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

From: Garner, et al., Mechanisms of injury by explosive devices
Anesthesiology Clinics 25: 147-160, 2007

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Effects of Experimental Blast Injury on the Brain

Neuronal swelling & injury, behavioral deficits, ⇧ oxidative stress

Cernak, et al., J Trauma 50:695-706, 2001

Neuronal/glial swelling, ⇧NO_x, active avoidance deficits

Cernak, et al., J Trauma 50:695-706, 2001

Widespread silver staining in neurons & white matter in pigs & rats

Bauman, et al., JNT 26:841-860, 2009; Long, et al., JNT 26:827-840, 2009

DAI, metabolic disturbances, cytoskeletal degradation, etc.

Cernak & Noble-Haiusslein, J CBF & M 30:255-266, 2010

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CEREBRAL CIRCULATION?

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Effects of Blast Injury on the Cerebral Circulation

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

Armonda, et al., Neurosurg 59:1215-1224, 2006

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

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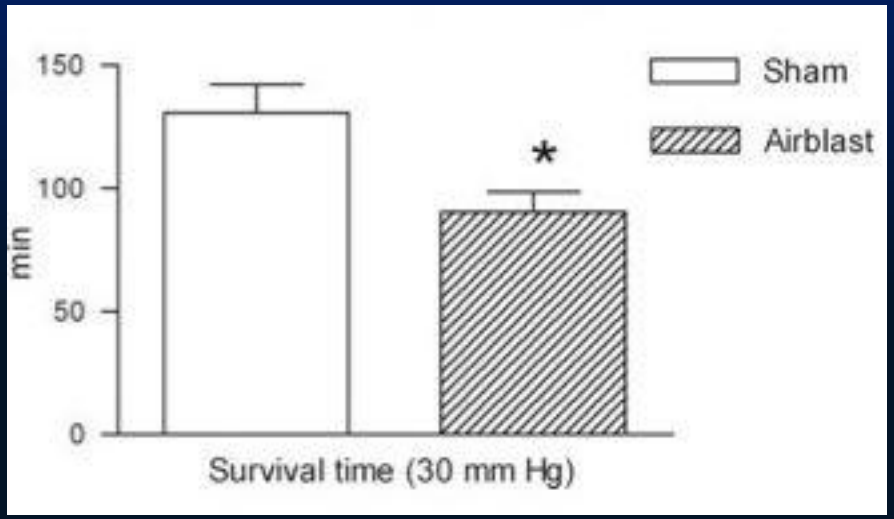
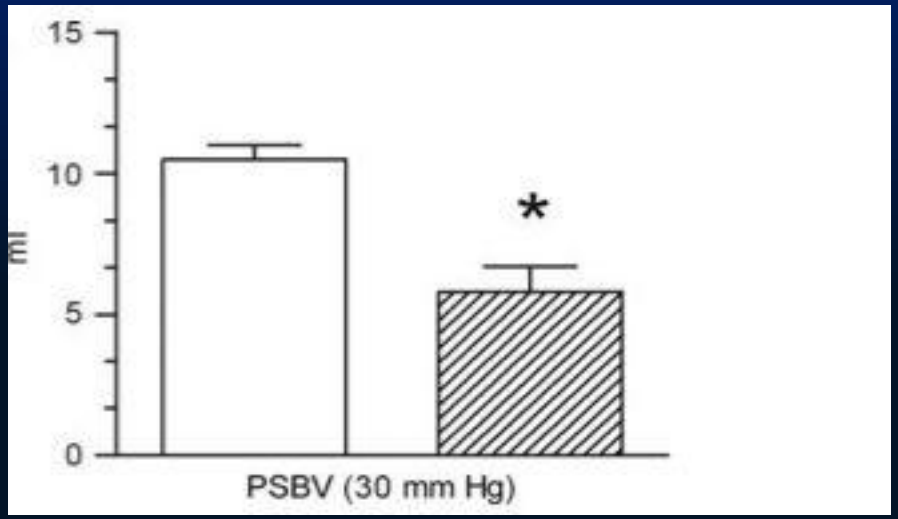
Blast overpressure & hemorrhagic hypotension

Long, et al., *Journal of Neurotrauma*, 2009

Rats exposed to 126 kPa airblast or sham injury followed by controlled hemorrhage to 30 mmHg.





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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

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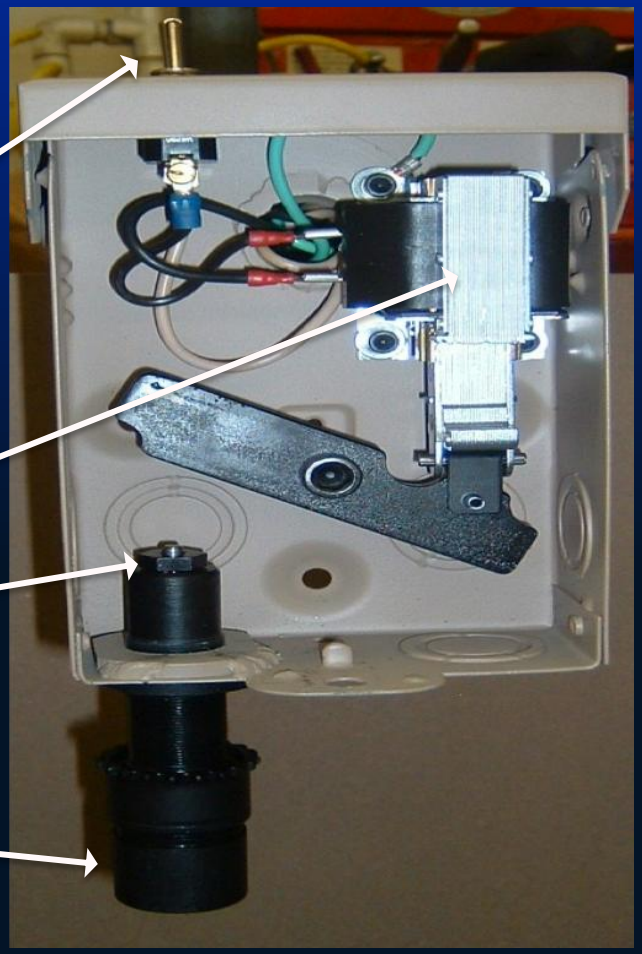
Vandenberg Blast-Induced Brain Injury Device

Firing button

Safety switch

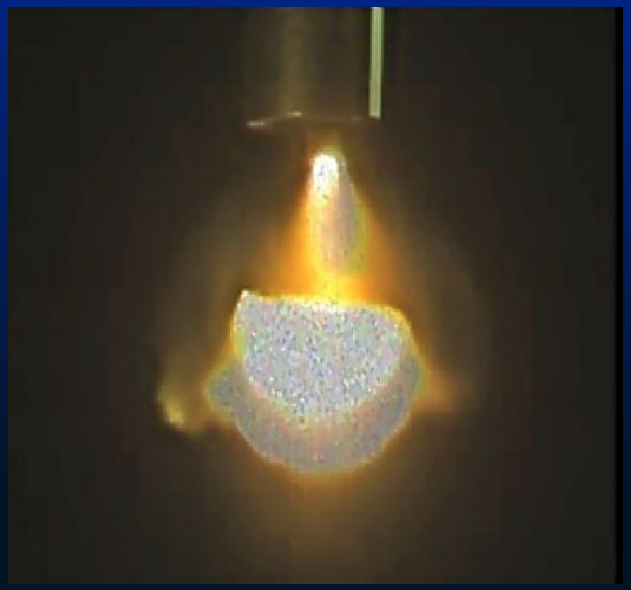
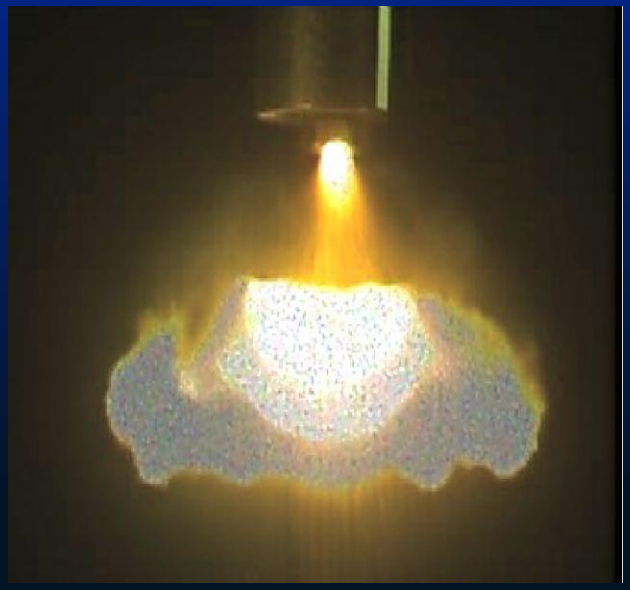


Firing solenoid

Firing pin

Firing chamber

Vandenberg blast: High-speed video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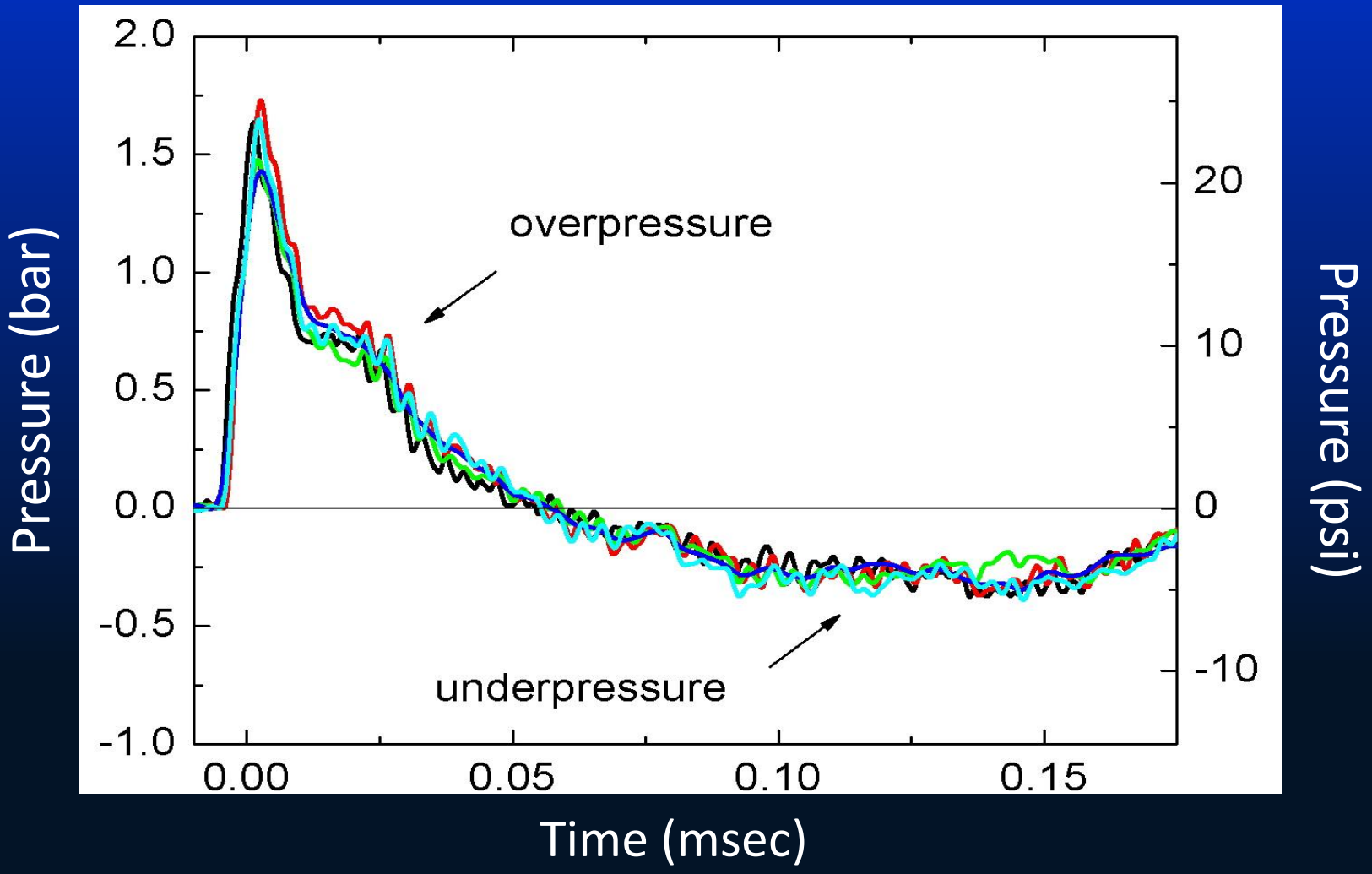
Pressure Waves Produced by the Vandenberg Blast Injury Device



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Effects of BINT on Arterial Blood Pressure & Cerebral Blood Flow

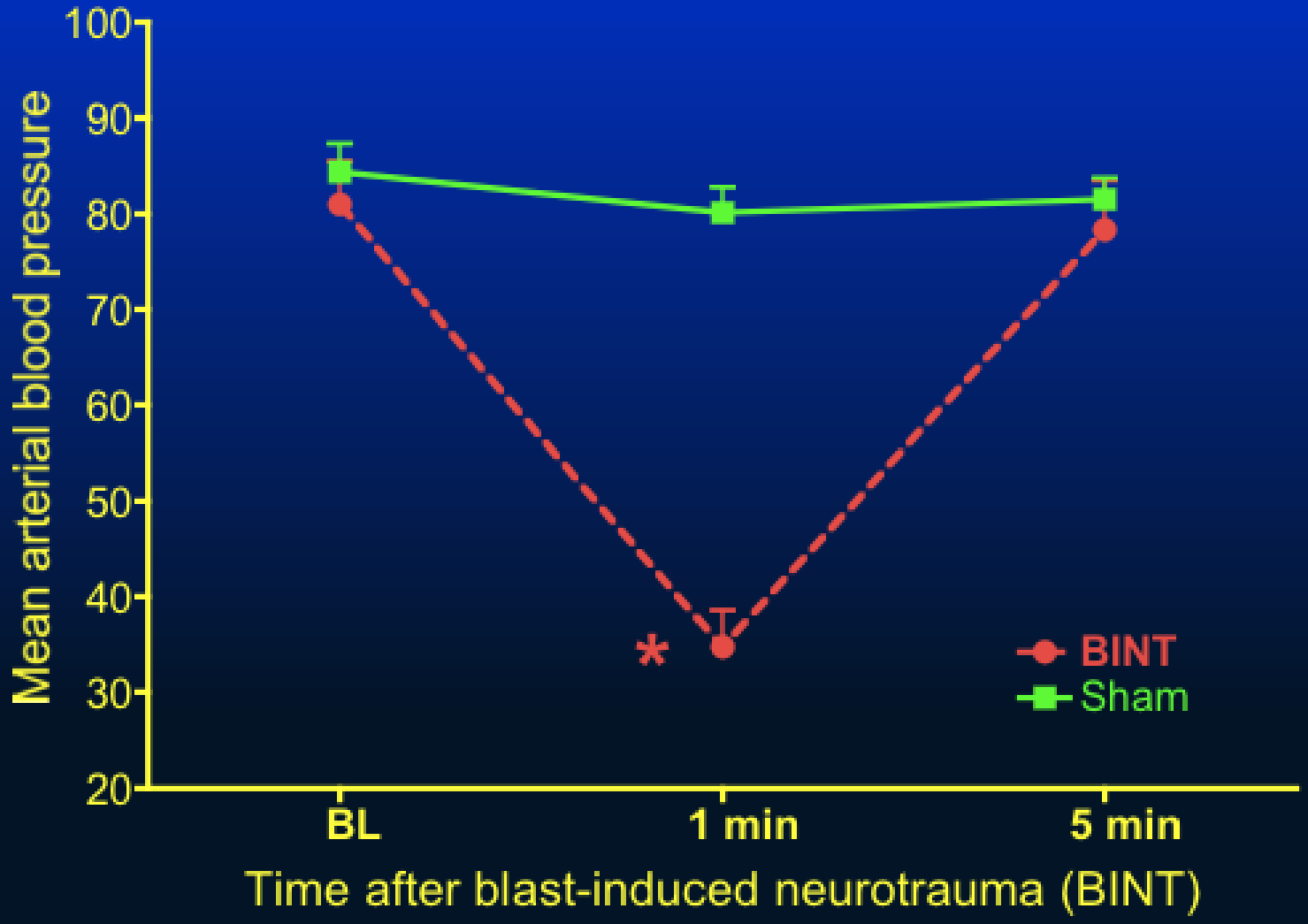
Rats were anesthetized, intubated, mechanically ventilated (2.0% isoflurane) & placed in headholder

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



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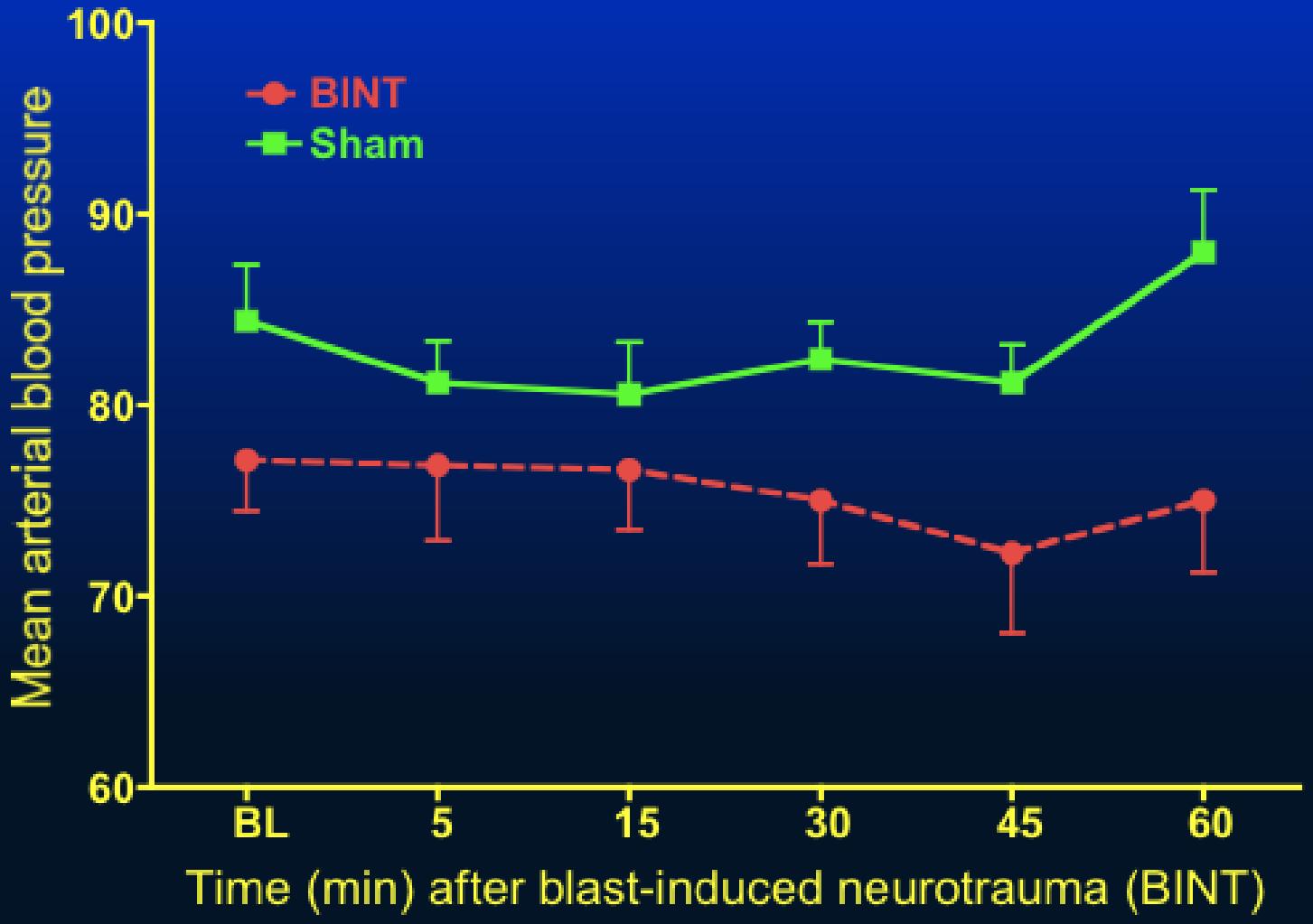

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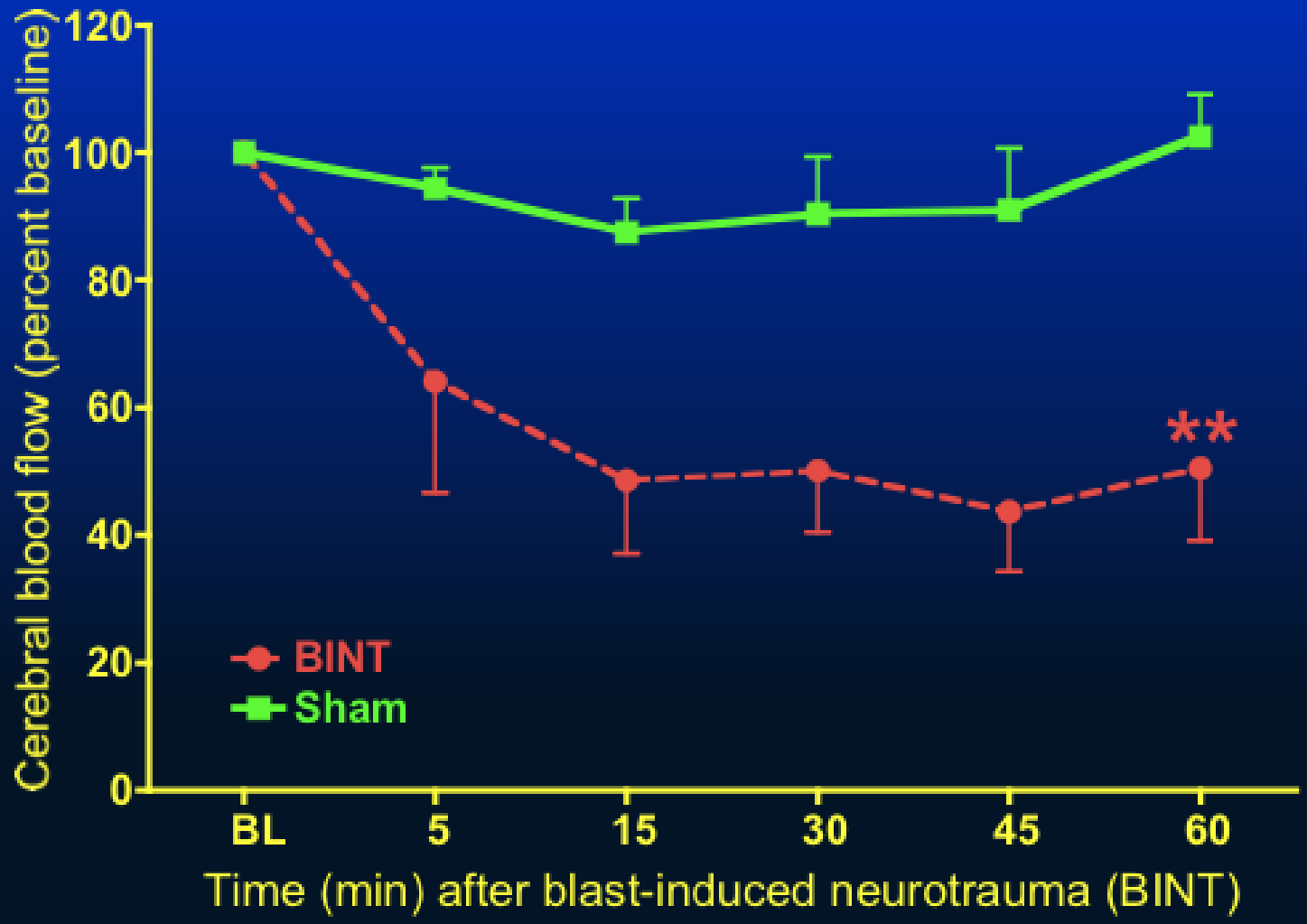
Effects of blast-induced neurotrauma (BINT) on cerebral blood flow in rats



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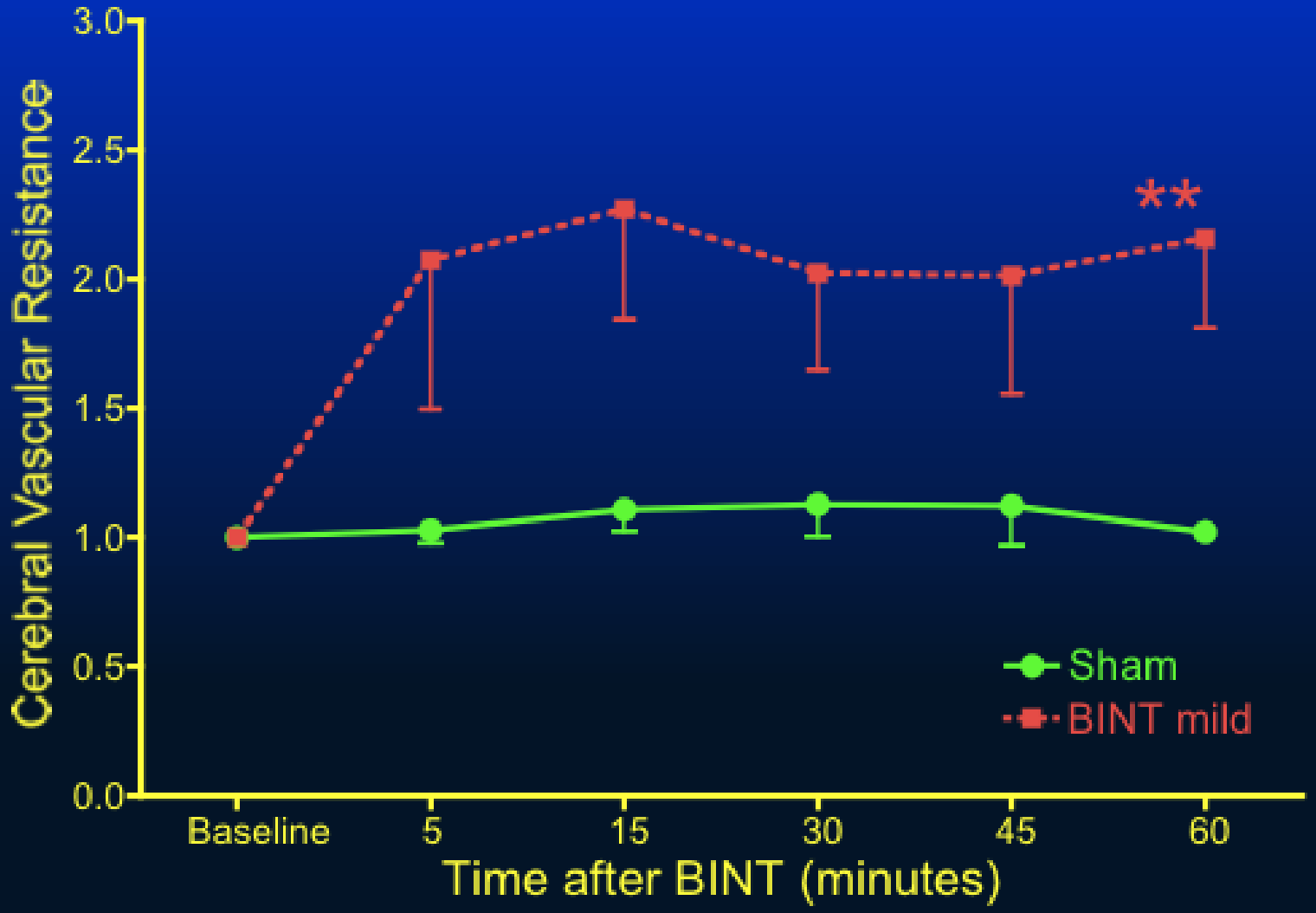
Effects of mild blast-induced neurotrauma (BINT) on cerebral vascular resistance in rats



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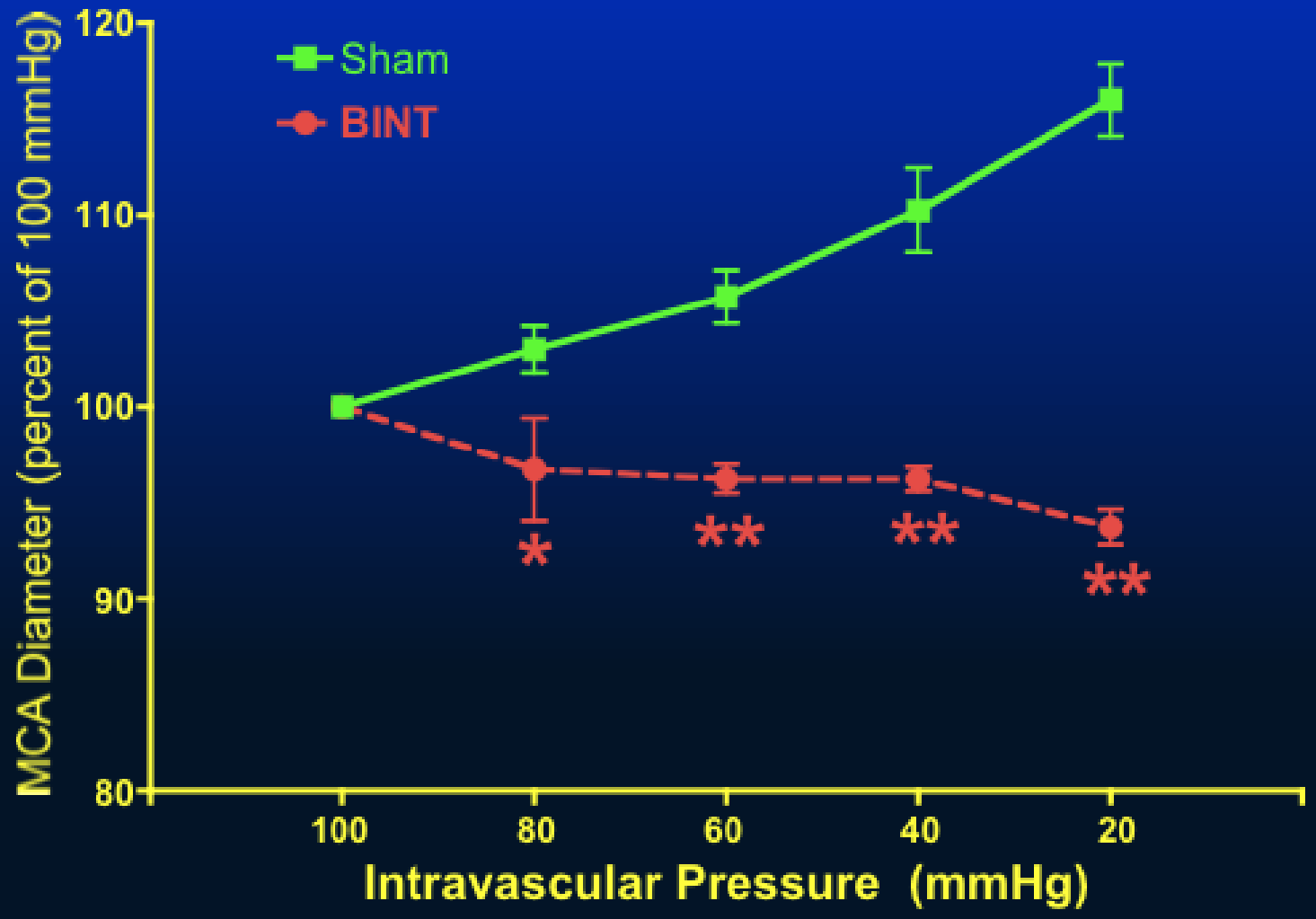
Responses to reduced intravascular pressure in rat middle cerebral arteries (MCA) harvested after blast-induced neurotrauma (BINT)



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Influence of abnormally low blood pressure on outcome after severe TBI

Blood pressure	Good Outcome (GR, MD)	Bad Outcome (SD, PVS, D)
Normal (> 90 mmHg)	64%	36%
Low on admission (< 90 mmHg)	40%	60%
Low in ICU	20%	80%
Both	15%	85%

Chesnut, et al. *J Trauma* 1997;42:S4-S9

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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)	
Percent mortality in patients (n = 5) with sustained hypotension	**100**
Percent mortality in patients (n = 9) without sustained hypotension	**0**

Nelson, et al., J Am Coll Surg 202:418-422, 2006

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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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