Effects of Blast Injury on Cerebral Blood Flow & Cerebral Vascular Reactivity

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Mechanisms of Blast Injury:

Primary  Effects of blast over/underpressure

Secondary  Effects of energized fragments accelerated by blast wind

Tertiary  Physical displacement of the body including impact & crush injury

Quaternary  All other effects including burns & toxins

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Effects of Experimental Blast Injury on the Brain

Neuronal swelling & injury, behavioral deficits, ↑ oxidative stress
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Neuronal/glial swelling, ↑NOₓ, active avoidance deficits
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Widespread silver staining in neurons & white matter in pigs & rats

DAI, metabolic disturbances, cytoskeletal degradation, etc.
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CEREBRAL CIRCULATION?

MOODY CENTER
For Traumatic Brain & Spinal Cord Injury Research ★ Mission Connect
Effects of Blast Injury on the Cerebral Circulation

Blast-induced TBI in 80% of pts. with traumatic cerebral vasospasm

Angiographic narrowing of cerebral arteries (pigs)
Bauman, et al., JNT 26:841-860, 2009

Impaired “cardiocompensatory resilience” during hemorrhage
Long, et al., JNT 26:827-840, 2009
Blast overpressure & hemorrhagic hypotension


Rats exposed to 126 kPa airblast or sham injury followed by controlled hemorrhage to 30 mmHg.
Vandenberg Blast-Induced Brain Injury Device

Ramset/Remington nail gun cartridges: widely available
.22, .25, .27, .32 caliber; 5 levels ea.

Solenoid-driven impactor

Interchangeable .22, .27 caliber firing chambers

Interchangeable chamber outlets
Vandenberg Blast-Induced Brain Injury Device

Safety switch
Firing solenoid
Firing pin
Firing chamber
Firing button
Vandenberg blast: High-speed video
Pressure Waves Produced by the Vandenberg Blast Injury Device

![Graph showing pressure waves produced by the Vandenberg Blast Injury Device. The graph plots pressure over time, with peaks indicating overpressure and troughs indicating underpressure.](image-url)
Effects of BINT on Arterial Blood Pressure & Cerebral Blood Flow

Rats were anesthetized, intubated, mechanically ventilated (2.0% isoflurane) & placed in headholder

Scalps were shaved & incised along midline; skull thinned for laser Doppler flowmetry (LDF) & a tail artery was cannulated

Baseline LDF & ABP measurements performed; rats were placed on a foam pad, covered with a silicone pad, subjected to moderate blast injury (n = 6) or sham blast (n = 6) & returned to headholder

LDF & ABP monitored for 60 min
Effects of blast-induced neurotrauma (BINT) on acute arterial blood pressure in rats
Effects of blast-induced neurotrauma (BINT) on arterial blood pressure in rats

Mean arterial blood pressure

Time (min) after blast-induced neurotrauma (BINT)
Effects of blast-induced neurotrauma (BINT) on cerebral blood flow in rats
Effects of mild blast-induced neurotrauma (BINT) on cerebral vascular resistance in rats
Responses to reduced intravascular pressure in rat middle cerebral arteries (MCA) harvested after blast-induced neurotrauma (BINT)
Influence of abnormally low blood pressure on outcome after severe TBI

<table>
<thead>
<tr>
<th>Blood pressure</th>
<th>Good Outcome (GR, MD)</th>
<th>Bad Outcome (SD, PVS, D)</th>
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<tbody>
<tr>
<td>Normal (&gt; 90 mmHg)</td>
<td>64%</td>
<td>36%</td>
</tr>
<tr>
<td>Low on admission (&lt; 90 mmHg)</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Low in ICU</td>
<td>20%</td>
<td>80%</td>
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<tr>
<td>Both</td>
<td>15%</td>
<td>85%</td>
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</tbody>
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Chesnut, et al. *J Trauma* 1997;42:S4-S9
Secondary hypotension

80% of pts treated by U.S. Marine Forward Resuscitation Surgical System (FRSS) during OIF presented with hemorrhagic shock.

40% of pts who required treatment during transport were treated for hypotension.

Chambers, et al., Arch Surg 140:26-32, 2005
Posttraumatic insults & outcome after blast injury

Retrospective analysis of 18 close-proximity blast patients (OIF)

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<td>Percent mortality in patients (n = 5) with sustained hypotension</td>
<td>100</td>
</tr>
<tr>
<td>Percent mortality in patients (n = 9) without sustained hypotension</td>
<td>0</td>
</tr>
</tbody>
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Summary

Experimental blast-induced neurotrauma (BINT) in rats is associated with significant but transient reductions in arterial blood pressure.

Experimental BINT in rats is associated with significant reductions in cerebral blood flow and significant increases in cerebral vascular resistance.

Experimental BINT in rats is associated with significantly reduced vasodilatory responses to reduced intravascular pressure in isolated MCAs.

These results suggest that blast-induced cerebral hypoperfusion, especially in the presence of hemorrhagic hypotension, may contribute to the pathophysiology of BINT.
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The Moody Center for Traumatic Brain & Spinal Cord Injury Research • Mission Connect

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