Dead or Alive? New Confirmatory Test Using Quantitative Analysis of Computed Tomographic Angiography

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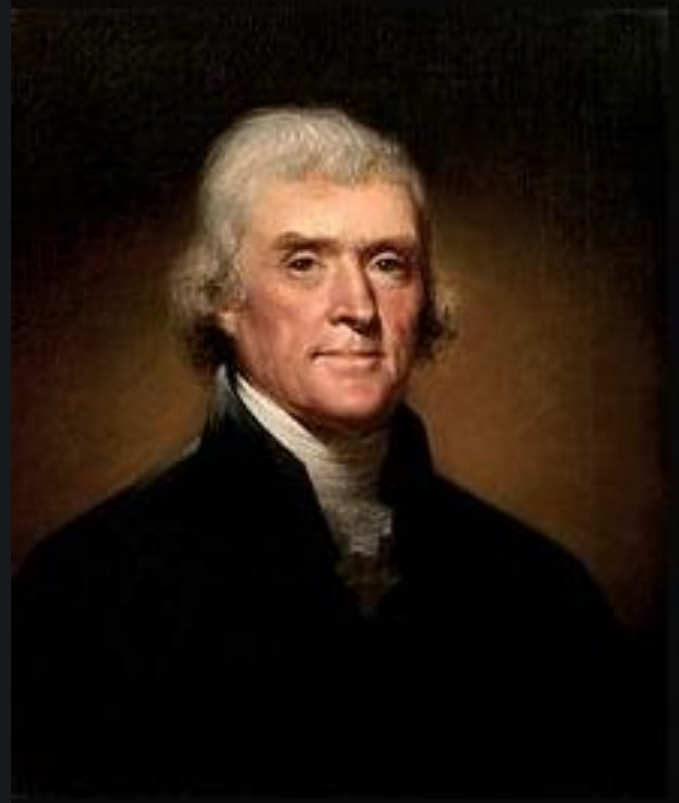
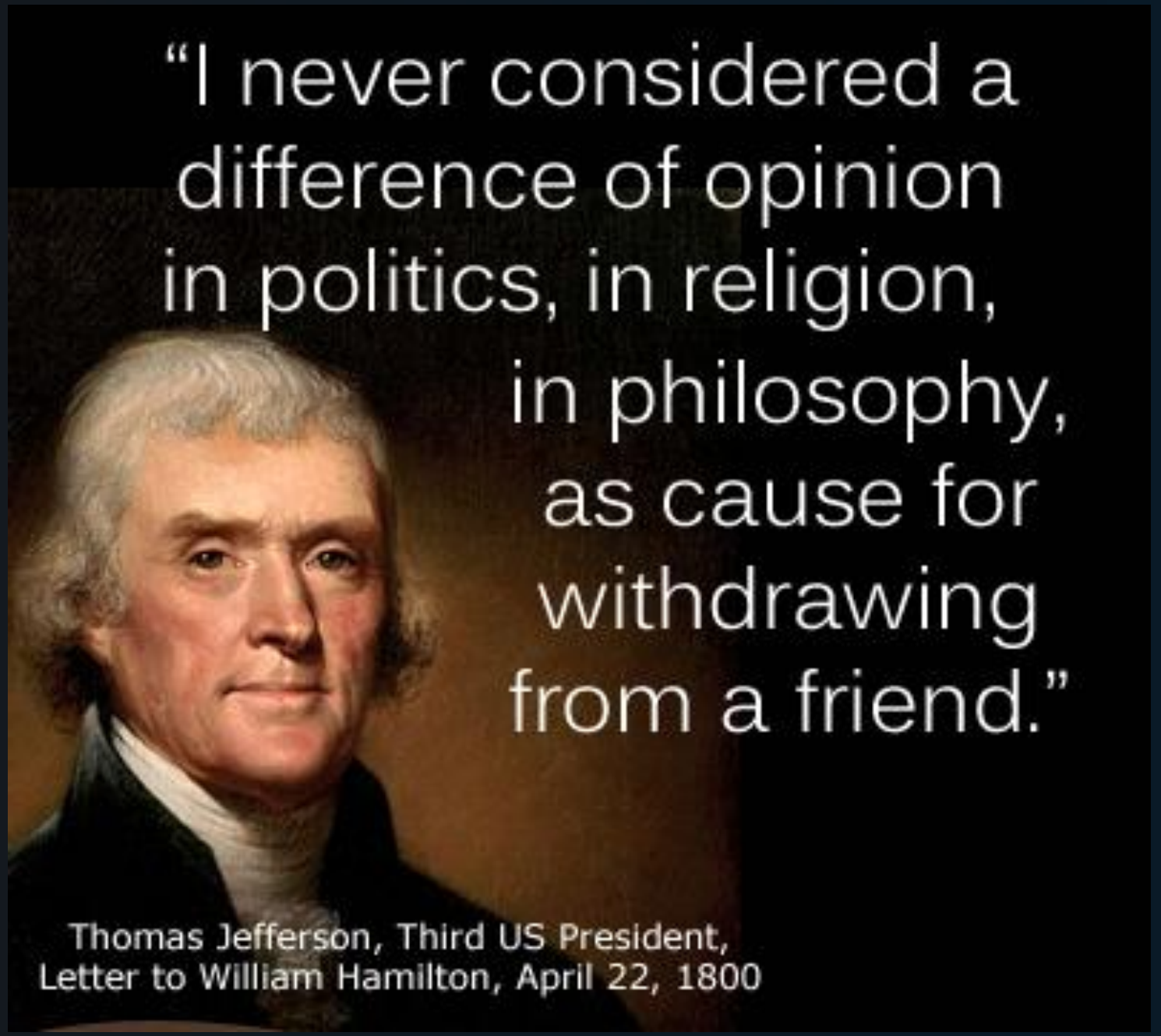


Government big enough to supply everything you need is big enough is big enough to take everything you have... The course of history shows that as a government grows, liberty decreases.

(Thomas Jefferson)


"I never considered a difference of opinion in politics, in religion, in philosophy, as cause for withdrawing from a friend."
Thomas Jefferson, Third US President,
Letter to William Hamilton, April 22, 1800

Disclosures

Consultant for Codman Neurovascular

Brain Death

- Definition: Irreversible cessation of all cerebral and brainstem functions
- Radiograhpically, is defined as cerebral blood flow arrest

- In the United States, clinical guidelines for the diagnosis of brain death are established per each state's law

Berenguer C, et al. Brain death confirmation: comparison of computed tomographic angiography with nuclear medicine perfusion scan. J Trauma. 2010;68(3):553-559.

Confirmatory Testing

Absence of cerebral electrical activity

- Electroencephalography

Evaluation of cerebral circulatory arrest

- four-vessel cerebral angiography- considered the gold-standard
- nuclear medicine perfusion test (NMPT)
- CT Angiography and CT Perfusion (CTA)

Cerebral Blood Flow

- Arrest of cerebral blood flow is defined as no intracranial filling at the level of the carotid bifurcation or circle of Willis, while external carotid circulation remains patent
- Persistent opacification of proximal arterial vessels on cerebral angiography of brain dead patients was a phenomenon initially described in 1977
- This was later defined as stasis filling in 1978

Korein J, et al. Brain death: I. Angiographic correlation with the radioisotopic bolus technique for evaluation of critical deficit of cerebral blood flow. Ann Neurol. 1977;2(3):195-205.

Kricheff II, et al. Angiographic findings in brain death. Ann NY Acad Sci. 1978;315:168-183.

Stasis Filling

- Consequence of increased intracranial pressure, high cerebrovascular resistance, and altered cerebral autoregulation mechanisms
  - Seen as delayed, weak, and persistent intracranial arterial opacification
- Results in cessation of capillary circulation while proximal arterial segments are still patent
  - Is consistent with cerebral circulatory arrest

Sawicki M, et al. Neuroradiology. 2013;55(9)1061-1069.

Incidence of Stasis Filling

- Cerebral Angiography - 5-28%
- Cerebral Computed Tomographic Angiography - 30-59%

Bohatyewicz R, et al. Transplantation Proceedings. 2010;42:3941-3946.

Combes JC, et al. Transplant Proc. 2007;39(1):16-20.

Flowers WM Jr, et al. South Med J. 2000;93(4):364-370.

Sawicki M, et al. Neuroradiology. 2013;55(9)1061-1069.

Purpose

1. Compare CTA to NMPT in its ability to diagnose brain death

2. Determine a Hounsfield unit threshold that discriminates between stasis filling and clinically significant cerebral perfusion

Methods

- Institutional review board approval was obtained
- Prospective study of a consecutive series of patients from March 2007 to April 2014
- Inclusion criteria were non-pregnant adults 18 years of age or older
- Informed consent was obtained from the patient's family prior to enrollment in the study

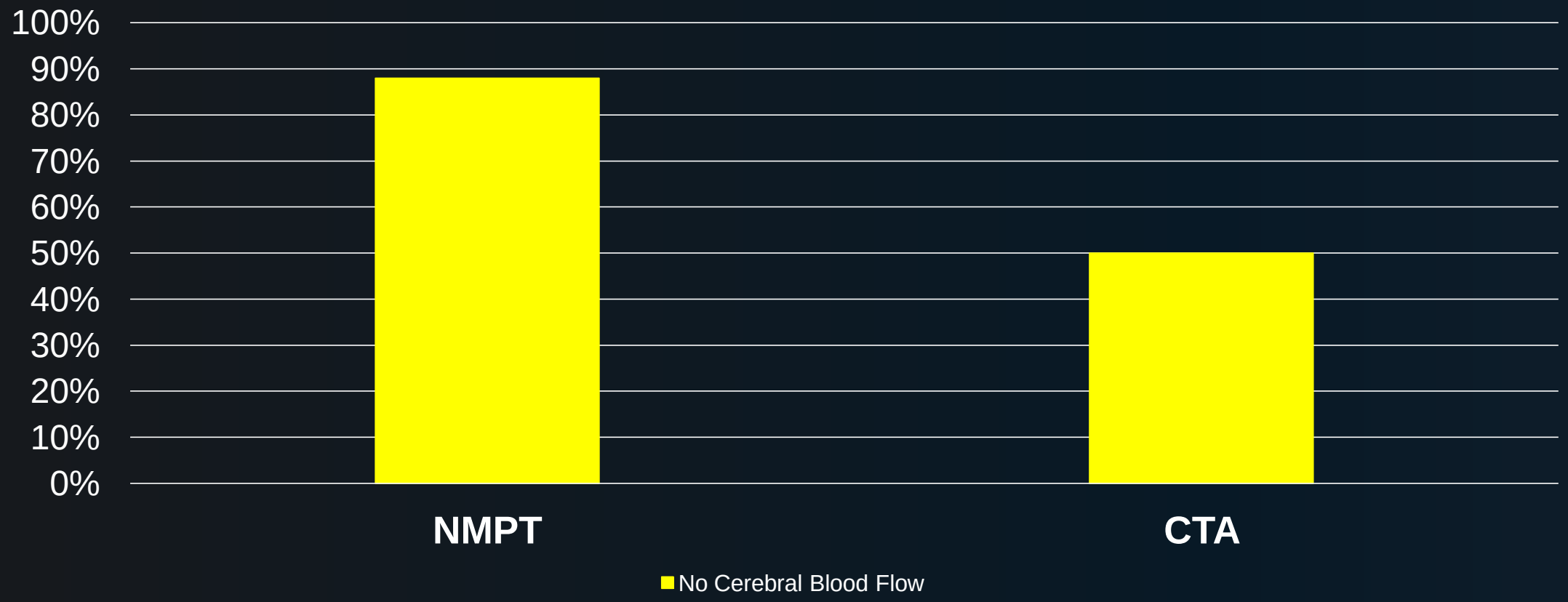
Methods

- Study patients (n=60) had a neurological examination consistent with brain death
  - NMPT was used as the reference standard and was performed on all our study patients followed immediately by CTA
- Randomly selected control group (n=20)
- Assessment of NMPT and quantitative CTA analysis was performed
- Anterior and posterior circulation was evaluated:
  - horizontal segment of middle cerebral artery (M1)
  - precommunicating segment of anterior cerebral artery (A1)
  - basilar artery (BA)

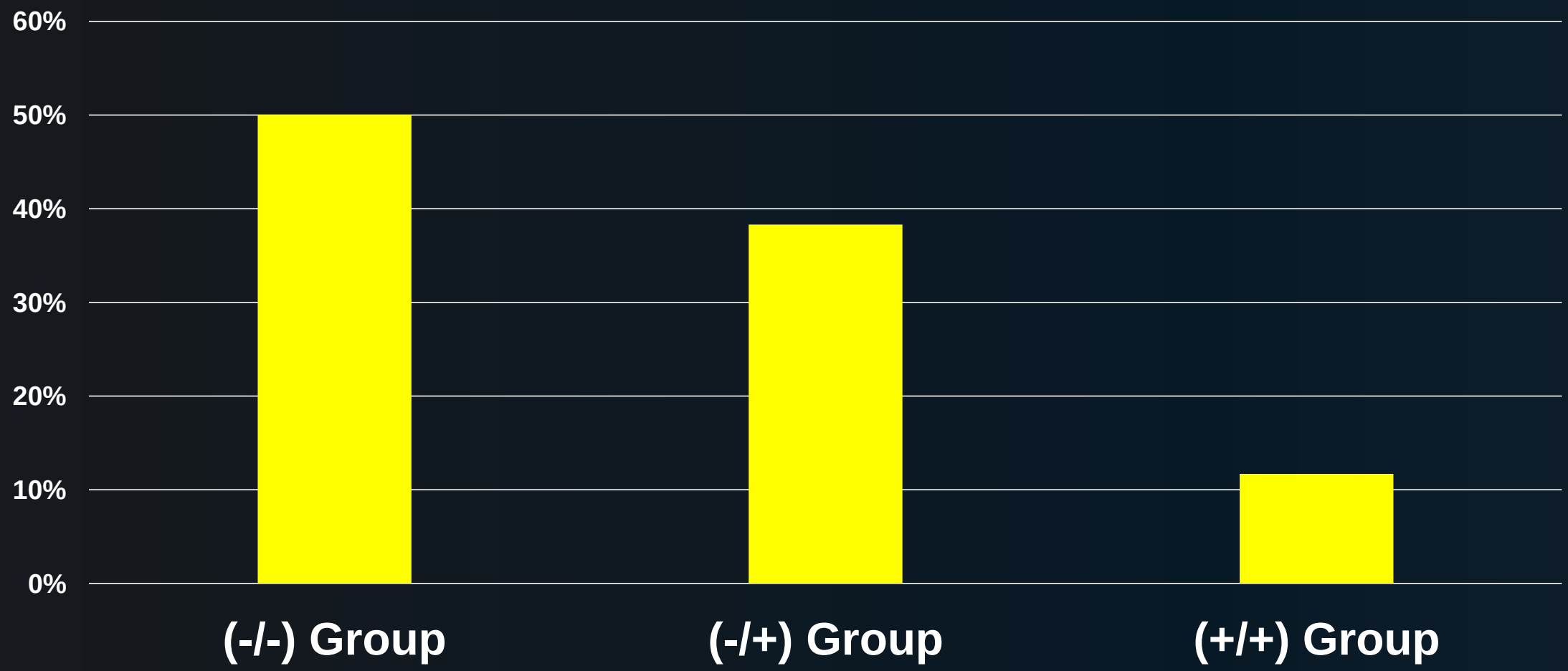
Demographics

Demographic Data		
Group	***Study Cohort***	***Control***
N	60	20
Age, Mean (years)	36.3	64.4
Age, Median (years)	33.2	64
Male	41 (68.4%)	4 (20%)
Female	19 (31.6%)	16 (80%)
Mechanism of Injury		
Hemorrhagic Stroke	7	0
Motor Vehicle Collision	15	0
Fall	5	1
Gun Shot Wound	12	1
Anoxic Brain Injury	4	0
Assault	2	0
Ischemic Stroke	1	7
Ruptured Aneurysm	4	1
Meningitis	1	0
Pedestrian vs Auto	5	0
Motorcycle Collision	1	0
All-Terrain Vehicle Collision	1	0
Headache	0	9
Toxic Encephalopathy	0	1

Percent of Study Cohort Patients with No Cerebral Blood Flow Seen on Imaging



Distribution of Patients Across Cerebral Blood Flow Categories



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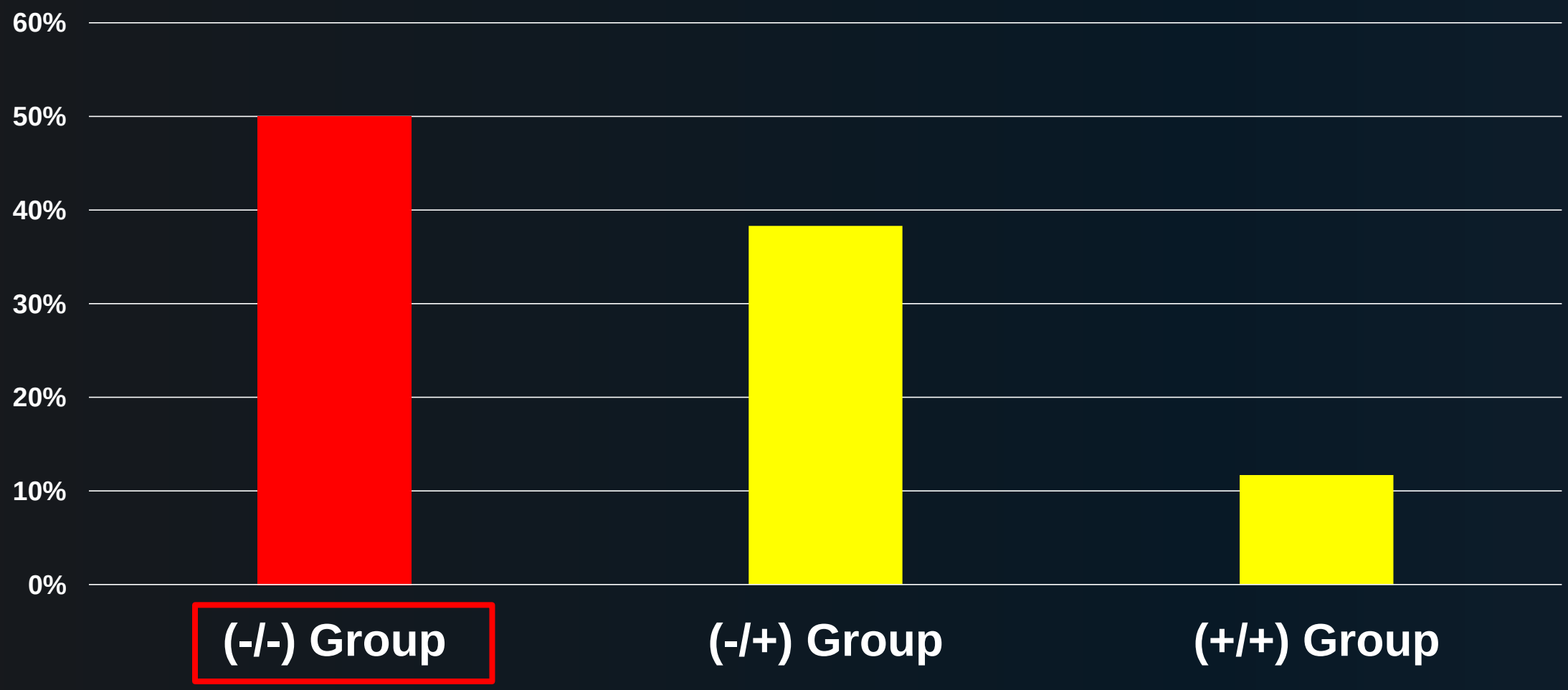

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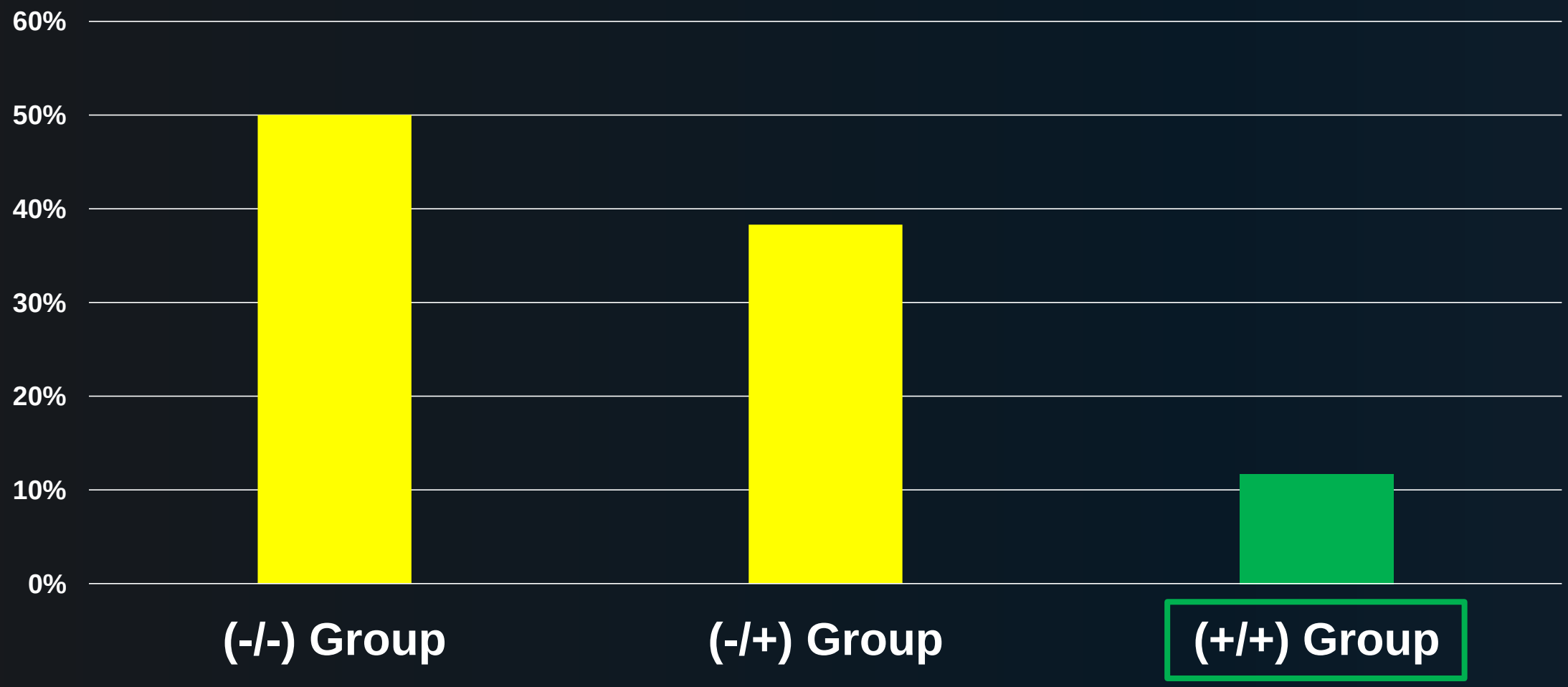

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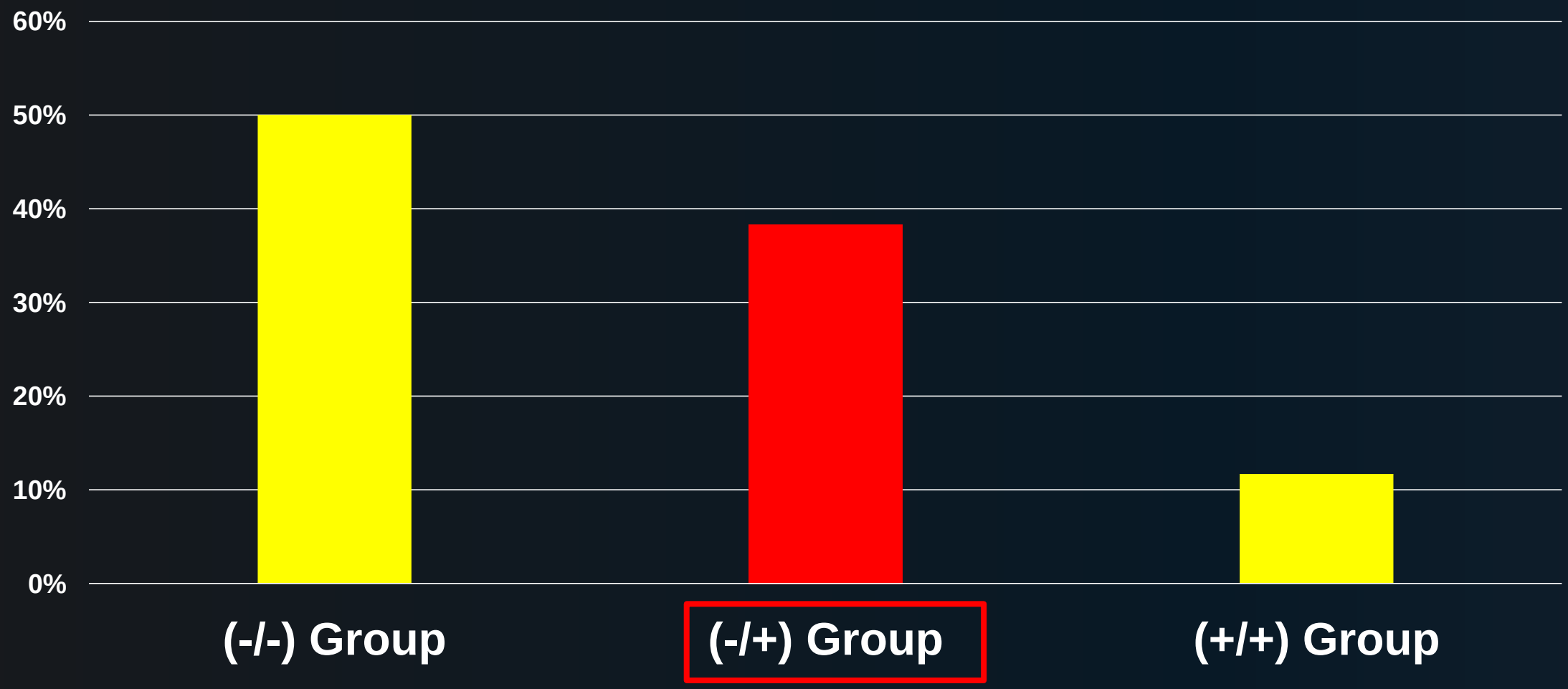

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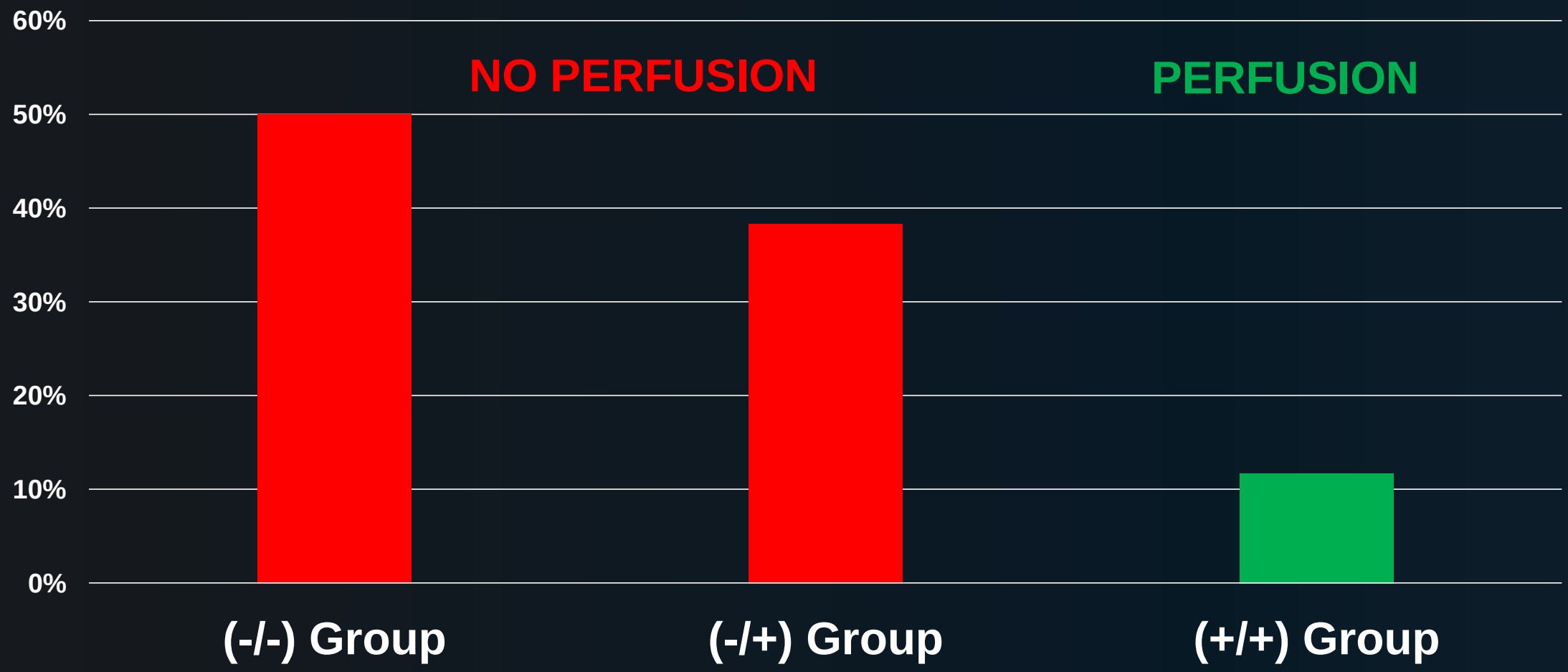
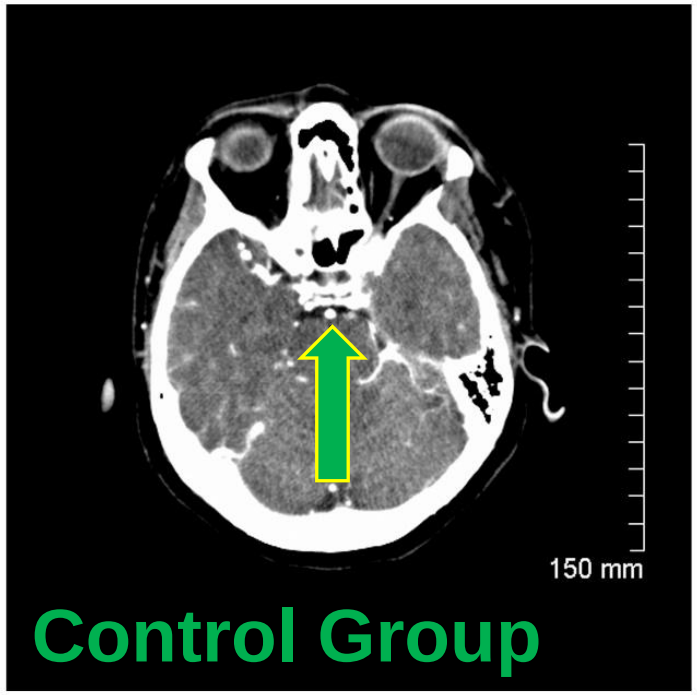
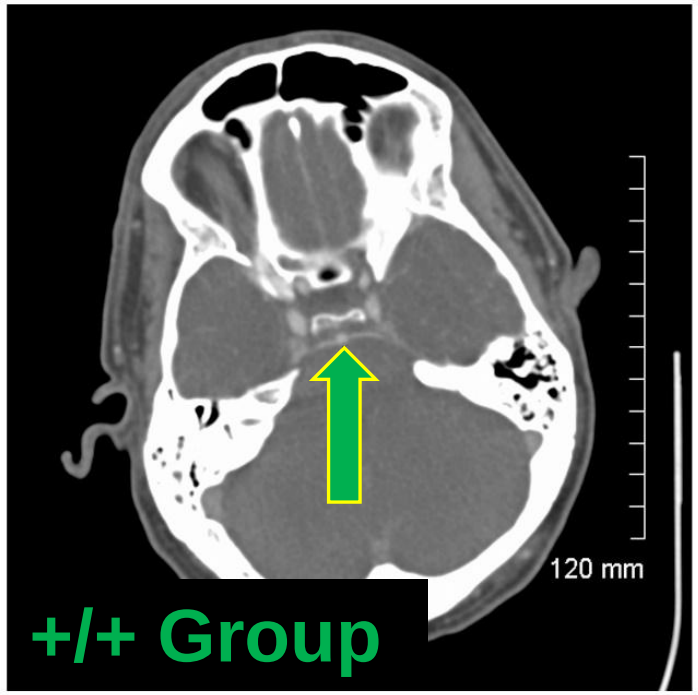
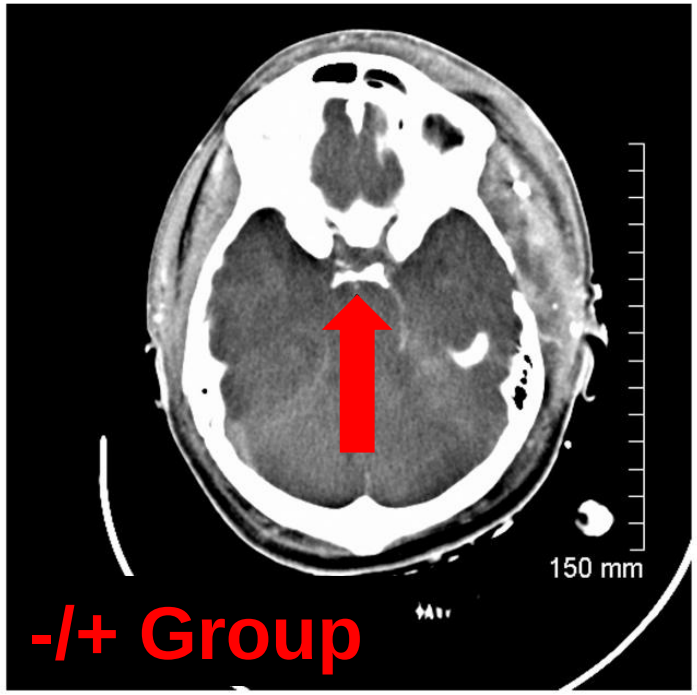
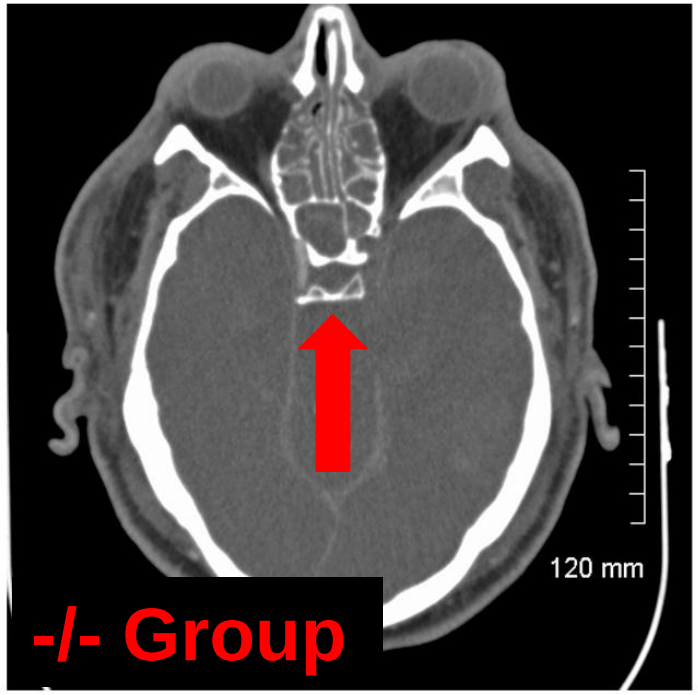


Basilar Artery (BA)

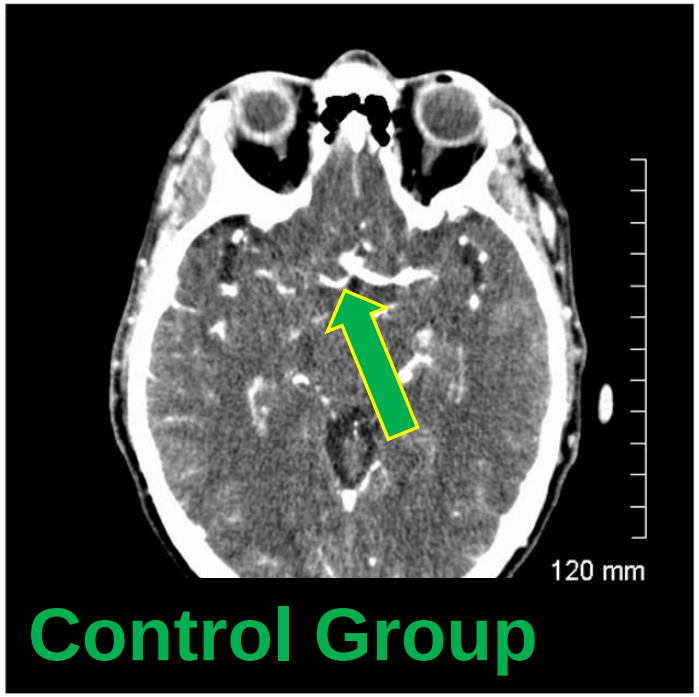


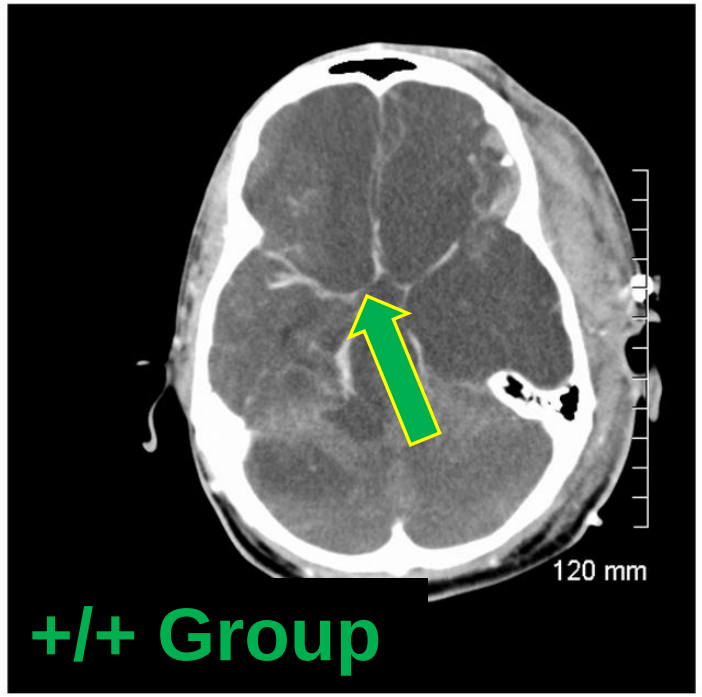


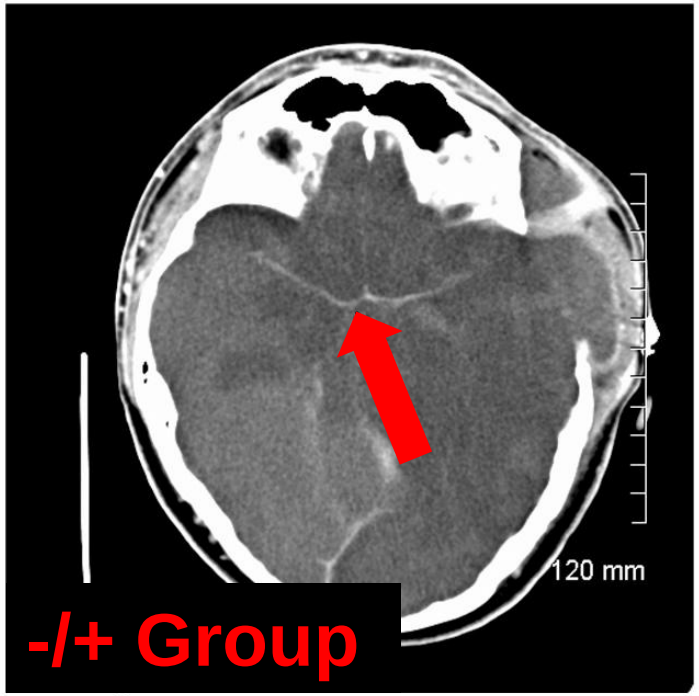


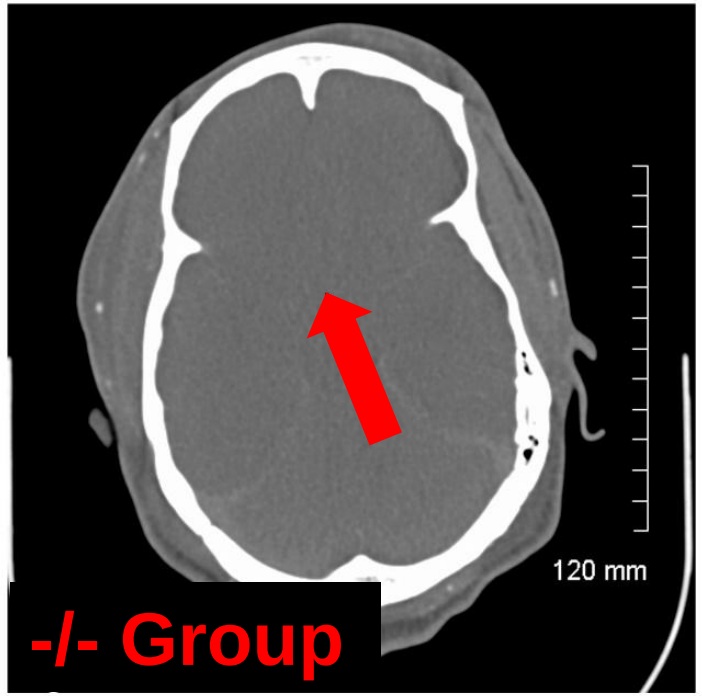


Precommunicating segment of anterior cerebral artery (A1)

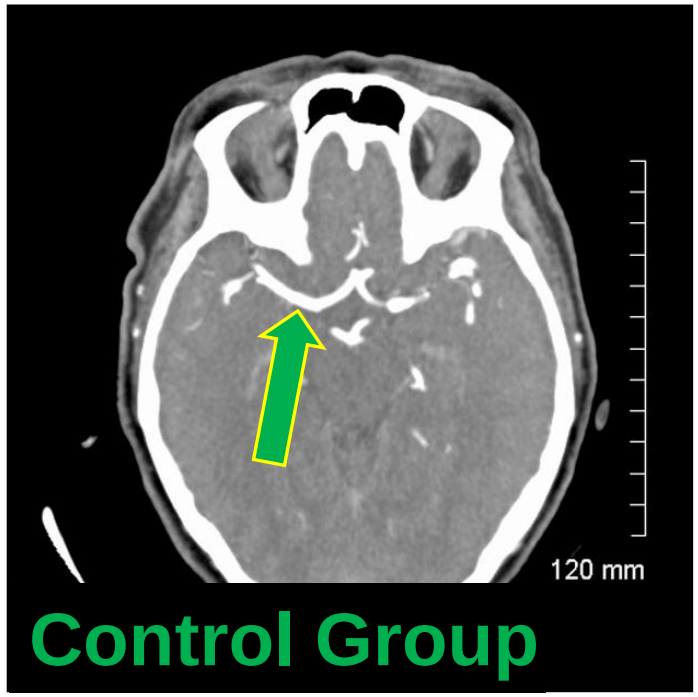


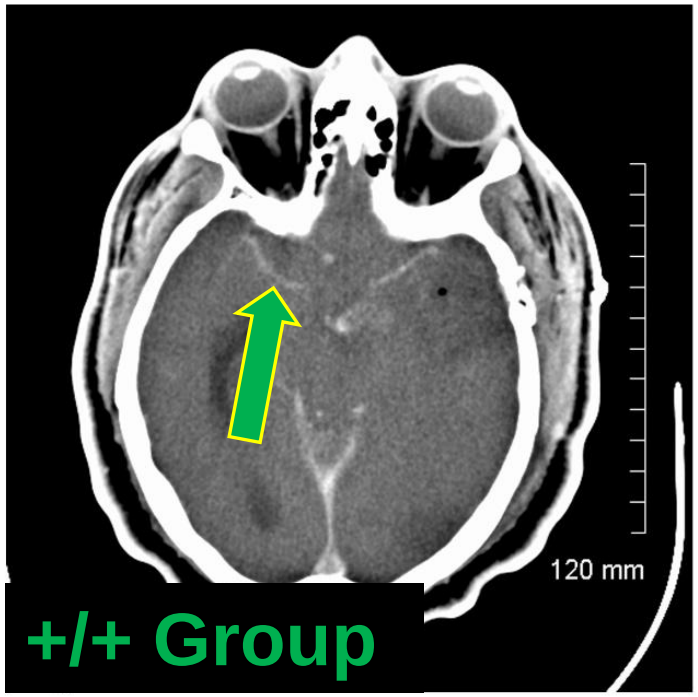


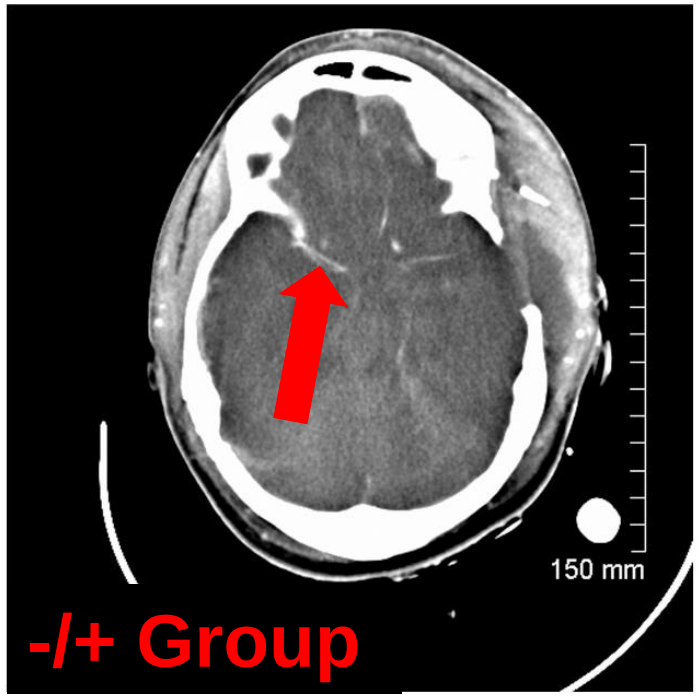


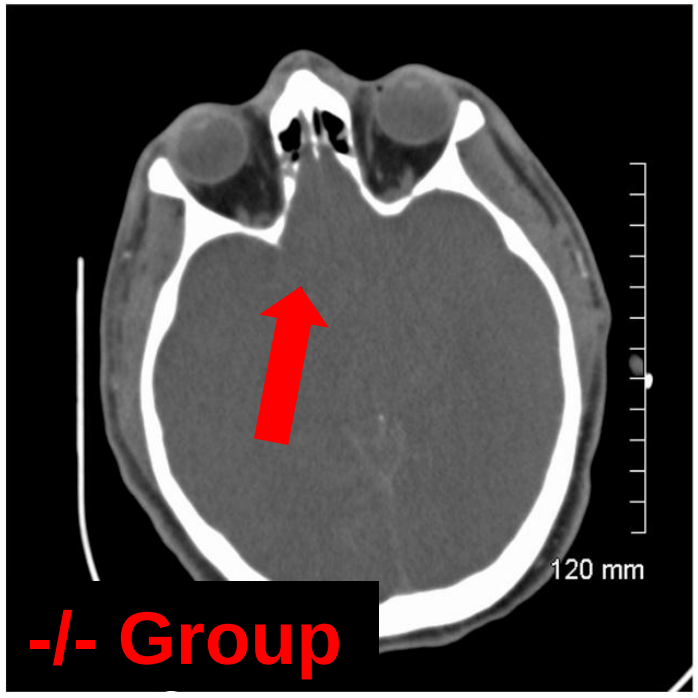


Horizontal segment of middle cerebral artery (M1)









CTA Average Hounsfield Unit Readings						
	Group	***n***	***Minimum***	***Maximum***	***Mean***	***SD***
M1	-/-	30	22.25	78.00	37.44	12.89
	-/+	23	36.80	131.25	64.73	20.86
	+/+	6	125.45	320.00	190.74	73.58
	Control	20	233.40	1317.15	634.32	252.35
A1	-/-	30	21.25	94.75	36.80	14.07
	-/+	23	34.21	105.10	53.43	17.25
	+/+	6	84.20	245.00	171.66	55.52
	Control	20	111.80	795.45	452.64	182.53
BA	-/-	30	19.50	75.00	35.68	12.42
	-/+	23	17.20	78.70	39.74	15.46
	+/+	6	112.00	293.50	200.48	57.51
	Control	20	189.40	924.80	540.67	193.62

Significant Differences Between Groups

Vessel	*Mean*	*SD*	*n*		*Mean*	*SD*	*n*	*p*
		-/-		*vs.*		-/+		
M1	37.44	12.89	30		64.73	20.86	23	.002
A1	36.80	14.07	30		53.43	17.25	23	.025
BA	35.68	12.42	30		39.74	15.46	23	.778

CTA Average Hounsfield Unit Readings				
	Group	*n*	*Minimum*	*Maximum*
M1	-/-	30	22.25	78.00
	-/+	23	36.80	131.25
	+/+	6	125.45	320.00
	Control	20	233.40	1317.15
A1	-/-	30	21.25	94.75
	-/+	23	34.21	105.10
	+/+	6	84.20	245.00
	Control	20	111.80	795.45
BA	-/-	30	19.50	75.00
	-/+	23	17.20	78.70
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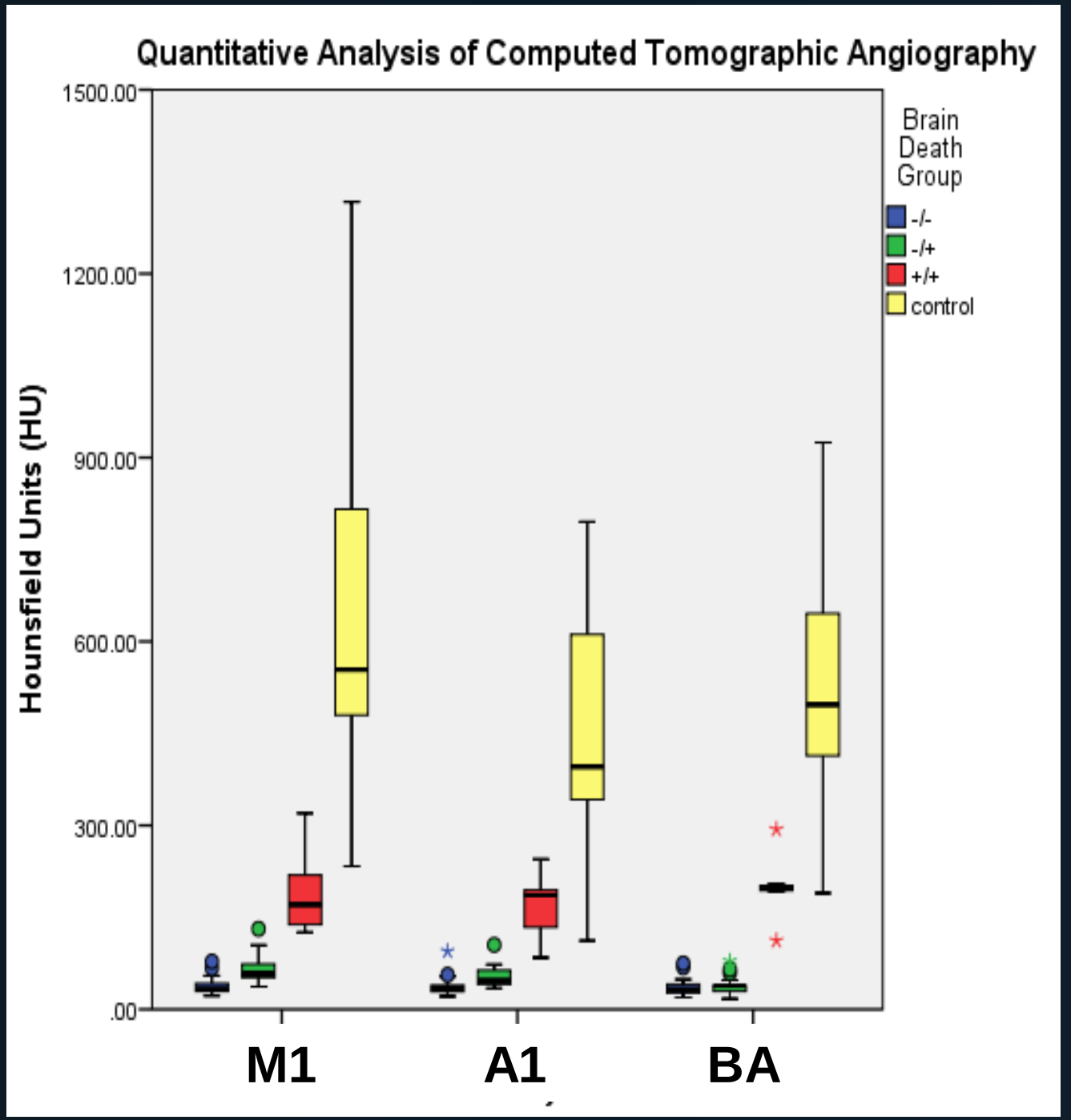

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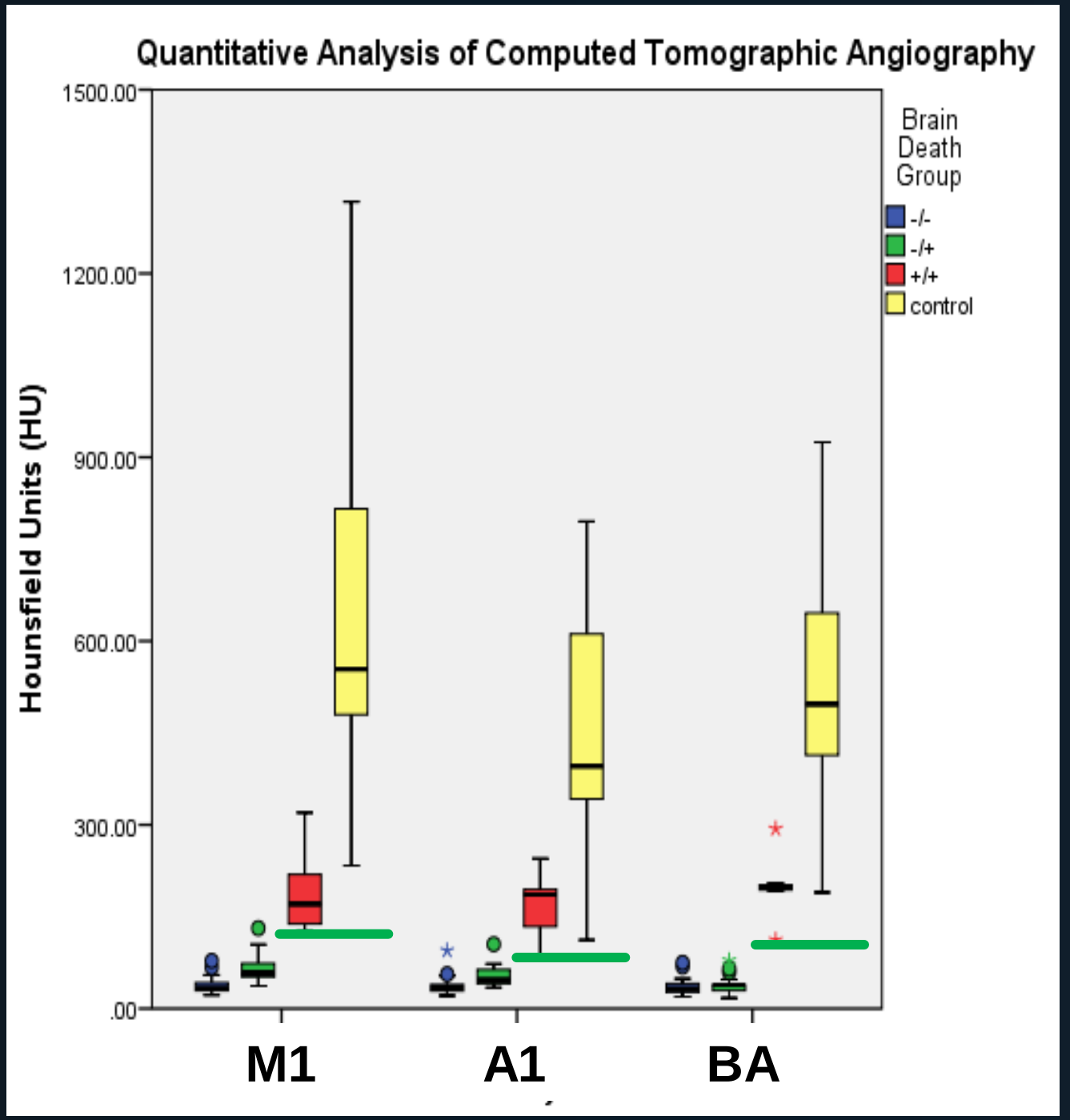

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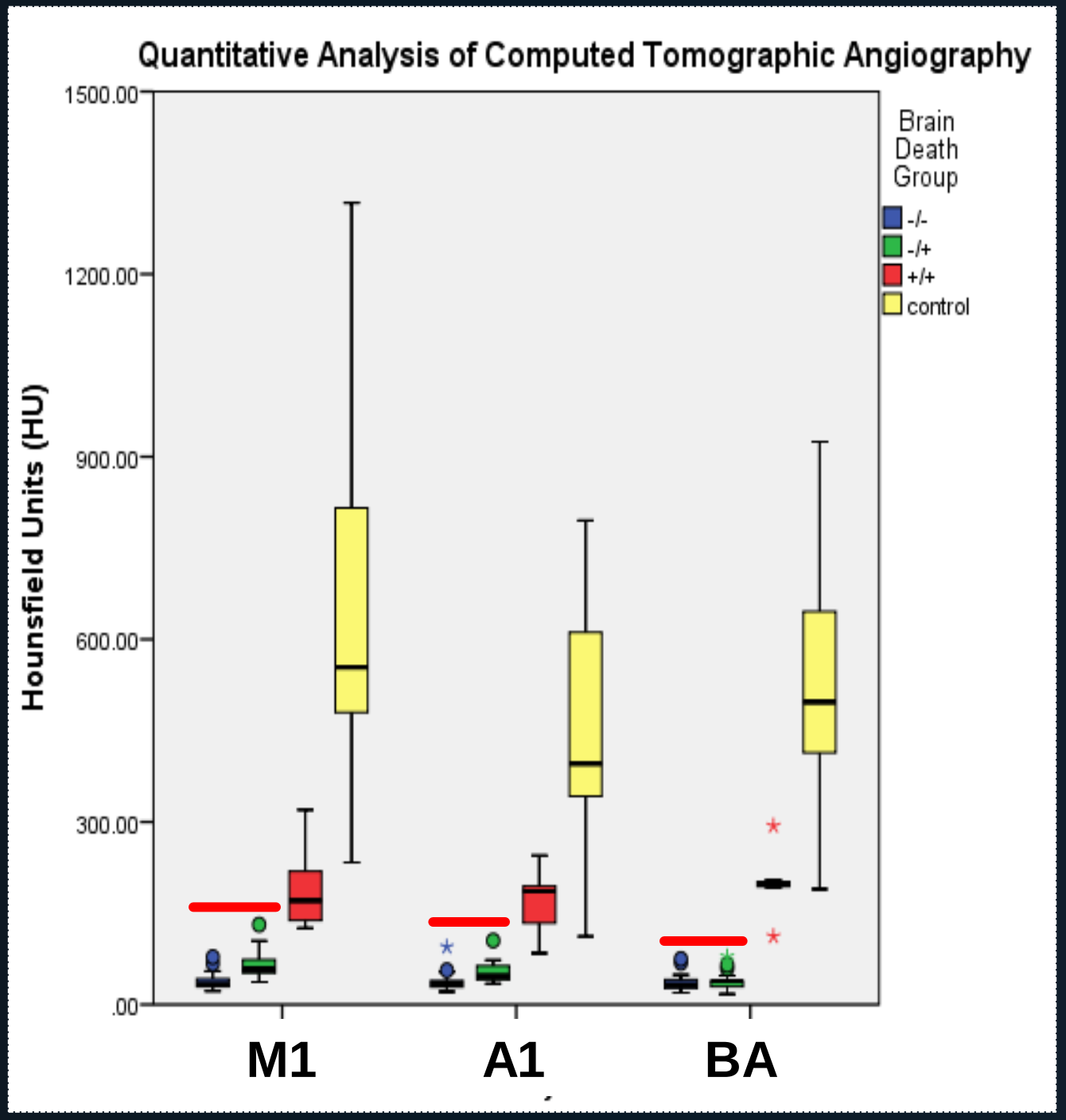

Results

Hounsfield unit threshold that discriminates between stasis filling and clinically significant cerebral perfusion:

- M1 HU less than 125
  - 98% sensitive, 100% specific
- A1 HU less than 80
  - 96% sensitive, 100% specific
- BA HU less than of 95
  - 100% sensitive, 100% specific