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

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Walter Reed Bethesda

Disclaimer

The views expressed in this manuscript are those of the authors and do not reflect the official policy of the Department of the Army, Department of the Navy, Department of the Air Force, the Department of Defense or the United States Government.

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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

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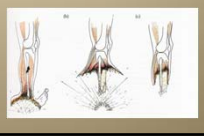
Dismounted Complex Blast Injury (DCBI)

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



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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

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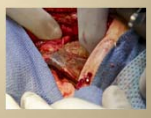
Wound Stabilization

- 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

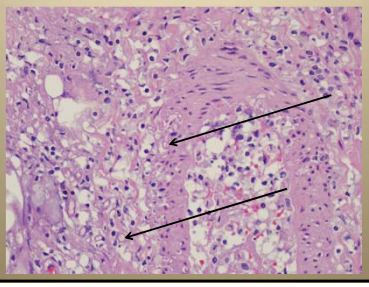
- Wound Closure
  - Indications/Timing/Follow-up
- Massive soft tissue destruction
  - Filling the defect
- Infectious disease adjuncts
  - Antimicrobial medications
  - Topical treatment-antimicrobial solns, beads, Dakins
  - Instill vacuum therapy

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



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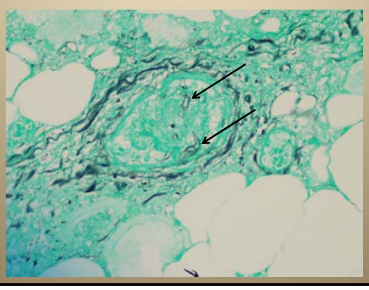
Intraoperative ID Protocol

- High Power GMS stain- angioinvasion



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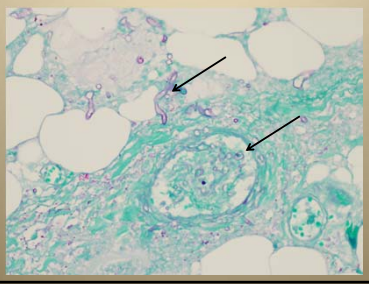
Intraoperative ID Protocol

- High Power PAS stain- angioinvasion



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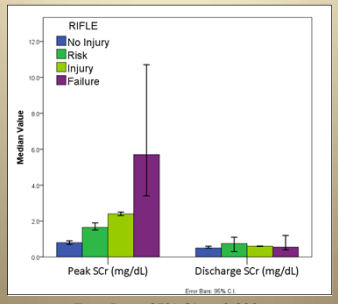
Vori and Ampho: Not so Terrible



Error Bars: 95% CI; p=0.299

Caruso J, Weisbrod A, Rodriguez C, et al. Vori and Ampho: Not so Terrible, presented at SIS, April 2013

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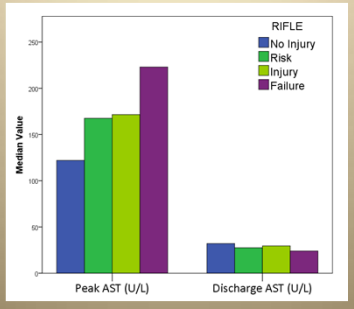
Vori and Ampho: Not so Terrible



p=0.373

p=0.955

Caruso J, Weisbrod A, Rodriguez C, et al. Vori and Ampho: Not so Terrible, presented at SIS, April 2013

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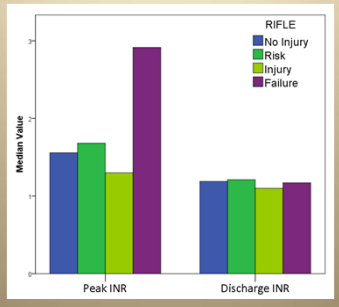
Vori and Ampho: Not so Terrible



p=0.052

p=0.580

Caruso J, Weisbrod A, Rodriguez C, et al. Vori and Ampho: Not so Terrible, presented at SIS, April 2013

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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

Rodriguez C, Weintrob A, Malone D, et al. Risk Factors Associated with IFI in Combat Trauma. In-press SI

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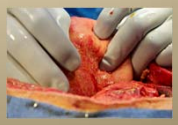
Independent Risk Factors for IFI

Characteristics	IFI Cases (N = 76)	Controls (N = 150)	P-value
Demographics, No. (%)			
Age, median (IQR)	23.1 (21.7, 26.3)	23 (21.4, 26.2)	0.725
Male	76 (100)	150 (100)	-
Injury Circumstances, No. (%)			
Blast Injury	**75 (98.7)**	**130 (86.7)**	**<0.001**
Dismounted	**69 (93.2)**	**108 (74.0)**	**<0.001**
LRMC ISS, median (IQR)	21 (17, 26)	21 (17, 24)	0.148

IFI – Invasive Fungal Infection
IQR - Interquartile Range
ISS - Injury Severity Score
LRMC - Landstuhl Regional Medical Center



Rodriguez C, Weintrob A, Malone D, et al. Risk Factors Associated with IFI in Combat Trauma. In-press SI

IFI Results

Characteristics	IFI Cases (N = 76)	Controls (N = 150)	P-value
Clinical Characteristics In Theater, median (IQR)			
Heart Rate	124.5 (103.3, 139.8)	110.0 (91.5, 129.5)	0.002
Systolic Blood Pressure	99.0 (79.5, 122.5)	123.0 (109.0, 142.3)	<0.001
Blood Gas – Base Deficit	9.0 (12.5, 4.0)	3.0 (6.0, 0)	<0.001
Blood Gas – pH	7.24 (7.12, 7.30)	7.31 (7.24, 7.39)	<0.001
Shock Index (≥1.5), No. (%)	24 (31.6)	10 (6.7)	<0.001
Blood Transfusion Requirements, median (IQR)			
Packed Red Blood Cells	29 (16, 39)	11 (4, 19)	<0.001
Fresh Frozen Plasma	27 (16, 37)	11 (4, 18)	<0.001

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Independent Risk Factors for IFI

Characteristics	IFI Cases (N = 76)	Controls (N = 150)	P-value
Amputations, No. (%)			
Lower Extremity	60 (78.9)	69 (46.0)	<0.001
Above the Knee	48 (63.2)	32 (21.3)	<0.001
Associated Injuries, No. (%)			
Genitalia/Groin	56 (73.7)	51 (34.0)	<0.001
Rectal/Bladder and Genitalia	4 (5.3)	1 (0.7)	0.0449
Colostomy	28 (36.8)	14 (9.3)	<0.001
Penetrating Abdomen	11 (14.5)	19 (12.7)	0.7052
Pelvis / Hip (Skeletal)	27 (35.5)	35 (23.3)	0.0523

Rodriguez C, Weintrob A, Malone D, et al. Risk Factors Associated with IFI in Combat Trauma. In-press SI

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

Toker S, et al. Deep vein thrombosis prophylaxis in trauma patients. Thrombosis 2011; 2011: 505373.
Holley A, et al. Thromboprophylaxis and VTE rates in soldiers wounded in operation enduring freedom and operation Iraqi freedom. Chest 2013 Sep;144(3).
Gillern SM, et al. Incidence of pulmonary embolus in combat casualties with extremity amputations and fractures. J Trauma 2011 Sep;71(3):607-12.

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 ($P < .20$)

Holley A, Petteys S, Mitchell J, et al. Thromboprophylaxis and VTE rates in soldiers wounded in Operation Enduring Freedom and Operation Iraqi Freedom. Chest 2013 Sep;144(3).

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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)

Holley A, Petteys S, Mitchell, J, et al. Thromboprophylaxis and VTE rates in soldiers wounded in operation enduring freedom and operation Iraqi Freedom. Chest 2013 Sep;144(3).

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VTE Disease

- VTE in WW NNMC 1 Mar 2003- 31 Dec 2007
- 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)

Gillern SM, et al. Incidence of pulmonary embolus in combat casualties with extremity amputations and fractures. J Trauma 2011 Sep;71(3):607-12.

Case vs. Suspect- AAST 2012

	Wound Necrosis Positive Cases (N = 77)	Wound Necrosis Negative Cases (N = 19)	p-value
IFI Antifungal Treatment Regimen, No. (%)			
No treatment	**12 (15.6)**	**16 (84.2)**	**<0.001***
Single Agent	**7 (9.1)**	**1 (5.3)**	**1.000**
Dual (Amphotericin B + Triazole)	**42 (54.5)**	**2 (10.5)**	**<0.001***
Combination (Dual +/- echinocandin)	**57 (74)**	**2 (10.5)**	**<0.001***
Systemic Antifungal Agents, No. (%)			
Amphotericin B (liposomal)	**60 (77.9)**	**3 (15.8)**	**<0.001***
Voriconazole	**59 (76.6)**	**2 (10.5)**	**<0.001***
Posaconazole	**17 (22.1)**	**0**	**0.020***
Caspofungin	**15 (19.5)**	**0**	**0.037***
Micafungin	3 (3.9)	0	1.000
Antifungal Duration, median days (IQR)			
Amphotericin B (liposomal)	**21 (12, 30)**	**4 (2, 6)**	**0.012***
Voriconazole	17 (9, 26)	14.5 (10.8, 18.3)	0.772
Total antifungal treatment	18 (7, 29)	4 (2.5, 13.5)	0.182
Hospitalization, median (IQR)			
Total Hospitalization (days)	49 (32, 68)	39 (29.5, 50.5)	0.091
Total Duration in ICU (days)	**10.5 (5.8, 20)**	**4 (3, 6)**	**<0.001***
Overall OR Visits	**15 (10, 19)**	**8 (6.5, 12)**	**0.008***
High-level Amputations†, No. (%)	15 (19.5)	1 (5.3)	0.182
Deaths, No. (%)	6 (7.8)	0	0.595

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

Lucas D, Dunne J, Rodriguez C, et al. Dedicated tracking of patients with R-IVCF improves retrieval rates. Amer Surg 78: 8; Aug 2012

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Methods

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

Lucas D, Dunne J, Rodriguez C, et al. Dedicated tracking of patients with R-IVCF improves retrieval rates. Amer Surg 78: 8; Aug 2012

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Results: Demographic Data

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

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

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Results: Primary Outcome Measure

R-IVCF Retrieved

	Registry	Control	p
n	56/93	6/20	
%	60%	30%	0.02

Two-tailed Fischer's Exact test

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Results: Secondary Outcome Measures

R-IVCF Retrieval Attempts

	Registry	Control	p
n	65/93	6/20	
%	70%	30%	0.002

Two-tailed Fischer's Exact test.

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Results: Secondary Outcome Measures

Time to retrieval attempt

	Registry	Control	p
Days	84 +/- 101	210 +/- 190	0.17

Retrieval success based on time to attempt

	Success	Failure	p
Days	93 +/- 117	117 +/- 125	0.53

Two-tailed t tests . Results reported as mean +/- STD

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Summary: R-IVCF Disposition

	Registry %	Control %	p
Retrieved	60	30	0.02
Failed retrieval attempt	10	0	
Ongoing indication	15	5	
Loss to follow up	5	65	<0.0001
Death	10	0	0.36

Two- tailed Fischer's Exact Tests

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Questions?

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)

Weisbrod, et al. "Fungus Among Us: A Large Case Series of Invasive Fungal Infections in Combat Casualties." Poster presentation at 2012 MHSRS in Ft Lauderdale, FL.

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 Liason
- 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 (mostly associated with m TBI) (1-7)
  - Secondary: Penetrating projectiles (10-12)
  - Tertiary: Acceleration / Deceleration (13)
  - Quaternary: Thermal / Chemical injuries (14)
- Incidence from other attacks
  - Israel and Madrid
- Injury dependency
  - Blast energy
  - Distance from blast
  - Body position
  - Body armor
  - Environment
- mTBI Definition and Dx
  - LOC < 30 min, GCS 13-15, aLOC < 24h, amnesia < 24h
  - Military Acute Concussion Evaluation (MACE)
  - Automated Neuropsychological Assessment Metrics (more useful with pre-injury baseline) measures cognitive ability and compares to pre-blast
- TBI and PTSD overlap
  - Residual PTSD more prevalent in mTBI caused by blast

Rosenfeld, et al; "Blast –related traumatic brain injury". Lancet Neurology 2013; 882-93.

“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, Medial Corp
United States Navy Reserve

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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

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ORIGINAL ARTICLE

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

CPT Daniel J. Stinner, MD, MAJ Travis C. Burns, MD, LTC Kevin L. Kirk, DO, and COL James R. Ficke, 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

J Trauma. 2010 Jun;68(6):1476-9.

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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

Controlled movements - arm raised

DARPA – Revolutionizing Prosthetics Program

- Benefit individuals at all levels of injury
  - Spinal Cord injury
- Control Strategies
  - Cortical Control

"Breakthrough"

Aired December 21, 2012

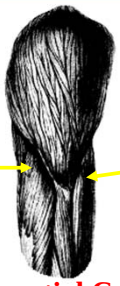
DARPA – Revolutionizing Prosthetics Program

- 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 ampuation 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

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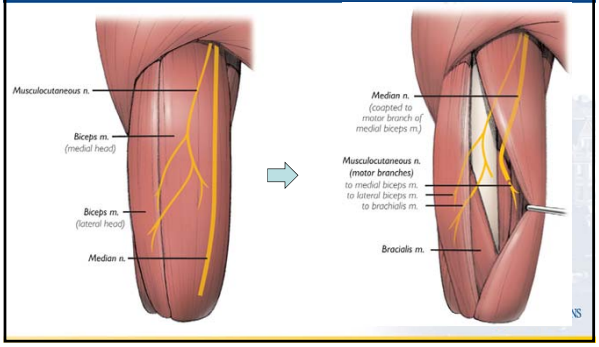
TMR for Transhumeral Amputation



TMR Nerve Transfers

Transfers	**Functions**
Median -> Medial head Biceps	Hand Close
Distal Radial –> Lateral Triceps	Hand Open
Ulnar -> Brachialis	Wrist/Hand
Residual	
Musculocutaneous -> Lateral biceps	Elbow flexion
Proximal Radial -> Long head Triceps	Elbow extension

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Targeted Muscle Reinnervation Advanced Algorithms

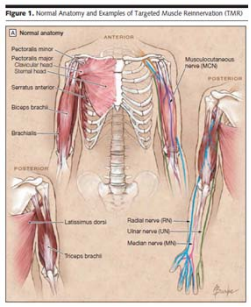

Figure 1. Normal Anatomy and Examples of Targeted Muscle Reinnervation (TMR)

Table.
Peripheral nerve actions (radial, median, and ulnar) of upper limb

Radial	Median
Elbow Extension	Pronation
Supination	Radial wrist flexion
Radial Wrist Extension	Midline wrist flexion
Ulnar Wrist Extension	Finger flexion at DIPs and MPs (digits 2 & 3)
Midline Wrist Extension	Finger flexion at PIPs
Index finger extension	Thumb flexion (distal)
Little Finger Extension	Thumb opposition
Thumb Extension	Thumb abduction
Finger Extension	Finger abduction
	Finger adduction

Ulnar
Ulnar wrist flexion
Finger flexion at DIP (digits 4 & 5)
Thumb flexion (proximal)
Thumb abduction
Little finger opposition
Little finger abduction
MP flexion (digits 3 & 4)

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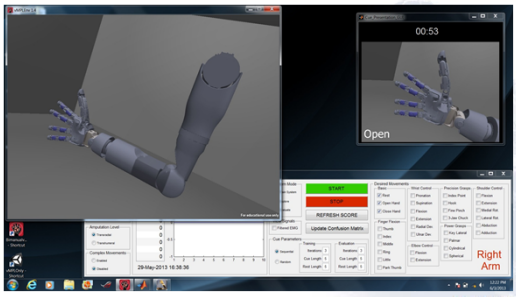
Virtual Interactive Environment



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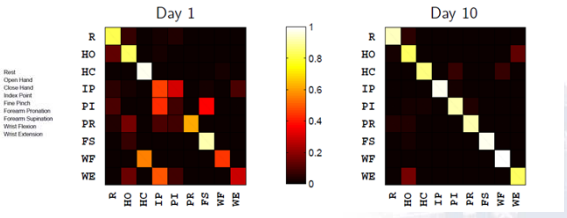
Virtual Reality Environment (VIE)



- Performance Feedback
- Real-time control and feedback

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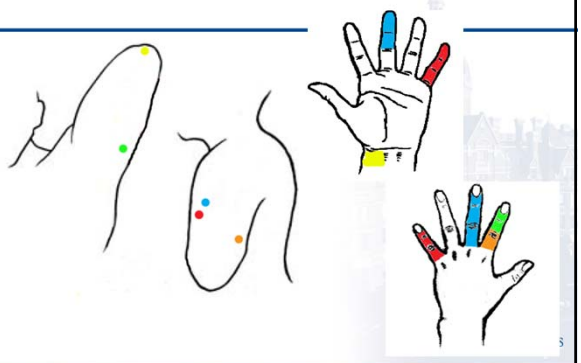
MPL Pattern Recognition Control after VIE Training

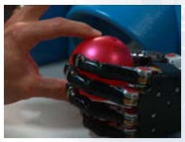
- Able to classify 13 separate distinct movements which included multiple grips and finger control at 10 months

Targeted Sensory Reinnervation



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



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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

Acknowledgments

- JHU Applied Physics Lab
  - Mike Mcloughlin
  - Bobby Armiger
- DARPA
  - Col Geoffery Ling
- JHU BME
  - Mike Powell
  - Rahul Kaliki
- Hanger
  - Brian Monroe
- Advanced Arm Dynamics
  - John Miguelez
  - Jamie Vandersea
- Rehab Institute of Chicago
  - Todd Kuiken
  - Greg Dumanian
- Walter Reed Army Medical Center
  - Paul Pasquina
  - Martin Baelcher
- National Rehabilitation Hospita
  - Alex Dromerick
  - Rahssan Holly
- JHH Physical Medicine and Rehabilitation
  - Marlis Gonzales
  - Mark Hopkins
  - Molly Ferris

Questions?

Targeted Muscle Reinnervation

Surgery for Upper Extremity Amputees

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January 9, 2014 23