PRE-HOSPITAL: PEDIATRIC POPULATION
CASE:

6 yo M presenting to school nurse with SOB while in the cafeteria

Pt is crying and voice is sounding hoarse.
CASE:

Physical Exam:
Hives around face + neck, becoming more pronounced
CASE:

9-1-1 called

Patient VS on EMS arrival:
HR 140, BP 85/40, RR 30, O2 sat 92% on RA.

Repeat physical exam: Wide spread urticaria. Lips are swollen. Capillary refill 4-5 seconds
CASE:

High flow O₂ started then upgrade to ventilations using bag-valve mask with 100% O₂

Broselow tape utilized:

- 20 kg
- Epinephrine 1:1,000
- Dose calculated at 2.1 mg (2.1 mL) and administered intramuscularly
CASE:

Inside the ambulance, patient is completely unresponsive and apneic.

Monitor shows pulseless ventricular fibrillation.

CPR is started
CASE:

Patient defibrillated at 50 joules and CPR continued. Pt in PEA.

Pt intubated, IO placed

Broselow tape utilized:
- Pt receives epinephrine 1:10,000 0.21 mg (2.1 mL) IO x2
- Pulse detected

On arrival, ED confirms tube and orders diphenhydramine and methylprednisolone.
- Diphenhydramine and methylprednisolone dose calculated correctly
- Nurse administers two fold dosing error of methylprednisolone
Correct use of Broselow to obtain weight

Incorrect use of Broselow to calculate medication dose

Epinephrine
- Correct concentration
- Incorrect dose (endotracheal tube cardiac arrest dose)

Methylprednisolone
- Correct dose
- Incorrect preparation of medication
PRE-HOSPITAL PEDIATRIC ENCOUNTERS
PRE-HOSPITAL PEDIATRIC POPULATION

United States: ~30 million children are evaluated annually in the ED
- 1.5-3 million (5-10%) arrive by ambulance
- 10% of all EMS transports are children

Seidel JS et al. 1991: 10,493 prehospital care reports analyzed in 11 counties of California

TABLE 3. Age Distribution of Emergency Medical Services Calls in Urban and Rural Areas

<table>
<thead>
<tr>
<th>Age</th>
<th>Urban, Frequency (%)</th>
<th>Rural, Frequency (%)</th>
<th>Total, Frequency (%)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–6 mo</td>
<td>350 (3.8)</td>
<td>50 (4.2)</td>
<td>400 (3.8)</td>
<td>.47</td>
</tr>
<tr>
<td>6–23 mo</td>
<td>840 (9.1)</td>
<td>70 (5.9)</td>
<td>910 (8.7)</td>
<td>.0002</td>
</tr>
<tr>
<td>2–5 y</td>
<td>1337 (14.4)</td>
<td>130 (10.9)</td>
<td>1467 (14.0)</td>
<td>.001</td>
</tr>
<tr>
<td>6–10 y</td>
<td>1248 (13.5)</td>
<td>156 (13.1)</td>
<td>1404 (13.4)</td>
<td>.75</td>
</tr>
<tr>
<td>11–14 y</td>
<td>1637 (17.7)</td>
<td>213 (17.9)</td>
<td>1850 (17.7)</td>
<td>.87</td>
</tr>
<tr>
<td>&gt;14 y</td>
<td>3845 (41.5)</td>
<td>572 (48.0)</td>
<td>4417 (42.3)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Total</td>
<td>9257</td>
<td>1191</td>
<td>10448</td>
<td></td>
</tr>
</tbody>
</table>

* Fisher’s Exact Test. Comparisons within an age group are relative to all other age groups combined.
Seidel JS et al. 1991: 10,493 prehospital care reports analyzed in 11 counties of California

**TABLE 9.** Frequency of Drug Administration in Urban and Rural Areas

<table>
<thead>
<tr>
<th>Drug</th>
<th>Urban, No. (%)</th>
<th>Rural, No. (%)</th>
<th>Total, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naloxone hydrochloride</td>
<td>139 (28)</td>
<td>16 (21)</td>
<td>155 (27)</td>
</tr>
<tr>
<td>Dextrose 50%</td>
<td>130 (26)</td>
<td>13 (17)</td>
<td>143 (25)</td>
</tr>
<tr>
<td>Ipecac</td>
<td>72 (14)</td>
<td>17 (22)</td>
<td>89 (15)</td>
</tr>
<tr>
<td>Diazepam</td>
<td>55 (11)</td>
<td>1 (1)</td>
<td>56 (10)</td>
</tr>
<tr>
<td>Epinephrine (1:1000)</td>
<td>51 (10)</td>
<td>2 (3)</td>
<td>53 (9)</td>
</tr>
<tr>
<td>Epinephrine (1:10 000)</td>
<td>14 (3)</td>
<td>4 (5)</td>
<td>18 (3)</td>
</tr>
<tr>
<td>Morphine</td>
<td>7 (1)</td>
<td>6 (8)</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Other</td>
<td>33 (7)</td>
<td>17 (22)</td>
<td>50 (9)</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>501</strong></td>
<td><strong>76</strong></td>
<td><strong>577</strong></td>
</tr>
</tbody>
</table>
MEDICATION ERRORS
Definition: “A medication error is any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer”

Examples:
- Wrong dose
- Wrong drug
- Wrong route
- Wrong rate of administration
- Wrong concentration
- Drug interaction
- Drug allergy

Swiss Cheese Model

The Swiss Cheese Model of Accident Causation

Some holes due to active failures (e.g., mistakes, procedural violations)
Other holes due to latent conditions (e.g., faulty equipment, lack of staff training)

Successive layers of defences, barriers and safeguards

Adapted by Meredith Baumgartner from the work of James Reason and Sir Liam Donaldson
MEDICATION ERROR: HOSPITAL

- 98,000 fatal medical mistakes per year
- Preventable errors one of the top 10 leading cases of death
- Medication errors account for almost 10% of these mistakes

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Pediatric patients experience adverse events related to medication errors at a rate of 3:1 compared to adults.

FACTORS: EMS ENVIRONMENT ≠ HOSPITAL

Emergent situation

Medication orders heavily dependent on verbal communication

Limited resources for double checking

High risk medications

Dynamic formulary

Infrequent pediatric patient exposure

BERNIUS M ET AL. PREHOSP EMERG CARE 2008;12:486-94
MEDICATION ERRORS

Hoyle JD et al. 2012

- Retrospective analysis of children (≤11 yo) treated in pre-hospital setting by paramedics from 8 EMS agencies in Michigan
- Errors in administering: Albuterol, atropine, dextrose, diphenhydramine, epinephrine, and naloxone
- Error: ≥20% deviation from correct weight based dose

Figure 2. Patient enrollment.
MEDICATION ERRORS:

Hoyle JD et al. 2012

<table>
<thead>
<tr>
<th>Drug</th>
<th>No. Incorrect Doses/Total Doses</th>
<th>% Incorrect Doses (95% CI)</th>
<th>No. Overdoses</th>
<th>Overdose Mean Error (% ± SD)</th>
<th>No. Underdoses</th>
<th>Underdose Mean Error (% ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuterol</td>
<td>55/236</td>
<td>23.3% (18.4, 29.1)</td>
<td>1</td>
<td>200*</td>
<td>54</td>
<td>48.4 ± 8.8</td>
</tr>
<tr>
<td>Atropine</td>
<td>20/41</td>
<td>48.8% (34.3, 63.5)</td>
<td>8</td>
<td>407 ± 277</td>
<td>12</td>
<td>46.8 ± 15.0</td>
</tr>
<tr>
<td>Dextrose</td>
<td>2/4</td>
<td>50.0% (15.0, 85.0)</td>
<td>1</td>
<td>200*</td>
<td>1</td>
<td>62.5*</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>7/13</td>
<td>53.8% (29.1, 76.8)</td>
<td>4</td>
<td>190.8 ± 45.3</td>
<td>3</td>
<td>53.3 ± 16.3</td>
</tr>
<tr>
<td>Epinephrine (1:1,000)</td>
<td>28/43</td>
<td>65.1% (50.2, 77.6)</td>
<td>6</td>
<td>655 ± 418</td>
<td>22</td>
<td>29.9 ± 22.4</td>
</tr>
<tr>
<td>Intravenous/intraosseus</td>
<td>13/25</td>
<td>52.0% (33.5, 70.0)</td>
<td>4</td>
<td>808 ± 428</td>
<td>9</td>
<td>35.5 ± 27.4</td>
</tr>
<tr>
<td>Endotracheal</td>
<td>14/14</td>
<td>100.0% (78.5, 100.0)</td>
<td>2</td>
<td>200,500*</td>
<td>12</td>
<td>22.8 ± 14.7</td>
</tr>
<tr>
<td>Intramuscular</td>
<td>1/4</td>
<td>25.0% (4.6, 69.9)</td>
<td>0</td>
<td>—</td>
<td>1</td>
<td>65.2*</td>
</tr>
<tr>
<td>Epinephrine (1:10,000)</td>
<td>12/21</td>
<td>57.1% (36.5, 75.5)</td>
<td>2</td>
<td>167,500*</td>
<td>10</td>
<td>13.8 ± 5.3</td>
</tr>
<tr>
<td>Intravenous/intraosseus</td>
<td>11/20</td>
<td>55.0% (34.2, 74.2)</td>
<td>1</td>
<td>167*</td>
<td>10</td>
<td>13.8 ± 5.3</td>
</tr>
<tr>
<td>Endotracheal</td>
<td>1/1</td>
<td>100.0% (20.7, 100.0)</td>
<td>1</td>
<td>500*</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Naloxone</td>
<td>1/2</td>
<td>50.0% (9.5, 90.5)</td>
<td>0</td>
<td>—</td>
<td>1</td>
<td>25.0*</td>
</tr>
</tbody>
</table>

Medication dosing error: 34.7% (95% CI: 30-39.8)

- Epinephrine: Highest % of incorrect doses
MEDICATION ERRORS

LAMMERS ET AL. 2012

N = 45 two person crews in Michigan

Simulation of an infant with AMS, seizures, and respiratory arrest using their own equipment and drugs

Debriefing and root cause analysis

Correct dose: +/- 10%

- Midazolam: 60% error rate
- 1 crew spent too much time calculating the dose and ran out of time
- Diazepam: 47% error rate

Figure 2. Drug administration errors. Fishbone diagram showing how a variety of factors, individually or combined, can result in a bad outcome.
POTENTIAL SOLUTIONS

Eliminate confusion:
- Pediatric Definition:
  - $\leq 14$ years of age OR
  - $\leq 40$ kg
- Focus on basics:
  - Minimum doses:
    - Albuterol: 2.5 mg
    - Atropine: 0.1 mg
  - Know correct adult doses

Braselow-Luten Tape
Dosing cards
POTENTIAL SOLUTIONS: BROSELOW-LUTEN TAPE

KAJI AH ET AL. 2006

- Observational analysis 1994-1997 vs. 2003-2004
- Children ≤12 yo requiring epinephrine for cardiac arrest
- Correct dose +/- 20%: 44.2 % vs. 64.9%

1994-1997

2003-2004

HOYLE JD ET AL. PREHOSP EMERG CARE. 2012;16:59-66
POTENTIAL SOLUTIONS: BROSELOW-LUTEN TAPE

KAJI AH ET AL. 2006
- Observational analysis 1994-1997 vs. 2003-2004
- Children ≤12 yo requiring epinephrine for cardiac arrest
- Correct dose +/- 20%: 44.2 % vs. 64.9%

HOYLE JD ET AL. 2012
- BLT use in 50% of cases
- Incorrect use of BLT 47% of cases

| Table 4. Incorrect Dosing Related to Documentation of Broselow-Luten Tape Use |
|-----------------|-----------------|-----------------|-----------------|
| Drug            | Broselow-Luten Tape Use Documented | Broselow-Luten Tape Use Not Documented |
|                 | No. Incorrect/Total | 95% CI          | No. Incorrect/Total | 95% CI          | p-Value |
| Atropine        | 10/27 (37.0%)     | 18.8, 53.3      | 10/14 (71.4%)     | 45.4, 88.3      | 0.04    |
| Epinephrine     | 31/46 (67.4%)     | 53.8, 80.9      | 9/18 (50.0%)      | 28.9, 71.1      | 0.20    |

*Epinephrine includes intravenous, intramuscular, and endotracheal routes. Note: No patient with Broselow-Luten tape use documented received dextrose. Albuterol and diphenhydramine are not listed on the Broselow-Luten tape. CI = confidence interval.
POTENTIAL SOLUTIONS: BROSELOW-LUTEN

LIMITATIONS

Buried somewhere in the rig...

Inconsistent dosing with protocols

Obesity (measurements accurate)?

Many medications

Small print
Bernius M et al. 2008:

- Prospective investigation
- Questionnaire answered with and without use of a dosing card
POTENTIAL SOLUTIONS: DOSING CARD/BOOKLET (CONT).

**TABLE 3. Individual Scores and Error Results**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Unaided Group</th>
<th>Aided Group</th>
<th>Difference (95% CI, p-Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean percentage correct</td>
<td>65%</td>
<td>94%</td>
<td>Percentage difference, 28% 95% CI, 25–31 p &lt; 0.001</td>
</tr>
<tr>
<td>% Total question errors</td>
<td>775/2,350 (33%)</td>
<td>138/2,106 (6.6%)</td>
<td>Percentage difference, 26.4% 95% CI, 24.2–28.7 p &lt; 0.001</td>
</tr>
<tr>
<td>Severe errors</td>
<td>491/2,350 (20.9%)</td>
<td>104/2,106 (4.9%)</td>
<td>Percentage difference, 16% 95% CI, 14–17.9 p &lt; 0.001</td>
</tr>
<tr>
<td>Tenfold errors</td>
<td>146/2,350 (6.2%)</td>
<td>16/2,106 (0.76%)</td>
<td>Percentage difference, 5.4% 95% CI, 4.4–6.5 p &lt; 0.001</td>
</tr>
<tr>
<td>Hundredfold errors</td>
<td>10/2,350 (0.4%)</td>
<td>1/2,106 (0.05%)</td>
<td>Percentage difference, 0.38% 95% CI, 0.05–0.7 p = 0.025</td>
</tr>
<tr>
<td>Correct endotracheal tube calculation</td>
<td>63/277 (23%)</td>
<td>241/246 (98%)</td>
<td>Percentage difference, 75% 95% CI, 69.6–80.9 p &lt; 0.001</td>
</tr>
<tr>
<td>Time for completion of questionnaire</td>
<td>11.4 min</td>
<td>7.1 min</td>
<td>Mean difference, 4.3 min 95% CI, 3.7–4.9 p &lt; 0.001</td>
</tr>
</tbody>
</table>

CI = confidence interval.

**TABLE 5. Evaluation of Errors in the Aided Group**

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation</td>
<td>51 (37%)</td>
</tr>
<tr>
<td>Wrong route of administration or unit of measure</td>
<td>33 (27.5%)</td>
</tr>
<tr>
<td>No response given</td>
<td>20 (14.5%)</td>
</tr>
<tr>
<td>Other</td>
<td>18 (13%)</td>
</tr>
<tr>
<td>Adjacent column</td>
<td>16 (11.6%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>138</td>
</tr>
</tbody>
</table>
POTENTIAL SOLUTIONS: DOSING CARD/BOOKLET (CONT)

ADVANTAGES

- Focused information
- Remove calculation step

CHALLENGES

- Dynamic formulary, products may change
- Difficult to read

2. Isolate administration routes

3. Remove non-emergent medications

4. Avoid placing similar concentrations together

1. Remove unnecessary information
POTENTIAL SOLUTION:

Electronic apps

Practice!

Consistency!

Weight from dispatch?
ADMINISTRATION

Standard concentrations

Dilution practice
- Epinephrine
- Dextrose
POTENTIAL SOLUTIONS: EDUCATION

- Seminars
- Simulations
- Research
PRE-HOSPITAL: PEDIATRIC POPULATION