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Area of ischemia on CTA source images is dependent on phase of contrast enhancement in acute large vessel stroke: implications for patient selection.

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Objective

Stroke is one of the leading causes of death and disability worldwide, with an age-adjusted incidence rate of 180 per 100,000 people in western countries. Successful reperfusion therapies rely on the rapid and reliable identification of irreversibly damaged tissue from salvageable ischemic penumbra ¹. We propose there is an optimal point on the time-tissue attenuation curve (TAC) which shows the greatest visual differentiation between unsalvageable infarcted tissue and viable tissue. Knowledge of this position could improve patient selection in the case of acute large vessel stroke.

Background

CT, a frequently used imaging modality for visualizing a stroke lesion, is recommended for initial work-up. CT angiography (CTA) is part of standard work-up for suspected large-vessel occlusions ². It can demonstrate the location of an intracranial clot and can assess collateral circulation ³.

As acute stroke patients are imaged earlier and earlier from onset, imaging is capturing more patients with viable tissue and delayed arrival of contrast rather than frank ischemia. Our group has noted on dynamic CTASI in large vessel stroke from a proximal clot; that tissue enhancement can be dependent on the time of arrival of contrast in collateral vessels. The tissue enhancement varies as contrast flows into the collateral arteries, arterioles, capillaries and veins, eventually washing out of the vessels. The area of hypoattenuation on CTASI can appear to fluctuate from phase to phase on the time-tissue attenuation curve (TAC).

We can see areas of hypodensity distal to an occlusion because of differences in tissue contrast between the area distal to an occlusion and normally perfused tissue. The correct interpretation of areas of hypodensity seen on CTASI may affect treatment algorithms. Patients with large areas of hypoattenuation on CTASI may be excluded from endovascular therapy whereas, in reality, a more delayed scan may demonstrate good collaterals. Therefore, a clear understanding of the imaging factors which influence CTASI is essential.

References

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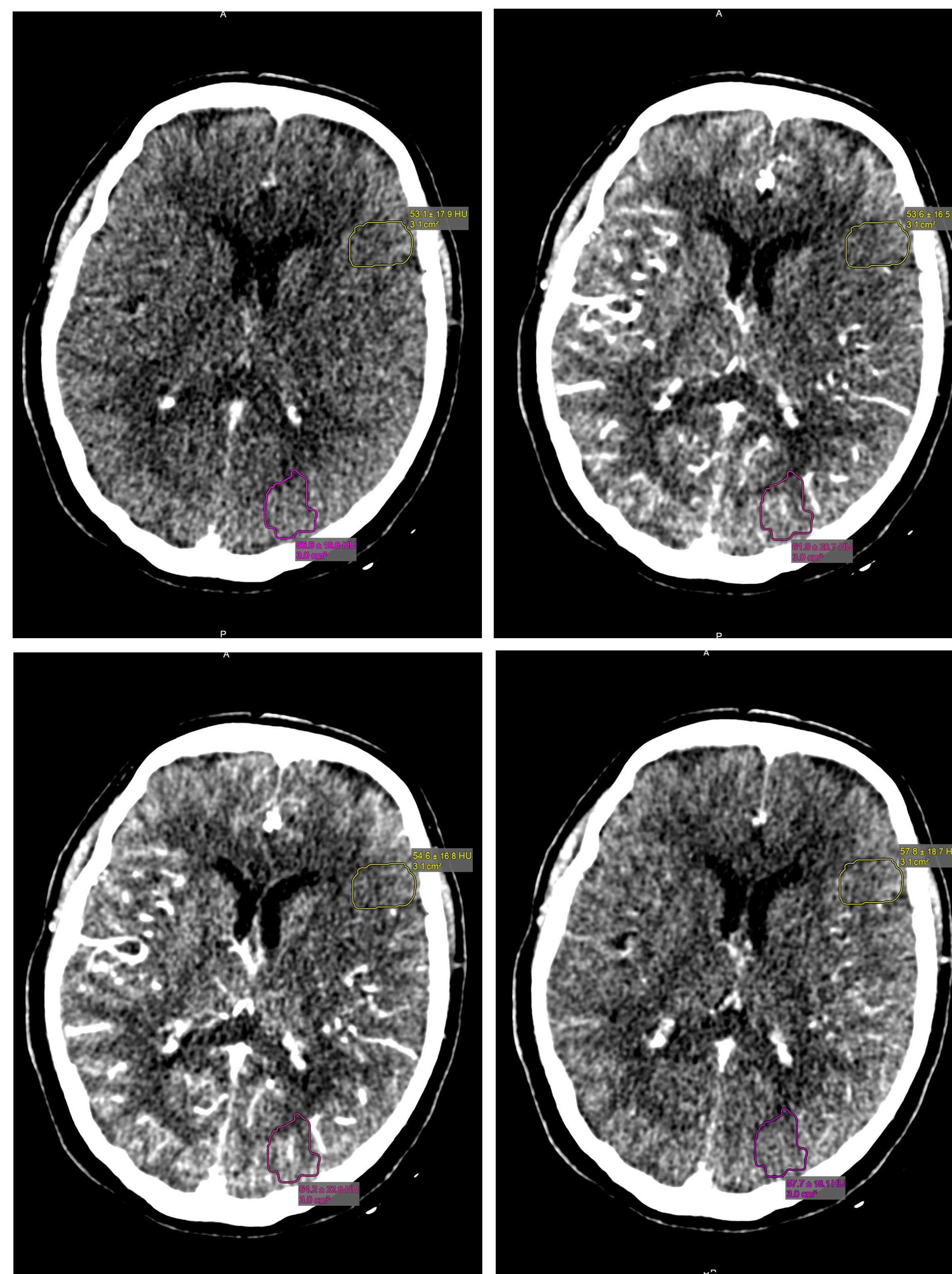


Figure 1: CTAS images depicting changes in area of hypoattenuation throughout the phases on the TAC. Top left: Baseline phase, Top right: Arterial peak phase, Bottom left: Notch phase, Bottom right: Venous Equilibrium phase

Methodology

45 consecutive patients with large vessel occlusion on dynamic time-resolved CTA/CTPerfusion were retrospectively identified from January-November 2014. Ischemic areas identified on CBV maps and region-of-interests were drawn to demarcate ischemic tissue from viable tissue on CTASI (Fig. 1). Ischemic versus viable tissue conspicuity was measured at 7 phases (baseline, arterial pre-peak, peak arterial, notch, venous peak, venous downslope, venous equilibrium) along the TAC (Fig. 2). Conspicuity by CTA phase was assessed using Friedman tests followed by post-hoc Bonferroni correction.

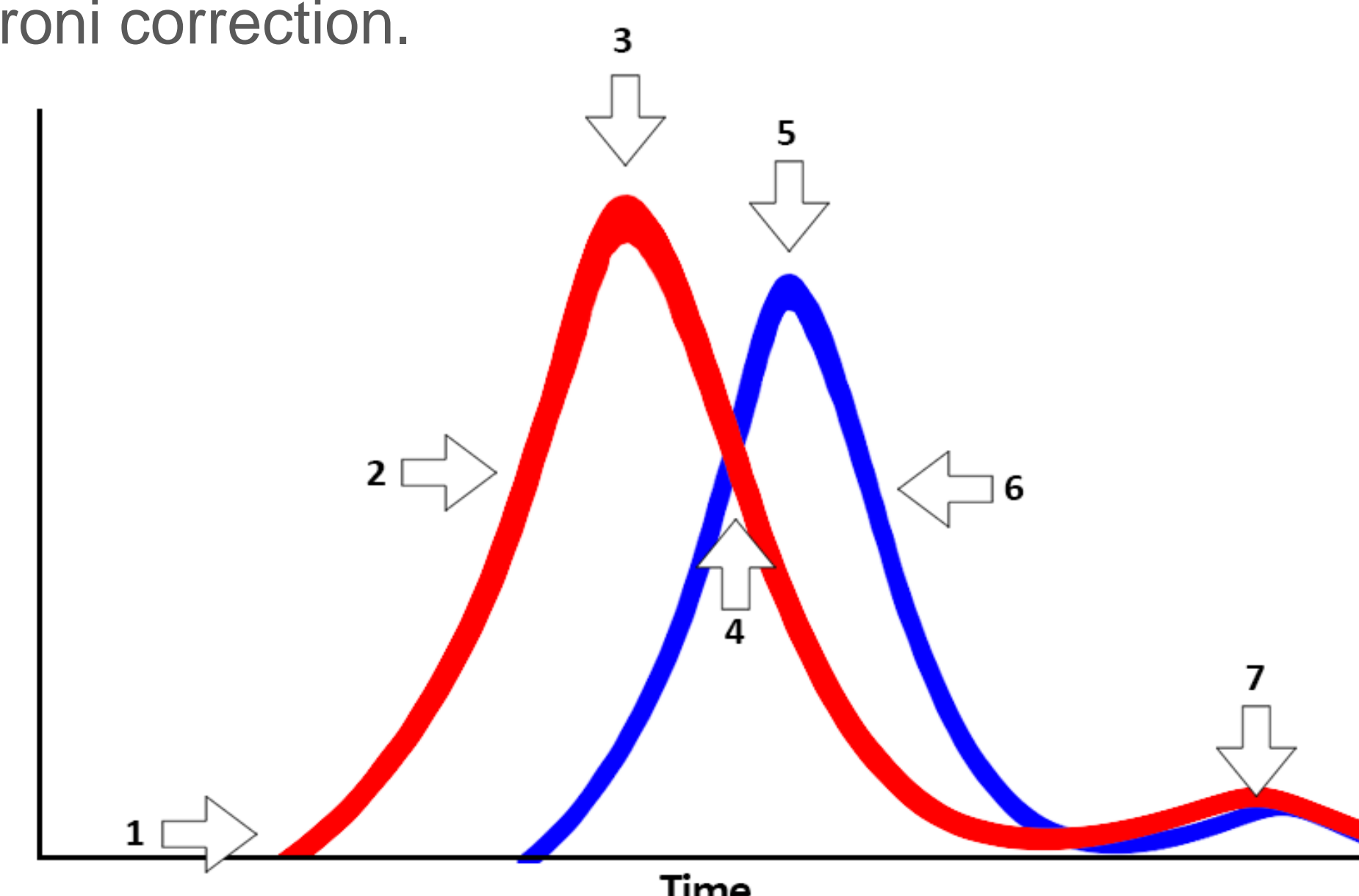


Figure 2: Time Tissue Attenuation curve. Red represents arterial, blue represents venous. The numbers 1-7 correspond to each specific phase.

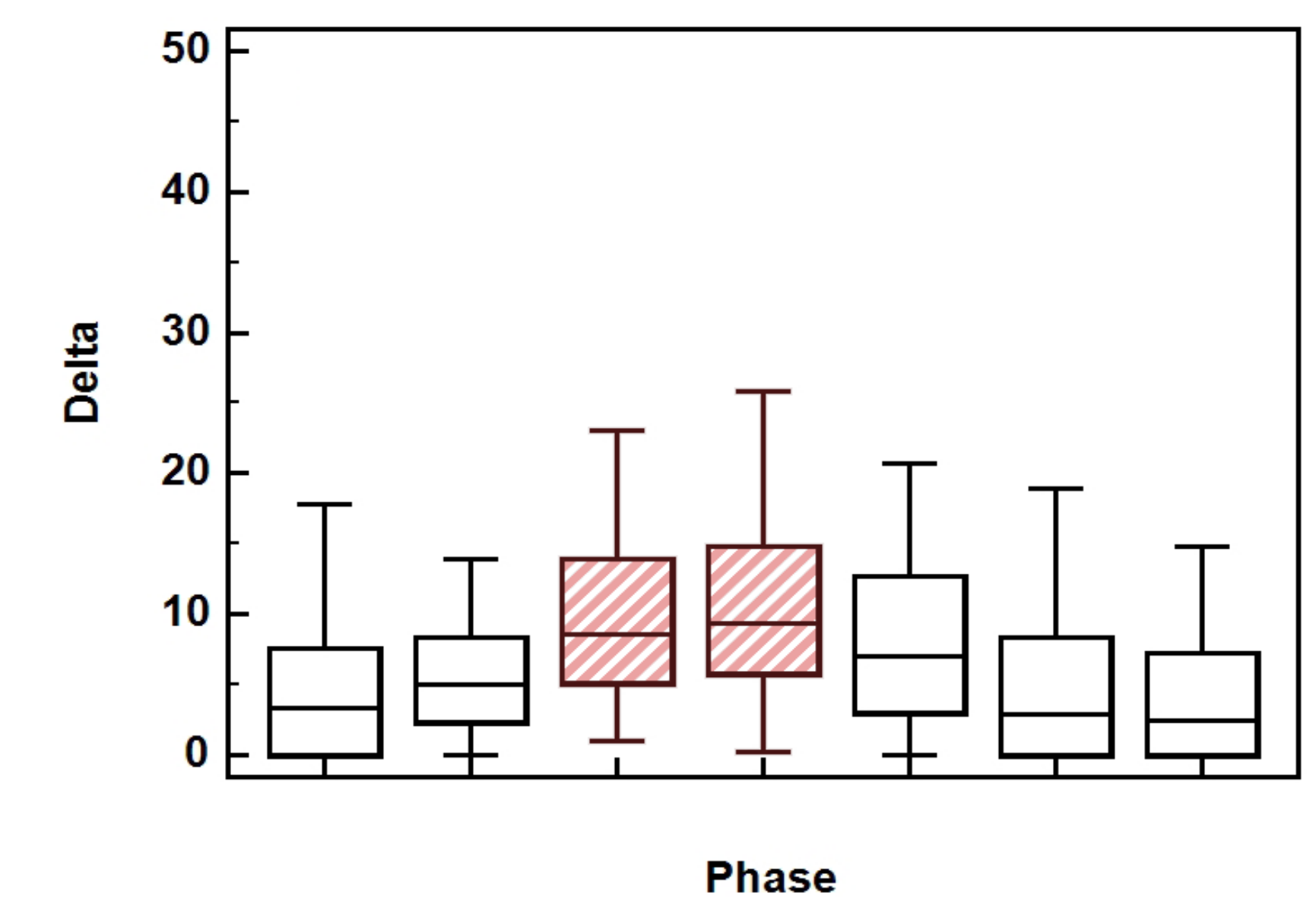


Figure 3: Box and whisker plot of the delta values for each phase, arranged in temporal order

Phase	Delta Value (IQR)
Baseline	3.30 (0.00-7.58)
Arterial Prepeak	5.00 (2.30-8.40)
Arterial Peak	8.60 (5.10-13.93)
Notch	9.40 (5.80-14.85)
Venous Peak	7.00 (3.05-12.73)
Venous Downslope	2.90 (0.00-8.38)
Venous Equilibrium	2.50 (0.00-7.23)

Figure 4: Mean Delta values for each phase with interquartile ratio

Results

The data of 45 patients (22 male, 23 female, mean age 69, ±16) were analyzed. The median sizes of the ischemic and viable ROIs were statistically similar (mean (IQR) 3.00 (2.90-3.10) versus 3.00 (2.90-3.10), respectively; P=0.78).

There was a significant phase effect on delta and ratio values (P<0.00001 for each). Post-hoc analysis revealed that the median notch and peak phase delta values were significantly greater than the baseline, pre-peak, downslope and venous phases (P<0.01 for each comparison). Also, the median peak venous and venous downslope phase deltas were significantly lower than each of the previous CTA phases (P≤0.05 for each comparison), except for the baseline delta figures (P=1.00) (Figs. 3, 4).

Discussion

The conspicuity of ischemic areas distal to a large artery occlusion in acute stroke is dependent on the phase of contrast arrival on time-resolved dynamic CTASI. The greatest conspicuity of areas of hypoattenuation between ischemic and normally perfused tissue is at the arterial peak and the immediately adjacent notch phase. This area falls at the mid-point of the TAC.

The time point seems to fall into a 'sweet-spot', where enough time has elapsed to allow contrast to travel adequately through the cortex but not so long that infarcted areas become obscured.