ↓ by 1-25 mg/dL/hr	BG ↓ by 1-50 mg/dL/hr	BG ↓ by 26-75 mg/dL/hr	NO INFUSION CHANGE
BG UNCHANGED OR BG ↓ by 1-25 mg/dL/hr	BG ↓ by 26-50 mg/dL/hr	BG ↓ by 51-75 mg/dL/hr	BG ↓ by 76-100 mg/dL/hr	↓ INFUSION by "Δ"
BG ↓ by > 25 mg/dL/hr OR see below†	BG ↓ by > 50 mg/dL/hr	BG ↓ by > 75 mg/dL/hr	BG ↓ by > 100 mg/dL/hr	HOLD x 30 min, then ↓ INFUSION by "2Δ"

†D50 INSULIN INFUSION: if BG ≤ 50 mg/dL, then BG ≥ 100 mg/dL, restart infusion @ 75% of most recent rate

*CHANGES IN INFUSION RATE ("Δ") are determined by the current rate:

Current Rate (U/hr)	Δ = Rate Change (U/hr)	2Δ = 2X Rate Change (U/hr)
< 3.0	0.5	1
3.0 - 6.0	1	2
6.5 - 9.5	1.5	3
10 - 14.5	2	4
15 - 19.5	3	6
20 - 24.5	4	8
≥ 25	≥ 5	10 (consult MD)

Solution - Glucommander

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

Glucommander History

- 1982 Paul Davidson develops protocols for intravenous insulin
- 1984 Dennis Steed writes Glucommander program based on Davidson's protocols
- Used in multiple hospitals throughout US
- Currently on a Palm platform

INSPIRATION FOR GLUCOMMANDER

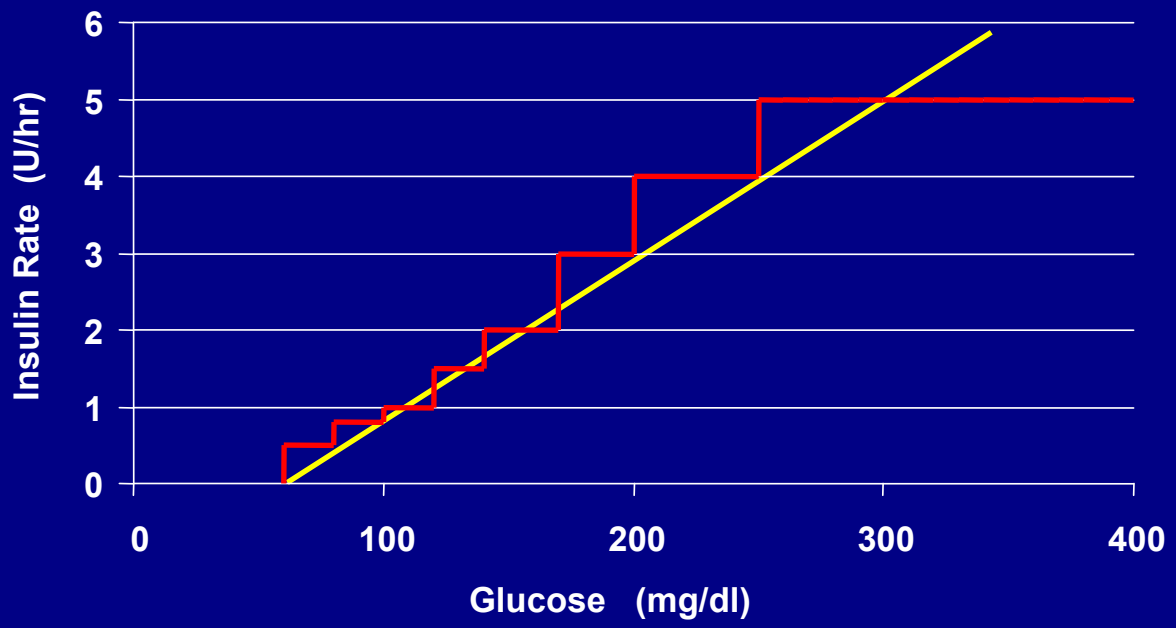
Practical Closed Loop Insulin Delivery

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.; Saint Louis, Missouri

Ann Int Med 1982 ;97:210-214

Slope = 0.02 = "Multiplier"



Glucommander Algorithm

- Insulin (u/hr) = multiplier x (BG – 60)
- Blood glucose checked periodically
  - Variable interval based on BG stability
  - Typically hourly
- Multiplier adjusted to seek target range

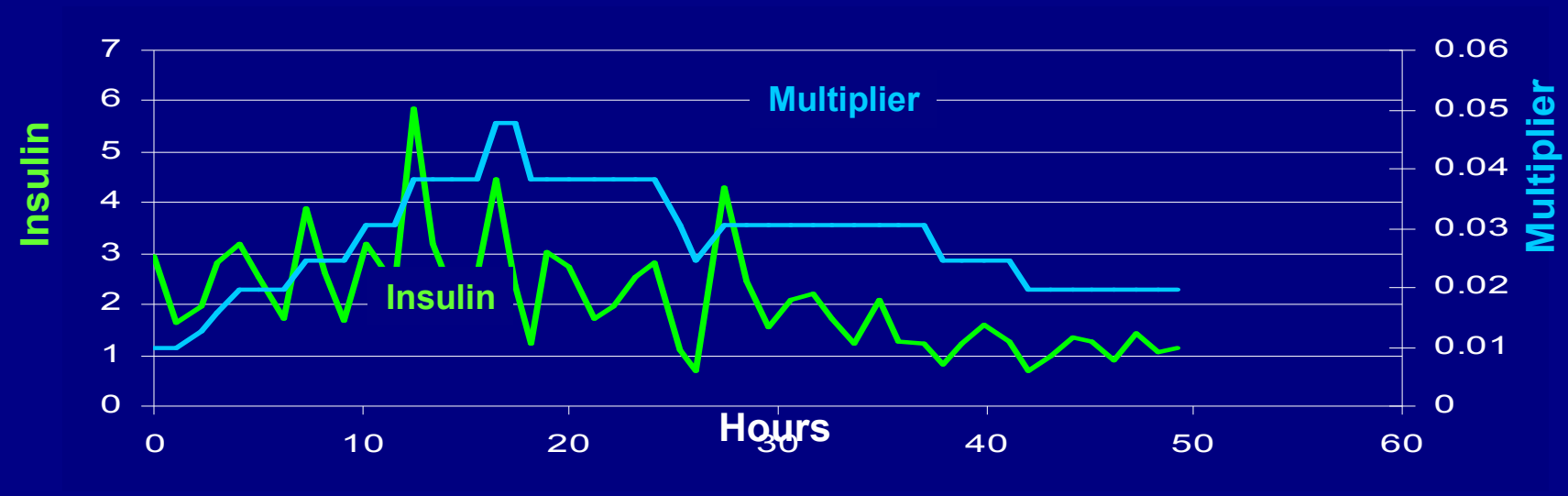
Physician View – Writing orders

- High Target Glucose
- Low Target Glucose
- Initial Multiplier
- Maximum interval
- Insulin concentration

Nurse View of Glucommander

- Computer periodically alarms
- Check blood glucose
- Enter glucose into computer
- Set insulin drip to rate from computer

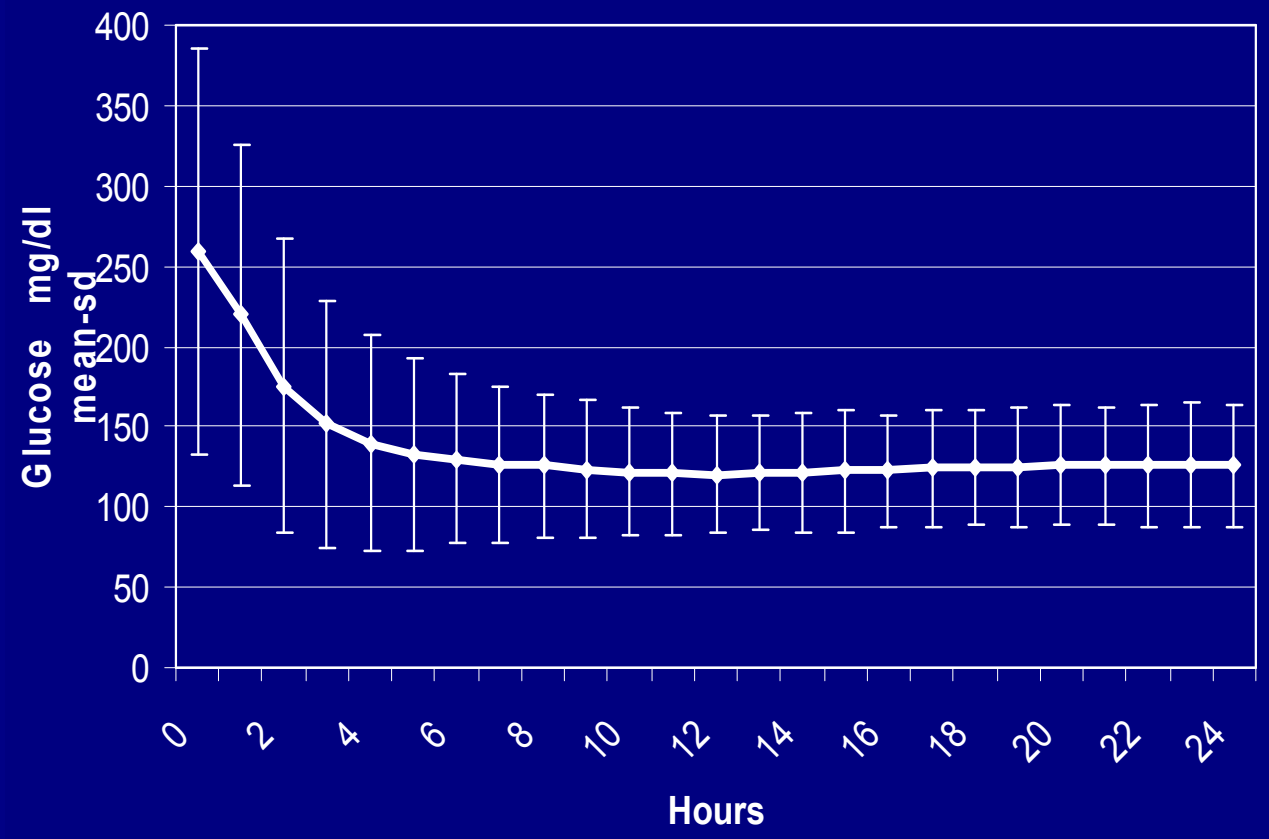
Typical Glucommander Run



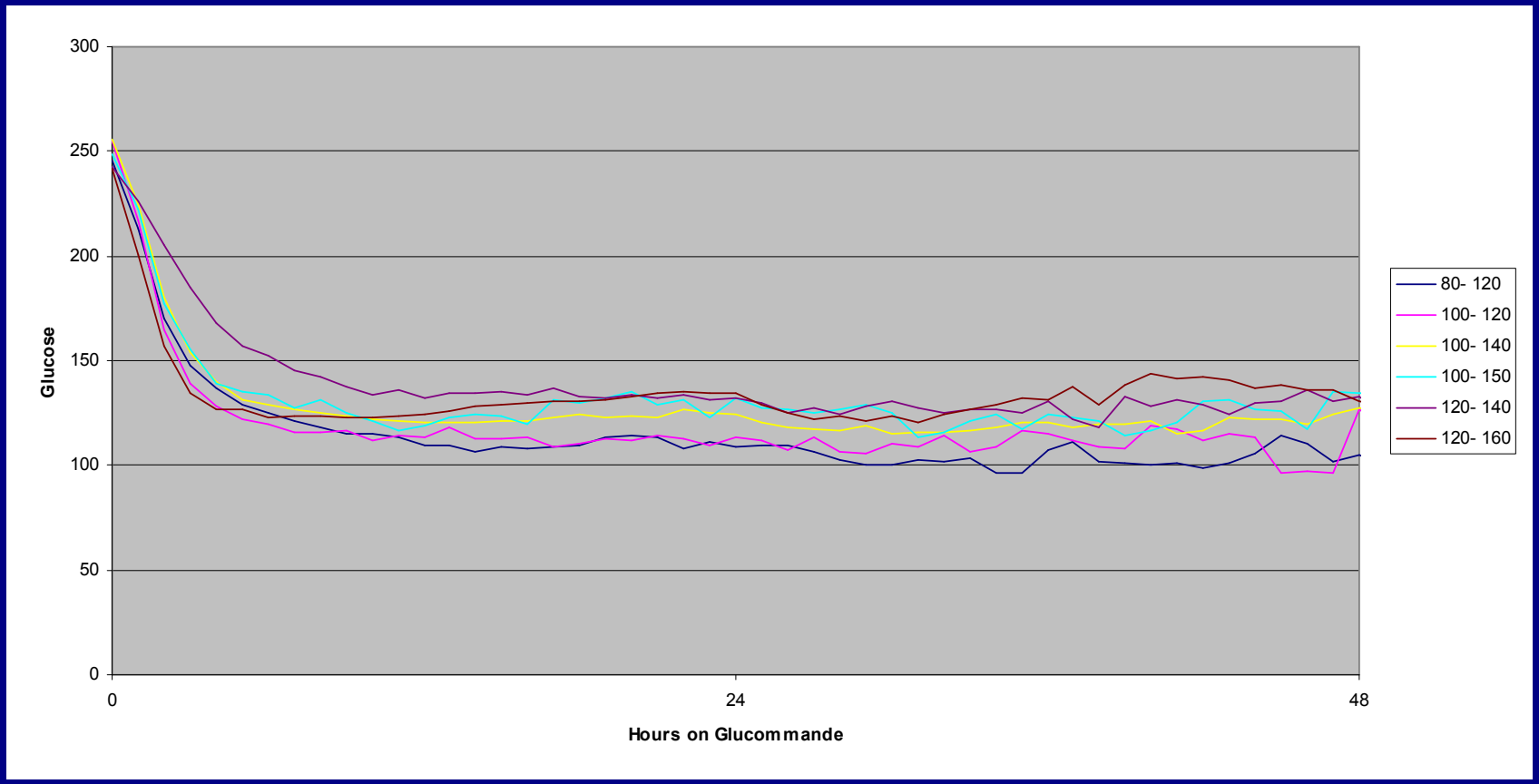
Database

- Collected all uses of Glucommander 1984-1998
- 5803 runs
- 120618 timed glucose / insulin pairs

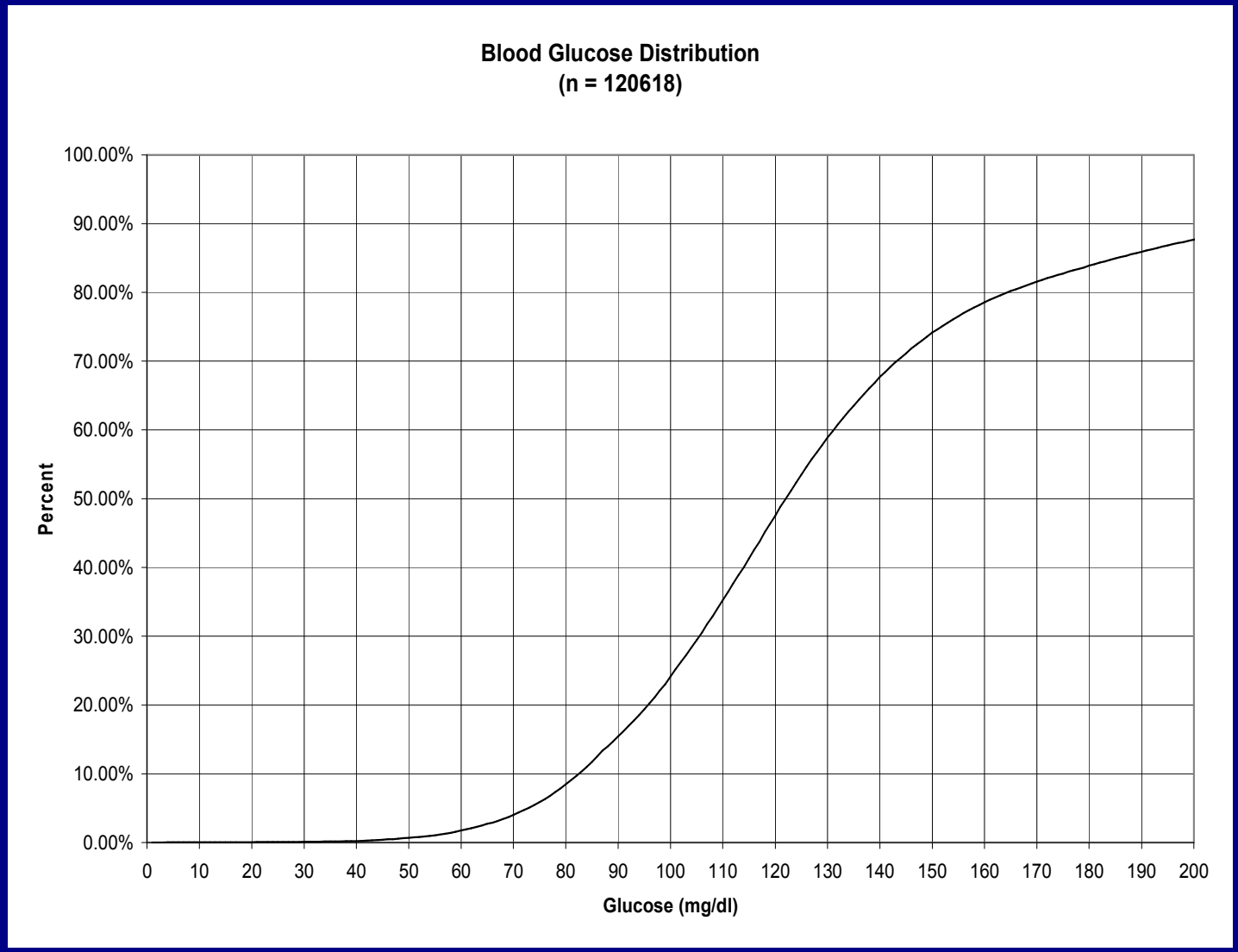
Average and Standard Deviation of of All Runs



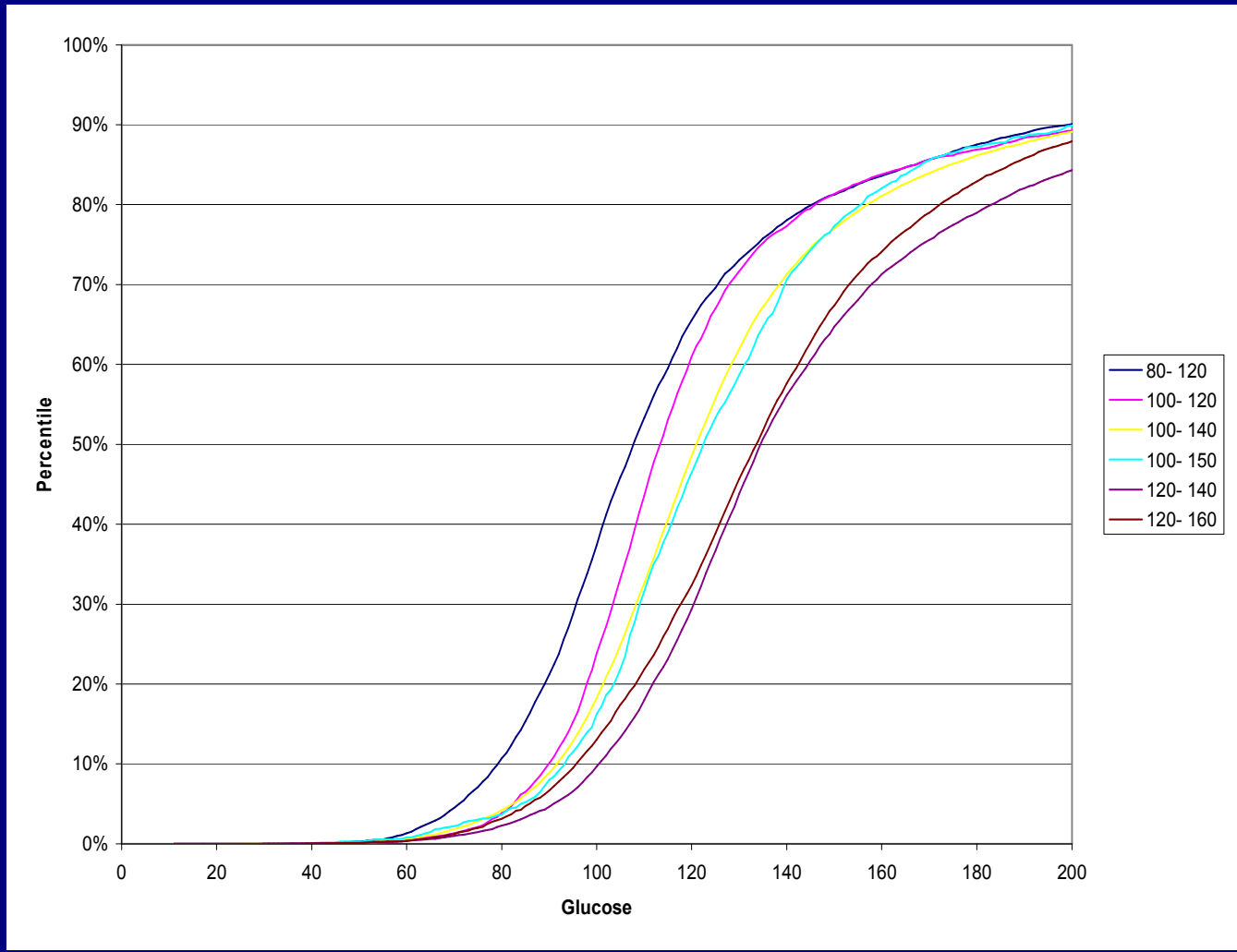
Treating to Target Range



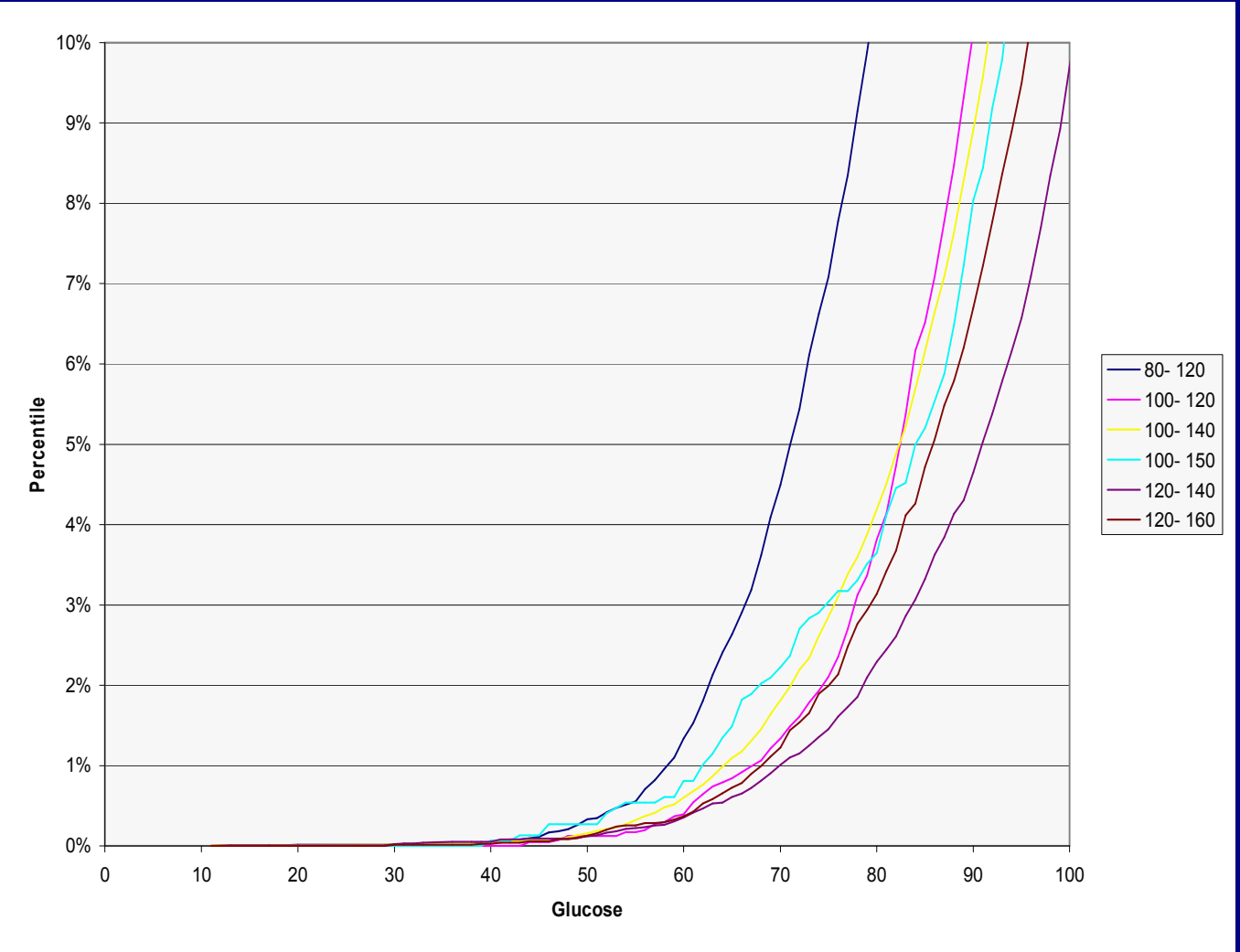
Performance



Distribution by Target



Hypoglycemia



Georgia Hospital Association

Diabetes Special Interest Group

Activities

- Founded in 2003 with goal: “To Monitor, Evaluate, and Enhance the Diabetes Care in the State of Georgia”
- Developed a number of guidelines for achieving tight glycemic control during hospitalization
- Conducting a series of sessions 2/25 – 8/26 describing guidelines and their implementation

Georgia Hosptial Association Diabetes SIG

http://www.gha.org/pha/health/diabetes/guidelines/index.asp

DIRECTIONS

TARGET BG 80-110 (1ML =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. If current BG Tier is lower than the previous BG Tier, STAY IN THE SAME COLUMN. If current BG Tier has not dropped (is the same or higher), MOVE 1 COLUMN TO THE RIGHT *If more than 16 columns are needed: See back of page*	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
	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	6.8	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
	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
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

BG	D50W	ACTION (Figure No.2)
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 * Contact physician if BG is under 60 for 2 consecutive BG measurements
30-49	25 ml IV Push	
Under 30	30 ml IV Push	

NOTIFY PHYSICIAN IF: (Figure No.3)

* BG is less than 60 for 2 consecutive BG measurements
* BG reveals a 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 enteral feeding, TPN, or IV insulin infusion is stopped

TO TRANSITION FROM IV TO SQ WHEN BG IS 80-140

* Basal Dose = 10 times the rate shown in orange for the current column
* Bolus Dose for each meal = 1/3 the Basal Dose
* Correction Factor = 80 divided by the rate shown in orange for the current column

Implementing Inpatient Management

Recent AACE developments

Improving Inpatient Diabetes Care: A Call to Action Conference

- January 30 – 31, 2006, Washington, DC
- Sponsored by AACE, ADA, others.
- Goal: "… develop strategies and eliminate the roadblocks for implementation of intensive glycemic control."

Sought Answers to Questions

- Does glycemic control improve clinical outcomes for inpatients with hyperglycemia?
- Is cost a barrier to improved inpatient care?
- Has inpatient diabetes management become a quality and safety concern?
- What are the systematic barriers and challenges to improved diabetes management?
- What are effective strategies for achieving improved diabetes management in hospitalized patients?
- The newly hyperglycemic patient – what to do?
- What are the areas needing further researcb?

Recommendations

- Identify elevated blood glucose in all hospitalized patients.
- Establish a multidisciplinary team approach to diabetes management in all hospitals.
- Implement structured protocols for aggressive control of blood glucose in both intensive care units and other hospital settings.
- Create educational programs for all hospital personnel caring for people with diabetes.
- Plan for a smooth transition to outpatient care with appropriate diabetes management.

Role of the Clinical Endocrinologist

- In the 17 page conference report and recommendations, the word endocrinologist was not mentioned other than as part the name of the organization (AACE).
- “Diabetes management may be effectively offered by primary care physicians or hospitalists, but involvement of appropriately trained specialists or specialty teams may reduce length of stay, improve glycemic control, and improve outcomes.”

Post Cardio Thoracic Hyperglycemia

Piedmont Hospital Experience

Genesis of the Project

- Response to Institute for Healthcare Improvement (IHI) campaign
- Hospital administration and cardiovascular surgery established goal to reduce perioperative CT surgery hyperglycemia

Project History

- Interdisciplinary committee formed to develop protocols which would be primarily nurse driven in response to order sets
- Intravenous insulin using Glucommander
- Consultation with endocrinologist for specific indications

Early Outcomes

Paul Davidson

Program Slides

- www.adaendo.com