Mass Trauma: Who Will Care For Injured Children?

"Disaster Management and Emergency Preparedness: The Pediatrician’s Role"
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Columbia University/Harlem Hospital

Most Disasters Worldwide Involve Physical Trauma And Burns

- 100% of natural disasters cause physical trauma
  - Virtually all natural disasters involve children
  - 25-40% of acutely injured patients are children
  - Most injuries are minor, require little surgical care
  - Surgeons have a limited role in natural disasters
  - Local hospitals are often destroyed during the event
- 98% of all terrorist events cause physical trauma
  - 75% of terror events worldwide are caused by bombs
  - 23% of terror events worldwide are caused by firearms
  - 1.5% of pediatric trauma in Israel is caused by terror
  - 7-10% of terror victims in Israel are pediatric patients
  - Children are increasingly targeted as victims of terror

Five Likely Bomb Threats

VADM Richard H. Carmona, MD, MPH, FACS, United States Surgeon General

- Single 1-5 kg confined space bomb
  - Bus, shop, disco, fast food restaurant
- Single 100 kg TNT-equivalent car bomb
- Many synchronized bombs – simultaneous, sequential
  - Multiple 5 kg bombs aboard subways and trains
  - Several large 100-500 kg car and truck bombs
  - Mixed adulterants using firebomb or CBRN
  - Inside 100 office buildings across the United States
- Ambulance truck bomb collapses a hospital
- Tanker ship explosion consumes a city

Planning for Pediatric Blast Trauma

- Pediatric injuries are to be expected following blast trauma, with most children injured in closed or confined, rather than open, spaces, greatly increasing the magnitude of forces of injury
- As with adult blast terror injuries, most patients will either die at the scene, or sustain minor injuries, leaving only a small number in the "penumbra" of the blast wave who will sustain major injuries and survive to require hospital care, but who typically will not begin to arrive at the trauma center until some 30-60 minutes after the terror event
- Most survivors with major injuries will require early operation and subsequent care in a pediatric critical care unit, followed by lengthy hospitalization and rehabilitation, both physical and psychological

Mitigation of Pediatric Blast Trauma

- In contrast to military ordnance, environment rather than shrapnel determines the pattern of injury
  - Open air: 70% of fatalities die at the scene; 10% of survivors die, 20% are admitted, 70% are treated & released
  - Rescue is straightforward
  - Nails cause occult injuries out to 100 m – x-ray every scratch
  - Closed space: 80% of fatalities die at the scene; 20% of survivors die, 20% are admitted, 60% are treated & released
  - Rescue is straightforward with buses, but complicated with trains
  - Blast lung is a serious problem – mortality exceeds 70%
  - Building collapse: 90% of fatalities die at the scene; 30% of survivors die, 5% are admitted, 65% are treated & released
  - Rescue is complicated, so consider buddy and passerby rescue
  - Crush, blunt, penetrating, and burn injuries predominate

Mitigation of Pediatric Blast Trauma

- The approximate number and likely destination of casualties can be predicted
  - Half arrive during the first 60 min
  - Half go to the closest 3 hospitals
  - Half go to other hospitals
- Surge capability depends upon the rate limiting step for maximum victim throughput
  - Numbers of ORs & RNs, and ICU beds & RNs, determine hospital capability to care for critically ill patients
  - Numbers of x-ray machines & x-ray technologists determine hospital capability to care for all other patients
  - Regional hospital capacity for blast trauma is likely adequate in most areas unless a regional resource trauma center is a primary or secondary target
Early Care of Pediatric Blast Trauma

- **Airway**
  - Recovery position for blast facial trauma not involving spine

- **Breathing**
  - Needle decompression for blast lung causing tension ptx

- **Circulation**
  - Tourniquets for active bleeding from traumatic amputations
  - Chitosan, QuikClot for active bleeding from soft tissues
  - Hypotensive resuscitation to SBP 60 + 2x age in yr
  - Damage control laparotomy/thoracotomy for hemorrhage
  - Completion amputations for unsalvageable mangled limbs
  - Fasciotomy/escharotomy to avoid compartment syndromes
  - Active/passive rewarming to avoid coagulopathies
  - Fresh whole blood for treatment of coagulopathies

  - Recombinant factor VIIa for treatment of coagulopathies

  - Hypotensive resuscitation to SBP 60 + 2x age in yr

  - Damage control laparotomy/thoracotomy for hemorrhage

Late Care of Pediatric Blast Trauma

- **Compartment syndrome despite fasciotomy**
  - Often develops during aeromedical transport

- **Wound management**
  - Many closed wounds must be reopened

- **Tertiary survey**
  - Should be performed by different team

- **Vascular surgery**
  - Intimal tears caused by shock wave

- **Documentation**
  - Essential for subsequent echelons of care

- **Feedback**
  - All providers must learn of outcome

Response to Pediatric Blast Trauma: Combined Blast Lung/Blast Burn Injury

- **Lung:** fluid restriction; **burn:** fluid resuscitation
- Cover both maintenance and resuscitation needs
- **Modified Parkland (O’Neill) Formula**
  - Maintenance: Holliday-Segar Formula
    - 100 ml/kg (0-10 kg) + 50 ml/kg (10-20 kg) + 20 ml/kg (20+ kg)
  - Resuscitation: 2-3 ml/kg%TBSA
  - Modified Rule of Nines for Children (Lund-Browder Chart)
- Titrate against urine output
  - Infant: 2 ml/kg/hr
  - Child: 1.2 ml/kg/hr
  - Adolescent: 0.5-1 ml/kg/hr
  - Aim for urine specific gravity of 1.010

Pediatric Disaster Medical Response: Hospital Preparation and Mitigation

- **Preparation**
  - Disaster plan must address pediatric issues
  - Pediatric life support and disaster training
  - Pediatric specific disaster drills
  - Regional pediatric surge capability

- **Mitigation**
  - Pediatric team leader and coordinator
  - Pediatric job action sheets
  - Pediatric decontamination unit
  - Pediatric resuscitation equipment
  - Pediatric foods and drugs
  - Pediatric safety and security issues

Pediatric Disaster Medical Response: Surge Capacity Planning Assumptions

- Pediatric surge capacity ≠ pediatric surge capability
- **Federal target: 500 patients/1,000,000 people**
- **New York:** a model for surge capability analysis
- New York State: 700 beds/1,000,000 children
- New York State: 3,000 beds/1,000,000 adults
- New York City: 248 PICU beds, 1,019 pediatric beds
- Israeli blast terror experience: mean age 12 yr
- Israeli blast terror experience: 33% need PICU
Pediatric Disaster Trauma Care:  
Fuzzy Math?

- Needed pediatric surge capability in New York City: 1,000 beds
- Half the patients are over 12 yrs; could be treated in adult TCs
- Surge PICU beds needed in New York City: $500 \times 0.33 = 167$
- Average PICU occupancy in New York City: $248 \times 0.80 = 200$
- Staffed PICU beds typically open daily in New York City: 47*
- New York City must therefore find about 120 more PICU beds
- The 23 PICU hospitals could likely open 4 pediatric PACU beds
- There are 4 other PICUs and PACUs in adjacent counties
- Together they could accept about 116 additional patients; so,
- For blast terror, there may be just enough PICU beds, but . . .
- The calculations are only as good as our assumptions, and . . .
- The Israeli experience with limited MCEs says we need 15-30!

*Source: NYSDOH HERDS Critical Asset Survey August 2004, excluding KCHC NICU beds

Pediatric Trauma Disaster Care:  
Fuzzy Thinking?

- WTC response was likely an aberration
  - WTC appears not to have involved children
  - It was soon learned there were few child victims
  - It was also learned there were few critical victims
  - Immediate plans for mass discharge were aborted
- Pentagon response seems far more likely
  - CNMC immediately discharged 50 patients
  - Even so, PICU beds were in very short supply
  - Use WTC data as a starting point for discussion
  - Plan and drill for worst case scenario as described

New York City Regional Trauma System  
Adult and Pediatric Trauma Centers

- The City of New York
  - Pop. 8,008,278
  - Area 303 mi$^2$
  - P.D. 26,402/mi$^2$
- Bronx
  - Pop. 1,322,650
  - Area 42 mi$^2$
  - P.D. 31,708/mi$^2$
- Brooklyn
  - Pop. 2,486,650
  - Area 71 mi$^2$
  - P.D. 34,917/mi$^2$
- Manhattan
  - Pop. 1,537,195
  - Area 23 mi$^2$
  - P.D. 66,939/mi$^2$
- Queens
  - Pop. 2,229,379
  - Area 109 mi$^2$
  - P.D. 21,708/mi$^2$
- Staten Island
  - Pop. 443,728
  - Area 58 mi$^2$
  - P.D. 7,605/mi$^2$

Tiered Response to Pediatric Disasters  
Pediatric Trauma Surge Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Ped TC</th>
<th>Adult TC</th>
<th>CH - Trm</th>
<th>GH + Ped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pediatric Trauma Service</td>
<td>E</td>
<td>D</td>
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<tr>
<td>Pediatric Surgeon Director</td>
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<td>Pediatric Surgeon Staff</td>
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<td>Pediatric Emergency Medicine</td>
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<td>D</td>
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<td>Pediatric Critical Care</td>
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<tr>
<td>Pediatric Medical / Surgical</td>
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<tbody>
<tr>
<td>ATLS/ATCOT/NCC Training</td>
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<tr>
<td>Training for All Staff</td>
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<tr>
<td>All Hazards Decon Training</td>
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<tr>
<td>Training for ED Staff</td>
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<tr>
<td>Blast Trauma / PALS Training</td>
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<tr>
<td>Blast Trauma / PALS Drills</td>
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<td>Pediatric Emergency Care</td>
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<td>E (Area)</td>
<td>D (Beds)</td>
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<tr>
<td>Care Area / Beds</td>
<td>E (Unit)</td>
<td>D (Beds)</td>
<td>E (Unit)</td>
<td>D (Beds)</td>
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<tr>
<td>Pediatric Intensive Care</td>
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<td>D (Beds)</td>
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<td>Care Area / Beds</td>
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<td>E (Unit)</td>
<td>D (Beds)</td>
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<tr>
<td>Pediatric Acute Care Area</td>
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<td>E (Unit)</td>
<td>D (Beds)</td>
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<tr>
<td>Ped Trauma &amp; Child Protective Svcs</td>
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<tr>
<td>Child Life Support Programs</td>
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<tr>
<td>Ped Social Work / Child Protective Svcs</td>
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<td>Ped Injury Prev / Community Services</td>
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<tr>
<td>Pediatric Trauma Education Programs</td>
<td>E</td>
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<td>D</td>
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<tr>
<td>Pediatric Trauma Research / PI &amp; PS</td>
<td>E</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Pediatric Trauma Manager / Registrar</td>
<td>E</td>
<td>D</td>
<td>-</td>
</tr>
</tbody>
</table>

Pediatric Chain of Survival

**Cooper A, Barlow B.** *Pediatrics* 1995;96:184-198

**Pediatric Assessment Triangle**

AAP, ACEP, PEPP, 2000, APLS, 2002

**Appearance**
- alertness
- distractibility
- consolability
- eye contact
- quality of cry
- spontaneous movement

**Work of Breathing**
- retractions
- flaring
- head bobbing
- see-saw resp
- grunting
- stridor

**Circulation to Skin**
- pale
- mottled
- blue
- gray

**START Triage Grid Modified for Children**

<table>
<thead>
<tr>
<th>MCE Pediatric Triage Category</th>
<th>Hazardous SAR Area (HAZMAT/USAR Technicians)</th>
<th>Safe SAR Area OR Safe CCP Area (CPR/EMTs/Paramedics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead/Expectant</td>
<td>Decapitation, OR multiple or severe</td>
<td>NON-ambulatory, P + R absent, NO response to 5 BVM breaths</td>
</tr>
<tr>
<td>(Black)</td>
<td>dismemberment with NO signs of life</td>
<td></td>
</tr>
<tr>
<td>Immediate</td>
<td>NON-ambulatory, WITH signs of life present or absent</td>
<td>NON-ambulatory, P + R present, WITH: Respiratory rate &lt; 30 or &gt; 10, and if both, 5 BVM breaths, OR unable to follow simple commands, OR infant &lt; 12 mo</td>
</tr>
<tr>
<td>(Red)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed</td>
<td>None</td>
<td>NON-ambulatory, P + R present, WITH: Respiratory rate &lt; 30 and &gt; 10, AND able to follow simple commands</td>
</tr>
<tr>
<td>(Yellow)</td>
<td>AMBULATORY + breathing or crying</td>
<td>AMBULATORY, P + R present, WITH: Respiratory rate &lt; 30 and &gt; 10, AND able to follow simple commands</td>
</tr>
<tr>
<td>Urgent</td>
<td>None</td>
<td>CNS initially tagged Delayed (Yellow) OR Minor (Green) who later exhibits signs of: Respiratory distress or failure, OR altered mental status, OR major injury to torso or head</td>
</tr>
<tr>
<td>(Orange)</td>
<td>AMBULATORY, P + R present, WITH: Respiratory rate &lt; 30 and &gt; 10, AND able to follow simple commands</td>
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</tr>
</tbody>
</table>

**Tier 1 - Pediatric Hospital (+ PICU)**

Intended to receive red, orange, yellow patients
- Committed to subspecialty pediatric care
- Pediatric surgical service
- Pediatric intensive care unit
- Pediatric emergency service
- Comprehensive pediatric subspecialty support
- Anesthesiology, neurosurgery, orthopaedic surgery with experience in management of children
Tier 2 - Pediatric Hospital (- PICU)

Intended to receive green patients
- Committed to general pediatric care
- Pediatric surgical consultants
- Pediatric resuscitation capable ED
- Pediatric transfer agreement

New York City Pediatric Hospitals (n = 35)

Density per 100,000 Children of New York City Pediatric Population, 2008

Summary
- Most pediatric disaster events involve physical trauma
- Pediatric casualties are to be expected following disasters
- Pediatric response and recovery depend upon pediatric planning and mitigation
- Pediatric surge capacity requires regional planning efforts