Preventing Surgical Site Infections

Glucose Control

E. Patchen Dellinger, MD
University of Washington
Diabetes, Glucose Control, and SSIs After Median Sternotomy

Latham. ICHE 2001; 22: 607-12
Hyperglycemia and Risk of SSI after Cardiac Operations

No increased risk:
- Elevated HgbA1c
- Preoperative hyperglycemia

Increased risk:
- Diagnosed diabetes
- Undiagnosed diabetes
- Post-op glucose > 200 mg% within 48h

Hyperglycemia and Risk of SSI after Cardiac Operations

- Hyperglycemia - doubled risk of SSI
- Hyperglycemic:
  - 48% of diabetics
  - 12% of nondiabetics
  - 30% of all patients
- 47% of hyperglycemic episodes were in nondiabetics

Deep Sternal SSI and Glucose

Glucose Control and Deep Sternal Wound Infections

![Graph showing glucose control and deep sternal wound infections](image)

Glucose Control and Mortality after CABG in 3554 Diabetics

3 BG in the Portland Protocol

- Glucose is measured every 30-120 minutes on the day of operation and the next two days (POD1 & POD2).
- 3 BG is the average of all those measurements over 3 days.

Courtesy of Anthony Furnary
Glucose Levels and Infection after CABG in NonDiabetics

Day
SCIP only mandates glucose control for cardiac surgery
Hyperglycemia and Infection

- Does it apply only to cardiac surgery?
- Do WBC struggling to work in syrup know whether they are in a median sternotomy or an abdominal incision?
Early (48h) Postoperative Glucose Levels and SSI after Vascular Surgery

Perioperative Hyperglycemia in Noncardiac Surgical Patients: Does it Increase Postoperative Infections?

Postop inf = pneumonia, SSI, UTI, sepsis within 30 d

Variables = postop gluc, age, race, diabetes, ASA, emergent, op duration, transfusion

Significant: postop gluc > 180 O.R.=2.03
   gluc increase of 40 O.R.=1.9
   ASA & emergent

Perioperative Hyperglycemia in Noncardiac Surgical Patients

**Mastectomy, Hyperglycemia, and SSI**

260 patients, 5 glucose determinations (pre-op, at anesthesia induction, intra-op, in PACU, at 24 hrs)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds Ratio</th>
<th>C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt; 50</td>
<td>3.7</td>
<td>(1.5-9.2)</td>
</tr>
<tr>
<td>Pre-Op ChemoRads</td>
<td>2.8</td>
<td>(1.4-5.8)</td>
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<tr>
<td>Any gluc ≥ 150 mg%</td>
<td>2.9</td>
<td>(1.2-6.2)</td>
</tr>
</tbody>
</table>

Villar-Compte. AJIC 2008; 36:192-8
Postop Glucose (within 48h) and SSI – General Surgery

Relative Risk

Glucose

Postoperative Glucose and Mortality in Noncardiac Surgery

Hyperglycemia in non-diabetic patients was more dangerous than hyperglycemia in diabetics!

Frisch. Diabetes Care. 2010; 33: 1883-8
<table>
<thead>
<tr>
<th></th>
<th>Basal Bolus</th>
<th>Sliding Scale</th>
<th>p value</th>
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<tbody>
<tr>
<td>Patients</td>
<td>104</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>Mean Fasting</td>
<td>155</td>
<td>167</td>
<td>0.04</td>
</tr>
<tr>
<td>Mean Daily</td>
<td>157</td>
<td>176</td>
<td>0.001</td>
</tr>
<tr>
<td>Readings &lt; 140</td>
<td>53%</td>
<td>31%</td>
<td>0.001</td>
</tr>
<tr>
<td>Wound infections</td>
<td>3</td>
<td>11</td>
<td>0.05</td>
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<tr>
<td>Any complication</td>
<td>9</td>
<td>26</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Umpierrez. Diabetes Care 2011; 34: 256-61
# Intensive vs. Conventional Insulin Rx in Diabetics having D2 Gastrectomy for Cancer

Randomized Prospective Trial

<table>
<thead>
<tr>
<th>Target glucose</th>
<th>79 – 110 mg%</th>
<th>180 – 200 mg%</th>
<th>p value</th>
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</thead>
<tbody>
<tr>
<td>Patients</td>
<td>92</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Wound infections</td>
<td>4 (4%)</td>
<td>12 (14%)</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Intra-Abd Inf</td>
<td>2 (2%)</td>
<td>9 (10%)</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Any complication</td>
<td>7 (8%)</td>
<td>16 (18%)</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Hypogly (&lt;40 mg%)</td>
<td>6 (7%)</td>
<td>1 (1%)</td>
<td>&lt;0.12</td>
</tr>
</tbody>
</table>

Intensive vs. Conventional Insulin Rx in Diabetics having D2 Gastrectomy for Cancer
Randomized Prospective Trial

Intensive vs. Conventional Insulin Rx in Diabetics having D2 Gastrectomy for Cancer Randomized Prospective Trial

Perioperative Hyperglycemic and Total Knee or Hip Arthroplasty
1948 operations with 101 infections

Univariate risk factors

- BMI
- Operative duration
- Knee > hip
- Comorbidity score

Perioperative Hyperglycemia and Total Knee or Hip Arthroplasty
Fasting Blood Glucose in Hospital

Perioperative Hyperglycemia and Total Knee or Hip Arthroplasty

Fasting Blood Glucose POD #1

Hgb A1c vs. Glucose as Risk Factor for SSI – Gastric Bypass

<table>
<thead>
<tr>
<th>A1c Level</th>
<th>n</th>
</tr>
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<tr>
<td>&lt; 6.5%</td>
<td>310</td>
</tr>
<tr>
<td>6.5-7.9%</td>
<td>92</td>
</tr>
<tr>
<td>≥ 8%</td>
<td>66</td>
</tr>
</tbody>
</table>

Perna. Surg Obes Rel Dis 2012; 8: 685-90
Hgb A1c vs. Glucose as Risk Factor for SSI – Gastric Bypass

Multivariate Analysis

Odds ratio = 1.27 (1.06-1.51) for every 20 mg% increase in mean glucose level during hospitalization (p=0.008).

Mean glucose more significant than any level above 200 Mg% or not.

Hgb A1c not significant.

Perna. Surg Obes Rel Dis 2012; 8: 685-90
SCOAP Data on Perioperative Glucose Levels and Insulin Use

11,630 patients from 2005-2010 with
  Bariatric operation (5,360)
  Colectomy (6,273)
Who either
  Experienced hyperglycemia \[\text{glucose} > 180\] (3,383)
  Or did not (8,247)
During the perioperative period or on
POD 1 or POD 2

SCOAP Data on Perioperative Glucose Levels and Insulin Use

Diabetic pts 4098 (35%)
  Hyperglycemic 2369 (58%)

Nondiabetic pts 7532 (65%)
  Hyperglycemic 1014 (13%)

30% of all hyperglycemic patients were not diabetic!

Composite Infection
Hyperglycemia vs No Hyperglycemia
All Patients

Composite Infection
Hyperglycemia vs No Hyperglycemia
Diabetic Patients

Composite Infection
Hyperglycemia vs No Hyperglycemia Nondiabetic Patients

Composite Infection in Hyperglycemic Patients With and Without Use of Insulin

Operative Reintervention in Hyperglycemic Patients With and Without Use of Insulin

Mortality in Hyperglycemic Patients With and Without Use of Insulin

Hyperglycemia Impairs Immunity

Nonenzymatic glycosylation of proteins:

• Inactivates IgG
• Decreases Complement Activation
• Increases Collagenase Activity
• Impairs Leukocyte Function
  – Delays chemotaxis
  – Impairs phagocytosis
  – Decreases bactericidal activity
Hyperglycemia and the Cardiovascular System

1. Hyperglycemia impairs ischemic preconditioning
2. Hyperglycemia reduces collateral blood flow
3. Hyperglycemia may help induce myocyte death
4. Hyperglycemia may have other effects on BP, cardiac rhythms, platelet abnormalities

Impact of Insulin Administration Independent of Glucose Levels

1. Insulin inhibits lipolysis, & elevated free fatty acids are associated with poor outcomes, esp cardiac arrhythmias

2. Insulin inhibits inflammatory growth factors that are important in myocardial infarction

3. Insulin stimulates endothelial nitric oxide synthase

4. Insulin with euglycemia inhibits proinflammatory cytokines, adhesion molecules, and chemokines

Amer Assoc Clinical Endocrinologists-Position Statement, 16 Dec 2003
Glucose Control

Proven important for SSI risk:

- Cardiac surgery
- General surgery
- Colorectal surgery
- Vascular surgery
- Breast surgery
- Hepato-pancreatico-biliary surgery
- Orthopedic surgery
- Trauma surgery
Regardless of the Diagnosis of Diabetes (or not), Hyperglycemia Increases

- Morbidity
- Mortality
- Length of Stay
Unrecognized Diabetes in Hospitalized Patients 1034 Consecutive Patients Screened

- 33% of Surgical Patients with glucose >200 mg% had no prior history of diabetes
- 38% of Medical Patients with glucose >200 mg% had no prior history of diabetes
- Mean peak glucose = 299 mg%
- 27/41 (66%) with ≥ 2 determinations > 200 mg%

Glucose in NonDiabetics having Colectomy at Cleveland Clinic

<table>
<thead>
<tr>
<th>Highest Gluc</th>
<th>N (%)</th>
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<tbody>
<tr>
<td>≤ 125 mg%</td>
<td>816 (33%)</td>
</tr>
<tr>
<td>126-200 mg%</td>
<td>1289 (53%)</td>
</tr>
<tr>
<td>200 mg%</td>
<td>342 (14%)</td>
</tr>
<tr>
<td>All patients</td>
<td>2447 (100%)</td>
</tr>
</tbody>
</table>

Kiran, et al. ASA abstract, 2013 meeting
Glucose in NonDiabetics having Colectomy at Cleveland Clinic

<table>
<thead>
<tr>
<th>Highest Gluc</th>
<th>SSI*</th>
<th>Sepsis¤</th>
<th>Reop¤</th>
<th>Mort+</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 125 mg%</td>
<td>2.9%</td>
<td>0.6%</td>
<td>3.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>126-200 mg%</td>
<td>4.8%</td>
<td>2.2%</td>
<td>5%</td>
<td>0.3%</td>
</tr>
<tr>
<td>200 mg%</td>
<td>6.1%</td>
<td>3.5%</td>
<td>7.3%</td>
<td>1.2%</td>
</tr>
<tr>
<td>All patients</td>
<td>4.4%</td>
<td>1.8%</td>
<td>4.7%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

*p<0.03, ¤ p<0.01, + p<0.05

Kiran, et al. ASA abstract, 2013 meeting
Glucose in NonDiabetics having Colectomy at Cleveland Clinic

Kiran, et al. ASA abstract, 2013 meeting
Glucose Levels & SSI

• The exact “best” level of glucose control in the perioperative period is not known.

• High glucose levels unequivocally increase the risk of SSI and other perioperative infections.

• Tight glucose control in the perioperative period is tricky.

• Hypoglycemia increases the risk of morbidity and mortality.

• Some examples of successful glucose control programs follow.
Why *Not* Use Insulin Drip on Every Patient with Elevated Blood Glucose?

- Patients are adequately controlled with subq and sliding scale
- Patients will become hypoglycemic
- It takes too much nursing time to check blood glucose levels
- You can do it in an ICU but not on the floor
- You need an endocrine consult
- Nondiabetics don’t need this
American College of Endocrinology Consensus Development Conference on Inpatient Diabetes and Metabolic Control

The use of standardized protocols that are developed by multidisciplinary teams is associated with improved glycemic control and lower rates of hypoglycemia. In addition to specifying insulin dose, protocols should also include specific guidelines for identifying patients at risk for hypoglycemia and actions to be taken to prevent and treat hypoglycemia.

Amer Assoc Clinical Endocrinologists-Position Statement, 16 Dec 2003
The Rabbit 2 basal bolus protocol is online at http://care.diabetesjournals.org/lookup/suppl/doi:10.2337/dc10-1407/-/DC1

### Basal Bolus Regimen with Insulin Glargine and Glulisine

#### 1.A. Insulin Orders

- Discontinue oral antidiabetic drugs (sulfonylureas, repaglinide, nateglinide, metformin, pioglitazone, rosiglitazone, sitagliptin) and non-insulin injected antidiabetic medication (pramlintide, exenatide) on admission.

- Starting insulin total daily dose (TDD): 0.5 units per kg of body weight.
  - Reduce insulin TDD to 0.3 units per kg of body weight in patients ≥ 70 years of age and/or with a serum creatinine ≥ 2.0 mg/dL.

- Give half of total daily dose as insulin glargine and half as insulin glulisine.

- Give insulin glargine once daily, at the same time of the day.

- Give insulin glulisine in three equally divided doses before each meal. Hold insulin glulisine if patient not able to eat.
### 1.B. Supplemental insulin

- Give supplemental insulin glulisine following the “sliding scale” protocol (1E) for blood glucose > 140 mg/dl.

- If a patient is able and expected to eat all, give supplemental glulisine insulin before each meal and at bedtime following the “usual” column.

- If a patient is not able to eat, give supplemental glulisine insulin every 6 hours (6-12-6-12) following the “sensitive” column.
Rabbit 2 Protocols

1.C. **Insulin adjustment**

- If the fasting and predinner BG is between 100 - 140 mg/dl in the absence of hypoglycemia the previous day: no change
- If the fasting and predinner BG is between 140 - 180 mg/dl in the absence of hypoglycemia the previous day: increase insulin TDD by 10% every day
- If the fasting and predinner BG is >180 mg/dl in the absence of hypoglycemia the previous day: increase insulin TDD dose by 20% every day
- If the fasting and predinner BG is between 70 - 99 mg/dl in the absence of hypoglycemia: decrease insulin TDD dose by 10% every day
- If a patient develops hypoglycemia (BG <70 mg/dL), the insulin TDD should be decreased by 20%.

1.D. **Blood glucose monitoring.** Blood glucose will be measured before each meal and at bedtime (or every 6 hours if a patient is not eating) using a glucose meter
### 1.E. Supplemental Insulin Scale

<table>
<thead>
<tr>
<th>Blood Glucose (mg/dL)</th>
<th>Insulin Sensitive</th>
<th>Usual</th>
<th>Insulin Resistant</th>
</tr>
</thead>
<tbody>
<tr>
<td>141-180</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>181-220</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>221-260</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>261-300</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>301-350</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>351-400</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 400</td>
<td>14</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>

**Check appropriate column below and cross out other columns**

The numbers in each column indicate the number of units of glulisine or regular insulin per dose. Supplemental” dose is to be added to the scheduled dose of glulisine or regular insulin.
CONSULT ENDOCRINE SERVICE FOR:
- Acute Care patients on insulin infusion receiving oral nutrition or intermittent tube feeding

GOAL Blood Glucose (BG) RANGE:

ACUTE CARE OR ICU: 100-180 mg/dL initiate when ordered
ICU ONLY: 100-140 mg/dL initiate when BG>140 x 2
- Discontinue all previous insulin orders.
- Insulin Infusion: 100 units insulin/100 mL NS given IV infusion, at:
  - Algorithm 1: Start here for most patients.
  - Algorithm 2: Start here if S/P CABG surgery, solid organ transplant, receiving glucocorticoids, or patient receiving >80 units/day of insulin as an outpatient.
- NO PATIENT STARTS AT ALGORITHM 3 OR 4.

See back of form for the Algorithms and decision tree

When transitioning to SubQ: Use www.uwmedres.org/resources for dosing assistance: Give specified basal SubQ insulin dose, and then stop insulin infusion in 2 hours.

Fluid/Nutrition Orders:
Recommendations for patients that are not eating:

DM Type 1 (10 grams glucose/hour) DM Type 2 (5 grams glucose/hr)
- D51/2 normal saline with ______ mEq/L Potassium chloride IV at ________ ml/hr
- D5LR with ______ mEq/L Potassium chloride IV at ________ ml/hr
- TPN or Enteral Feeds (see separate orders)
- Other ______________________________ at ________ ml/hr
**UW I.V. Insulin Infusion Protocol**

**Patient Monitoring:**
- Check BG every 1 hour until it is within **goal** range for 4 hours. Then decrease BG checks to every 2 hours. ALWAYS resume hourly checks if BG exits goal range.
- Hourly monitoring may be indicated for critically ill patients or patients having medical or surgical procedures even if they have stable BG.

**Notify the Provider:**
- For any BG increase >100 mg/dL from a stable baseline
- For 2 consecutive BG decreases of >100 mg/dL
- For any hypoglycemia which results in loss of consciousness **OR** does not resolve within 20 min of implementing the hypoglycemia protocol below

**Treatment of Hypoglycemia (BG <70 mg/dL) or symptoms of hypoglycemia**
- **Turn off** insulin infusion for any BG below goal AND
- Give 25 mL (1/2 amp) of 50% dextrose IV if BG 50-69 mg/dL **OR**
- Give 50 mL (1 amp) of 50% dextrose IV if BG < 50 mg/dL.
- Recheck BG every 20 minutes until BG ≥100 mg/dL
  - IF BG is <70 mg/dL repeat 25 mL (1/2 amp) 50% dextrose
  - WHEN BG is ≥100 mg/dL, restart the insulin infusion at a lower dose by using one algorithm **LEFT** from previous algorithm (see “Evaluating Trends & Using Algorithms” section).
BG monitoring: Check BG every 1 hour until it is within goal range for 4 hours. Then decrease BG checks to every 2 hours. ALWAYS resume hourly checks if BG exits goal range and when there is a change in algorithm. Check BG in 20-30 minutes as noted below. Hourly monitoring may be indicated for critically ill patients or patients having medical or surgical procedures even if they have stable BG.
UW I.V. Insulin Infusion Protocol

Insulin Infusion Algorithm Decision Tree

1. Blood Glucose in Goal Range?
   - Yes
   - Was decrease more than 30 mg/dL OR previous BG below goal range?
     - Yes
       - Move LEFT one algorithm and adjust rate to match BG range
       - Adjust rate hourly to match BG range in current algorithm until BG is in goal range X 4 hrs
       - Once within goal range for 4 hrs, check BG q2hr. Do NOT adjust rate unless BG < 110 or > 180
     - No
       - Adjust rate to match BG range in current algorithm
       - Recheck BG in 20-30 minutes if BG decreased >100 mg/dL

   - No
     - Below Goal Range and Hypoglycemia
       - TURN OFF insulin infusion
         - For BG 70-99 No dextrose
         - For BG 50-69 Give 25mL (½ amp) 50% dextrose
         - For BG < 50 Give 50mL (1 amp) 50% dextrose
       - Recheck BG in 20-30 min.
       - When BG has increased to goal range, move LEFT one algorithm. Adjust rate to match BG range

2. Above Goal Range
   - BG decreased > 75
     - Move LEFT one algorithm and adjust rate to match BG range
     - Recheck BG in 20-30 minutes if BG decreased >100 mg/dL
   - BG decreased 50-75
     - Adjust rate to match BG range in current algorithm
   - BG increased by any amt. or decreased <50
     - Move RIGHT one algorithm and adjust rate to match BG range

If TPN/Enteral nutrition is stopped or significantly reduced, decrease insulin infusion rate by moving LEFT one algorithm. Then, use algorithm table & instructions to determine subsequent rate changes AND check BG every 1 hour x 4 hours.
UW I.V. Insulin Infusion Protocol

<table>
<thead>
<tr>
<th>Algorithm 1</th>
<th>Algorithm 2</th>
<th>Algorithm 3</th>
<th>Algorithm 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG</td>
<td>Unit/hr</td>
<td>BG</td>
<td>Units/hr</td>
</tr>
<tr>
<td>100-120</td>
<td>0.5</td>
<td>100-120</td>
<td>1</td>
</tr>
<tr>
<td>121-140</td>
<td>0.8</td>
<td>121-140</td>
<td>1.5</td>
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<tr>
<td>141-160</td>
<td>1.2</td>
<td>141-160</td>
<td>2</td>
</tr>
<tr>
<td>161-180</td>
<td>1.5</td>
<td>161-180</td>
<td>2.5</td>
</tr>
<tr>
<td>181-210</td>
<td>2</td>
<td>181-210</td>
<td>3</td>
</tr>
<tr>
<td>211-240</td>
<td>2.5</td>
<td>211-240</td>
<td>4</td>
</tr>
<tr>
<td>241-270</td>
<td>3</td>
<td>241-270</td>
<td>5</td>
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<tr>
<td>271-300</td>
<td>3.5</td>
<td>271-300</td>
<td>6</td>
</tr>
<tr>
<td>301-330</td>
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<td>6.5</td>
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<tr>
<td>331-360</td>
<td>4.5</td>
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<td>7.5</td>
</tr>
<tr>
<td>&gt;360</td>
<td>5</td>
<td>&gt;360</td>
<td>8.5</td>
</tr>
</tbody>
</table>

<70 = Hypoglycemia See front of form for treatment

70-99: Off x 20-30 minutes & recheck BG

If NOT achieving glycemic control with Algo 4 X
>3 consecutive hours
Consider High Dose Infusion Protocol
UWMC HIGH DOSE Insulin Infusion Protocol

Initiate HIGH DOSE Insulin Infusion Orders **only after documented failure to achieve glycemic control with Algorithm 4 Standard Insulin Infusion Orders X ≥3 consecutive hrs**

**GOAL Blood Glucose (BG) RANGE – check one box:**

**ACUTE CARE OR ICU:** □ 100-180 mg/dL

**ICU ONLY:** □ 100-140 mg/dL
### UW I.V. Insulin Infusion Protocol

<table>
<thead>
<tr>
<th>Algorithm 5</th>
<th>Algorithm 6</th>
<th>Algorithm 7</th>
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<td>BG</td>
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</tr>
<tr>
<td>BG</td>
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<td>BG</td>
<td>Units/hr</td>
</tr>
</tbody>
</table>

<70 = Hypoglycemia See front of form for treatment

70-99: Off x 20-30 minutes & recheck BG

100-110: Recheck BG in 20-30 min, consider moving left one Algorithm

<table>
<thead>
<tr>
<th>BG</th>
<th>Units/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-120</td>
<td>3</td>
</tr>
<tr>
<td>121-140</td>
<td>5</td>
</tr>
<tr>
<td>141-160</td>
<td>7</td>
</tr>
<tr>
<td>161-180</td>
<td>9</td>
</tr>
<tr>
<td>181-210</td>
<td>11</td>
</tr>
<tr>
<td>211-240</td>
<td>14</td>
</tr>
<tr>
<td>241-270</td>
<td>17</td>
</tr>
<tr>
<td>271-300</td>
<td>20</td>
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<tr>
<td>301-330</td>
<td>23</td>
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<tr>
<td>331-360</td>
<td>26</td>
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<tr>
<td>&gt;360</td>
<td>29</td>
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</table>

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<tr>
<td>100-120</td>
<td>4</td>
</tr>
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<td>301-330</td>
<td>30</td>
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<tr>
<td>331-360</td>
<td>34</td>
</tr>
<tr>
<td>&gt;360</td>
<td>38</td>
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