Eastern Association for the Surgery of Trauma

27th Annual Scientific Assembly

Sunrise Session 06
Improvised Explosive Devices:
Care of Patients from Day 2 Onward

January 16, 2014
Waldorf Astoria Naples
Naples, Florida
Blast Injury: After the Dust Settles
Stabilization - Challenges

Debra L. Malone, MD, FACS, Col USAF

Disclaimer

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Introduction

• Dismounted Complex Blast Injury (DCBI) Definition
• Principles of Wound Stabilization/Repair
• Wound Complications
  – Large soft tissue defects
  – Infection
• Physiological Sequelae
  – SIRS/Sepsis
  – Pain
  – VTE
**Dismounted Complex Blast Injury (DCBI)**

Definition:
- Explosion-induced battle injury sustained by a war fighter on foot patrol
- Produces a specific pattern of wounds
  - Traumatic amputation of at least one leg
  - Minimum of severe injury to another extremity
  - Pelvic, abdominal, and/or urogenital wounding

**Wound Stabilization**
- Ensure adequate wash-out/debridement
- Vacuum wound therapy
- Evaluate QOD/QD on days 2-8 or until stable; immediately if SIRS-Sepsis
- Post-injury days 3-7:
  - Beware of infection – e.g., IFI
    - Unexpected wound necrosis
    - Mildly elevated WBC count, low-grade fever
    - Rapid progression to sepsis, massive tissue loss

**Wound Stabilization**
- Invasive Fungal Infection (IFI)
  - Risk Factors
  - Diagnosis
    - Clinical suspicion/Histopathology/Culture
  - Treatment Principles – CPG: WRNMMC-JTTS
    - Surgical debridement/Wound care adjuncts
    - Antifungal medications
      - Broad spectrum initially
      - Focus with culture data/time/wound characteristics
Wound Stabilization

- Wound Closure
  - Indications/Timing/Follow-up
- Massive soft tissue destruction
  - Filling the defect
- Infectious disease adjuncts
  - Antimicrobial medications
  - Topical treatment-antimicrobial solns, beads, Dakins
  - Instill vacuum therapy

Intraoperative ID Protocol

- Indication – infection/necrosis
- Three separate samples
  - Histopathology – fungal elements/angioinvasion
  - Culture – Bacterial/Viral
  - Culture – Mycobacterium/Fungal

Intraoperative ID Protocol

- High Power H&E stain- angioinvasion
Intraoperative ID Protocol

• High Power GMS stain - angioinvasion

Vori and Ampho: Not so Terrible

Error Bars: 95% CI; p=0.299
Vori and Ampho: Not so Terrible


Independent Risk Factors for IFI

- Case-control study
  - 1133 casualties eligible for study
  - 77 patients: 1:2 match with controls
    - ISS +/- 10, injury date +/- 3 months
- Multivariate analysis
  - Risk factors:
    - Mechanism of Injury
    - HD status at initial presentation
    - Traumatic amputation level
    - Associated injuries

### Independent Risk Factors for IFI

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IFI Cases (N = 76)</th>
<th>Controls (N = 150)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, median (IQR)</td>
<td>23.1 (21.7, 26.3)</td>
<td>23 (21.4, 26.2)</td>
<td>0.725</td>
</tr>
<tr>
<td>Male</td>
<td>76 (100)</td>
<td>150 (100)</td>
<td></td>
</tr>
<tr>
<td>Injury Circumstances, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast Injury</td>
<td>75 (98.7)</td>
<td>130 (86.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dismounted</td>
<td>69 (93.2)</td>
<td>108 (74.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LRMC ISS, median (IQR)</td>
<td>21 (17, 26)</td>
<td>21 (17, 24)</td>
<td>0.348</td>
</tr>
</tbody>
</table>

IFI: Invasive Fungal Infection  
LRMC: Landstuhl Regional Medical Center

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### IFI Results

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IFI Cases (N = 76)</th>
<th>Controls (N = 150)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Characteristics In Theater, median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Rate</td>
<td>124.5 (103.3, 139.8)</td>
<td>110 (91.5, 129.5)</td>
<td>0.002</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td>99.0 (79.5, 122.5)</td>
<td>123.0 (109.0, 142.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood Gas – Base Deficit</td>
<td>9.0 (12.5, 4.0)</td>
<td>3.0 (6.0, 0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood Gas – pH</td>
<td>7.24 (7.12, 7.30)</td>
<td>7.31 (7.24, 7.39)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Shock Index (≥ 1.5), No. (%)</td>
<td>24 (31.6)</td>
<td>10 (6.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood Transfusion Requirements, median (IQR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packed Red Blood Cells</td>
<td>29 (16, 39)</td>
<td>11 (4, 19)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fresh Frozen Plasma</td>
<td>27 (12, 15)</td>
<td>11 (4, 19)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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### Independent Risk Factors for IFI

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<tbody>
<tr>
<td>Amputations, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Extremity</td>
<td>60 (78.9)</td>
<td>69 (46.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Above the Knee</td>
<td>49 (65.2)</td>
<td>32 (21.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Associated Injuries, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genitourinary</td>
<td>58 (77.2)</td>
<td>51 (34.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rectal/Bladder/Genitalia</td>
<td>4 (5.3)</td>
<td>1 (0.7)</td>
<td>0.0409</td>
</tr>
<tr>
<td>Colostomy</td>
<td>28 (36.8)</td>
<td>10 (6.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Penetrating Abdomen</td>
<td>11 (14.5)</td>
<td>19 (12.7)</td>
<td>0.7025</td>
</tr>
<tr>
<td>Pelvic/Hip Abdomen</td>
<td>27 (35.5)</td>
<td>10 (6.7)</td>
<td>0.0032</td>
</tr>
</tbody>
</table>

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Pain Management

- Blast injury causes significant morbidity
- Multi-modality clinical problem
- Multi-modality treatment plan
  - Surgical Management
  - Medical Management (ID, etc.)
    - **PAIN Management

Pain Management

- Acute and Chronic problem
- Accompanied by emotional stress - PTSD
- Etiology of pain is multi-factorial
  - Disease, Inflammation, Injury
    - Musculoskeletal
    - Soft tissue
    - Neurological
      - *TBI

Pain Management

- Acute – “Re-regulate pain”
  - Adaptive component
    - Catecholamine – analgesic properties
    - Down regulate CNS
    - Protect all systems
  - Phantom Pain
- Chronic
  - Goal is prevention
  - Complex Regional Pain Syndrome (CRPS, “RSD”)
  - Treatment of pain is multi-modality
**Multi-Modality Pain Management**

- Pharmacological (IV, PO, Regional, Epidural)
  - NSAIDS
  - Gabapentinoids
  - Acetaminophen
  - Alpha-2 agonists
  - Ketamine
  - Esmolol
  - Opioids – “rescue,” adjunct role
- Non-Pharmacological
  - Transcutaneous Electrical Stimulation

**VTE Disease**

- 5-63% incidence of VTE in civilian trauma
- Wounded warriors
  - 9.1% incidence of VTE disease
  - 5.7% incidence of PE
- Ongoing research – etiology; therapy


**VTE Disease**

- 506 WW PI - WRAMC; Sept 2009-Mar 2011
- Data sources:
  - WRAMC EHR and DODTR data sets; ICD-9 Codes
- Diagnosis:
  - Extremity US and CT pulmonary angiography
- Statistical Analysis:
  - Univariate analyses and regression models (P < .20)

VTE Disease

- Mean ISS 18.4 +/- 11.7; IED MOI – 65%
- 46 (9.1%) WW with DVT prior to discharge
- 18 (3.6%) during Air evacuation
- 28 (5.5%) during hospital stay
- Independent predictor of DVT:
  - PRBC transfusion within 1st 24 hours (HR) 1.04 (95% CI, 1.02-1.07; P = .02)
- Protective for DVT:
  - LMWH 30 mg bid; majority of hosp days (HR) 0.31 (95% CI, 0.11-0.86; P = .02)


VTE Disease

- Retrospective review;
  - 1213 records; 263 WW; 103 amps; 145 long bone fx.
- PE: 150 (5.7%) patients; 3.7% in pts. with amps
- Bilateral LE amps
  - Independent RF for PE (p=0.007; OR 5.9)


Case vs. Suspect- AAST 2012

<table>
<thead>
<tr>
<th></th>
<th>Matched Suspect Cases</th>
<th>Matched Non-Suspect Cases</th>
<th>p value</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>125(85.7%)</td>
<td>13(42.9%)</td>
<td>.0001*</td>
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<tr>
<td>Death</td>
<td>Single (17/31)</td>
<td>17/54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Death + Pulmonary + +</td>
<td>7/31</td>
<td></td>
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<td></td>
<td>Venous + +</td>
<td>7/14</td>
<td></td>
</tr>
<tr>
<td>Blood</td>
<td>(7/31)</td>
<td>1(12.5%)</td>
<td>.0004*</td>
</tr>
<tr>
<td></td>
<td>(7/31)</td>
<td>0</td>
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</tr>
<tr>
<td></td>
<td>3.3%</td>
<td>0.0%</td>
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<tr>
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<td>(7/31)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>
VTE Disease

• All patients get DVT prophylaxis
• Patients with VTE disease receive therapeutic doses
• Doses are NOT held for operations/procedures
• Doses are held for placement of Epidural caths
  • Restarted after 6 hours
  • QD dosing

R-IVCF Registry

• NNMC Trauma R-IVCF registry created in 2007
  – Trauma Program Coordinator manages list
  – List maintained at twice weekly trauma multidisciplinary meetings
  – Team encouraged to either:
    • Plan for retrieval
    • Declare ongoing indications for filter
  – Program administrator responsible for communicating plan for retrieval to outpatient or rehab hospital providers

Methods

• Retrospective study with historical controls
• Inclusion criteria:
  – All patients on trauma service with R-IVCF placed
• Registry patients compared to historic controls
  – Registry
    • Jan 2007 to Jan 2011
    • 93 patients
  – Controls
    • Dec 2005 to Dec 2006
    • 20 patients

Methods

- Primary outcome measure
  - Filter retrieval
- Secondary outcome measures
  - Filter retrieval attempts
  - Time to filter retrieval attempt
  - Loss to follow-up


Results: Demographic Data

<table>
<thead>
<tr>
<th></th>
<th>Registry</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>93</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>% Male</td>
<td>99%</td>
<td>100%</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean Age (years)</td>
<td>27 +/- 6</td>
<td>22 +/- 5</td>
<td>0.0005</td>
</tr>
<tr>
<td>Mean ISS</td>
<td>25 +/- 10</td>
<td>20 +/- 12</td>
<td>0.08</td>
</tr>
<tr>
<td>Mortality</td>
<td>10%</td>
<td>0%</td>
<td>0.36</td>
</tr>
<tr>
<td>Mechanism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast</td>
<td>65%</td>
<td>65%</td>
<td>1.00</td>
</tr>
<tr>
<td>Penetrating</td>
<td>18%</td>
<td>30%</td>
<td>0.24</td>
</tr>
<tr>
<td>Blunt</td>
<td>16%</td>
<td>5%</td>
<td>0.30</td>
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</table>

Two-tailed t-test for age and ISS (mean +/- SD). Two-tailed Fischer's Exact test for gender, mortality, and mechanism.

Results: Primary Outcome Measure

R-IVCF Retrieved

<table>
<thead>
<tr>
<th></th>
<th>Registry</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>56/93</td>
<td>6/20</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>60%</td>
<td>30%</td>
<td>0.02</td>
</tr>
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</table>

Two-tailed Fischer’s Exact test
Results: Secondary Outcome Measures

R-IVCF Retrieval Attempts

<table>
<thead>
<tr>
<th></th>
<th>Registry</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>65/93</td>
<td>6/20</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>70%</td>
<td>30%</td>
<td>0.002</td>
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</table>

Time to retrieval attempt

<table>
<thead>
<tr>
<th></th>
<th>Registry</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>84 +/- 101</td>
<td>210 +/- 190</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Retrieval success based on time to attempt

<table>
<thead>
<tr>
<th></th>
<th>Success</th>
<th>Failure</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>93 +/- 117</td>
<td>117 +/- 125</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Summary: R-IVCF Disposition

<table>
<thead>
<tr>
<th></th>
<th>Registry %</th>
<th>Control %</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieved</td>
<td>60</td>
<td>30</td>
<td>0.02</td>
</tr>
<tr>
<td>Failed retrieval attempt</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Ongoing indication</td>
<td>15</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Loss to follow up</td>
<td>5</td>
<td>65</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Death</td>
<td>10</td>
<td>0</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Blast Injuries: Hospital Wide Effects

Carlos J. Rodriguez, DO, MBA, FACS

Hospital-Wide Effects

- Main OR Scheduling
  - Depending on patient load, may effect elective OR scheduling
  - OR every other day for median 15 trips
- Length of Stay
  - 21-60 days depending on infectious and VTE post injury course
- Blood Product Utilization in 77 patients (1st 24 hr)
  - PRBC 29 (16,38)
  - FFP 27 (16,37)


Coordination of Services

- Resource intensive
- Multiple trips throughout hospital
  - Communication
  - Timing of medication dosing
- Rehabilitation
  - Inpatient
  - Outpatient
  - Cognitive
  - TBI
Coordination of Services

- Trauma Surgeons
- Orthopedic Surgeons
- Anesthesia (Pain Mgmt.)
- Behavior Health
- Neuropsychologists/TBI
- Phys Medicine & Rehab
- Plastic Surgery
- Neurosurgery
- Physical Therapy
- Recreational Therapy
- Occupational Therapy
- Inpatient Warrior Family Liaison
- Nurses (ICU, ward)
- Federal Recovery Coordinators
- Warrior Transition Unit (Army)
- Marine Corps Liaison
- Navy Liaison
- Army Liaison
- ICU, 4E, 4C, 4W reps
- VA Liaisons
- Trauma Nurse Coordinator
- Trauma PI Coordinator
- Nutrition Services
- Social Workers

“Blast Consultations”

- Standard
  - Physical Therapy
  - Occupational Therapy
  - Social Work
  - Rehabilitation Medicine
- TBI
- Audiology
- Dental
- Ophthalmology

“Blast Consultations”

- TBI (15-16 blast wave portals of entry)
  - Primary: Blast wave (loudly associated with an TBI (1-7)
  - Secondary: Penetrating projectiles (10-15)
  - Tertiary: Penetrating projectiles (10-15)
  - Quaternary: Penetrating projectiles (10-15)
- Incidence from other attacks
  - Israel and Madrid
- Injury dependency
  - Pilot trauma
  - Blast wave blast
  - Body position
  - Body armor
  - Environment
- mTBI Definition and Dx
  - LOC: < 30 min, GCS 13-15, aLOC < 24h, amnesia < 24h
- mTBI and PTSD overlap
  - Residual PTSD more prevalent in mTBI caused by blast

“Blast Consultations”

• Standard
  – Physical Therapy
  – Occupational Therapy
  – Social Work
  – Rehabilitation Medicine
• Audiology (7/12 - 1/14)
  – 53 of 200 patients with ruptured TM
  – 20 with bilateral TM rupture
• Dental
  – Screening on all patients
Motor Control for Trauma and Advanced Prosthetics

Albert Chi, MD
Assistant Professor, Division of Acute Care Surgery
Johns Hopkins Hospital
Lieutenant Commander, Medical Corp
United States Navy Reserve

Background

- 82% majority of trauma that currently occurs in Iraq and Afghanistan involves the upper and lower extremities
  - Wearing of protective body armor
  - MRAV (Multi-role Armored Vehicle)
  - IED (Improvised Explosive Devices)
    - Iraq – 155 artillery rounds
    - Afghanistan – nitrogen based bombs

Return to Duty Rate of Amputee Soldiers in the Current Conflicts in Afghanistan and Iraq

CPT Daniel J. Skinner, MD, MAJ Travis C. Berne, MD, ELC Kevin L. Kirk, DO, and COL James R. Finkle, MD

During the 1980s, 11 of 469 (2.3%) amputees returned to active duty

The number of amputees returning to duty has increased significantly, from 2.3% to 16.5%, due to advancements in combat casualty care and the establishment of centralized amputee centers

Applied Physics Lab
Modular Prosthetic Limb

- The robotic arm itself weighs nine pounds
- Capable of 17 degrees of freedom, and reacts with speed and agility to the user’s commands
  - Able to move each individual finger and rotating the wrist (26 joints)
  - Tactile measure temperature, pressure and acceleration
  - Capable of curling 50 lbs

DARPA – Revolutionizing Prosthetics Program

- Benefit individuals at all levels of injury
  - Spinal Cord injury
- Control Strategies
  - Cortical Control
“Breakthrough”
Aired December 21, 2012

DARPA – Revolutionizing Prosthetics Program

- Benefit individuals at all levels of injury
  - Missing upper extremity
- Control Strategies
  - Surface EMG Control

Targeted Muscle Reinnervation

- Following amputation, the control information remains in residual peripheral nerve
- The technique involves nerve transfers to spare muscles regions
- Surface EMGs used to control multiple DOF prosthesis with intuitive thought
- Ideal with high amputation levels including above elbow and should disarticulations
**Customary Myoelectric Fitting**
Following Transhumeral Amputation

1. Elbow Extend
   - Triceps
2. Hand Open

1. Elbow Flex
   - Biceps
2. Hand Close

**Sequential Control**

**TMR for Transhumeral Amputation**

**TMR Nerve Transfers**

<table>
<thead>
<tr>
<th>Transfers</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median -&gt; Medial head Biceps</td>
<td>Hand Close</td>
</tr>
<tr>
<td>Distal Radial -&gt; Lateral Triceps</td>
<td>Hand Open</td>
</tr>
<tr>
<td>Ulnar -&gt; Brachialis</td>
<td>Wrist/Hand</td>
</tr>
</tbody>
</table>

**Residual**

<table>
<thead>
<tr>
<th>Musculocutaneous -&gt; Lateral biceps</th>
<th>Elbow flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal Radial -&gt; Long head Triceps</td>
<td>Elbow extension</td>
</tr>
</tbody>
</table>
Targeted Muscle Reinnervation
Advanced Algorithms

Virtual Interactive Environment

Virtual Reality Environment (VIE)

- Performance Feedback
- Real-time control and feedback
**MPL Pattern Recognition Control after VIE Training**

- Able to classify 13 separate distinct movements which included multiple grips and finger control at 10 months.

---

**Targeted Sensory Reinnervation**

- Finger discrimination: four trials of 25 repetitions with 91% accuracy.
- Object density: Four trials of 27 repetitions was able to distinguish between hard, soft, and no object with 95% accuracy.

---

**MPL Sensory Feedback**

- Finger discrimination: four trials of 25 repetitions with 91% accuracy.
- Object density: Four trials of 27 repetitions was able to distinguish between hard, soft, and no object with 95% accuracy.
Myotrain Experience

- Diversity of Patients
  - Evaluated amputation levels
  - Including all levels of congenital limb loss
- All achieve control which exceed expectations
  - Goal multiple grip classifications
  - Intuitive control strategies

Traditional surgical approach

- Nerve endings identified
- Transected under tension
- Allowed to retract under proximal soft tissues
- Intent of neuroma formation in a well protected area

Future Directions

- Surgery
  - Change surgical approach to upper extremity amputation
    - Local Reinnervation
    - Targeted Sensory Reinnervation Surgery
    - WRNMMC Drs. Potter and Nanos
- Research
  - Clinical/Function Pattern Recognition studies
  - First Bilateral Shoulder TMR fitting
  - IMES participation
  - TMR patients at JHH
- Development of the JHH Neuroprosthetic program
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Questions?

Targeted Muscle Reinnervation Surgery for Upper Extremity Amputees

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