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ORIGINAL RESEARCH

Neurovascular/Stroke Imaging

A Comparison of CT Perfusion Output of Rapid.AI and Viz.ai software in the Evaluation of Acute Ischemic Stroke

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ABSTRACT

BACKGROUND AND PURPOSE: Automated CT Perfusion post-processing packages have been developed for managing acute ischemic stroke (AIS). These packages identify the volume of the ischemic core and penumbra by using advanced image processing techniques. This study aims to investigate the agreement of decision-making rules and output values derived from RapidAI and Viz.ai software packages in early and late time windows and to identify predictors of inadequate quality CT perfusion (CTP) studies.

MATERIALS AND METHODS: 129 AIS patients who had CTP performed upon presentation were analyzed. Imaging data were processed by two software packages: RapidAI and Viz.ai. Volumetric outputs were compared between packages by performing Spearman rank-order correlation and Wilcoxon signed-rank tests with sub-analysis performed at early (<6 hours) and extended (>6 hours) time windows. The concordance of selecting patients based on DAWN and DEFUSE3 eligibility criteria was assessed using Mcnemar test.

RESULTS: 108 out of 129 patients were found to have adequate quality studies. Spearman rank-order correlation coefficients were calculated on Tmax >6s volume, Tmax >10s volume, CBF <30% volume, Mismatch Volume, and Mismatch Ratio, between both software packages with correlation coefficients of 0.82, 0.65, 0.77, 0.78, 0.59 respectively. The Wilcoxon Signed-Rank Test was also performed on Tmax >6s volume, Tmax >10s volume, CBF <30% volume, Mismatch Volume, and Mismatch Ratio with P-Values of 0.30, 0.016, <0.001, 0.03, <0.001 respectively. In a one-sided test, CBF <30% was greater in Viz.ai (p<0.001). Although this resulted in statistically significant differences, it did not cause clinically significant differences when applied to the DAWN and DEFUSE 3 criteria. Lower ejection fraction (EF) predicted an inadequate study in both software packages (P = 0.018; 95% CI: 0.01, 0.113) and (P = 0.024; 95% CI: 0.008, 0.109); for RapidAI and Viz.ai, respectively. In Viz.ai, the presence of a clip, coil, or other metal predicted an inadequate study (P = 0.042; 95% CI: -3.225, -0.057).

CONCLUSIONS: Viz.ai predicted higher ischemic core volumes than RapidAI. Viz.ai predicted lower combined core and penumbra values than RapidAI at lower volumes and higher estimates than RapidAI at higher volumes. Clinicians should be cautious when using different software packages for clinical decision-making.

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INTRODUCTION

Large vessel occlusion (LVO) strokes of the anterior circulation contribute disproportionately to stroke-related dependence and mortality[1]. Mechanical thrombectomy is cost-effective and substantially reduces LVO stroke disability[2-4]. Delayed reperfusion leads to worse outcomes. Therefore, accurate and timely LVO identification and endovascular team notification are critical to maximizing the benefit of proven reperfusion therapies[5-6]. The use of advanced neuroimaging has been endorsed by the American Heart Association (AHA) guidelines after the positive results of DAWN (Diffusion Weighted Imaging DWI or Computerized Tomography Perfusion CTP Assessment With Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention) and DEFUSE-3 (Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3) in well-selected patients beyond 6 hours of onset of ischemic stroke symptoms[7-9]. These two trials were based on automated post-processing results derived from the RapidAI software package (iSchemaView, Menlo Park, CA, USA) to triage patients and proved beneficial for patients with perfusion mismatch. Advances in image

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analysis software and Artificial Intelligence (AI) technology have facilitated the development of automated infarct core analysis and LVO detection[10-12]. The role of CT perfusion (CTP) is to differentiate between irreversibly infarcted (unsalvageable ischemic core) and areas of potentially salvageable (penumbral) tissues. The brain is repeatedly scanned during the intravenous infusion of iodinated contrast media to create an attenuation-time curve. Perfusion measurements can then be calculated, such as relative cerebral blood volume (rCBV), relative cerebral blood flow (rCBF), mean transit time (MTT), and time to maximum peak (Tmax). These are then displayed on a brain map with color scales. Multiple software packages are currently available, and they differ in how the perfusion maps are calculated, which can result in lesion volume variability[13]. RapidAI utilizes a Fourier Transform deconvolution algorithm[14,15]. In our literature search, we did not find any reference to the implementation details of the Viz.ai algorithm. In this study, we assess the outcomes of the two most commonly available commercial automated packages: RapidAI and Viz.ai. We also compared the difference between these 2 software packages in triaging patients for endovascular treatment (EVT) by DAWN or DEFUSE-3 criteria.

MATERIALS AND METHODS

This was a multicenter retrospective study. We reviewed 1025 AIS patients admitted to three comprehensive stroke centers in Texas. We excluded patients who did not have both RapidAI and Viz.ai perfusion maps. We then excluded any patients without LVO, resulting in 129 patients from (HCA Houston Healthcare Kingwood (n=60, 46.51%), HCA Houston Healthcare Northwest (n=24, 18.60%), and Valley Baptist Medical Center Harlingen (n=45, 34.88%)) between October 2020 and August 2023 (Figure 1). We analyzed clinical and radiological data, including patient gender, age, ethnicity, vascular risk factors, National Institute of Health Stroke Scale (NIHSS), and intracranial atherosclerosis. We also collected CT perfusion outcome maps. We included patients who met the following criteria: (1) CTP performed on arrival at the comprehensive stroke center within the early (< 6 hours) or late (≥ 6 hours) from the last known well (LKW), (2) age ≥ 18 years, (2) NIHSS > 6, and (3) AIS caused by intracranial large artery occlusion. The software packages used in these hospitals during the study period were: RapidAI (RapidAI-IschemaView, version 5.2.2) and Viz CTP (Viz.ai, version 1.11). These software packages create threshold-based outputs for relative cerebral blood flow (rCBF), relative cerebral blood volume (rCBV), and time to maximum of the residue function (Tmax). Pre-procedural predicted Infarct Core Volume (ICV) was calculated based on the rCBF < 30% threshold, and hypoperfused tissue was calculated based on Tmax greater than 6 seconds (Tmax > 6s)[16]. We have compared the perfusion map results from RapidAI and Viz.ai, and the agreement between both software packages at different time windows using the Spearman Rank-Order correlation coefficient and the Wilcoxon Signed-Rank test. The magnitude of agreement was classified according to the following values: from 0.0 to 0.20 indicating poor agreement; 0.21 to 0.40 indicating fair agreement; 0.41 to 0.60 indicating moderate agreement; 0.61 to 0.80 indicating substantial agreement; and 0.81 to 1.0 indicating excellent agreement[17]. Statistical analysis was performed using (Scipy Stats 1.9.1)[18]. The data supporting this study's findings are available from the corresponding author upon reasonable request.

RESULTS

A total of 129 patients were included in the analysis. Out of 129 cases, 62 patients presented in the early time window. NIHSS on arrival was available in all patients (mean =16). 117 out of 129 had transthoracic echo with an ejection fraction (EF) documented. Nine patients had posterior circulation strokes. Summary statistics related to sex, race, age, comorbidities, smoking status, and features extracted from imaging are shown in Table 1. Viz.ai determined that 115 of the 129 studies were adequate for evaluation. RapidAI determined that 118 of the studies were adequate for evaluation. For the adequate studies, Spearman rank-order correlation coefficients were calculated for Tmax >6s volume, Tmax >10s volume, CBF <30% volume, Mismatch Volume, and Mismatch Ratio were all found to be concordant between both software packages of 0.82, 0.65, 0.77, 0.78, 0.59 respectively. The correlation coefficients at extended time windows remain significant at 0.88, 0.61, 0.7, 0.87, 0.80 for ≥ 6 hours and 0.74, 0.63, 0.83, 0.69, 0.78 for < 6 hours respectively (Tables 2A, 2B, 2C). A two-sided Wilcoxon Signed-Rank Test was also performed on Tmax >6s volume, Tmax >10s volume, CBF <30% volume, Mismatch Volume and, Mismatch Ratio with p-values of 0.306, 0.016, <0.001, 0.03, <0.001. There was a statistically significant difference in CBF <30% Volume at <6 hours (p<0.001) and >6 hours (p=0.007) between RapidAI and Viz.ai. We also performed a sub-analysis using the median as a cutoff and directional Wilcoxon signed-rank tests. This showed that Tmax >6s Viz.ai predicted lower values than RapidAI at volumes lower than the median (Tmax >6s < 78.5 mL, p<0.001), but at high volumes, Viz.ai predicted higher values than RapidAI at volumes higher than the median (Tmax >6s > 78.5 mL, p=0.029). In contrast, for CBF <30%, Viz.ai predicted greater irreversible ischemic core volumes at volumes above (CBF<30% < 9.5 mL, p=0.002) and below the median (CBF<30% > 9.5 mL, p<0.001).

Plots of the values and the lines of best fit are shown in Figures 2-5. We also ran a logistic regression on RapidAI and Viz.ai on whether or not the study was determined to be inadequate for analysis. The variance inflation factor was calculated for each variable to look for violations in the multicollinearity assumption of the logistic regression. Decreased EF predicted an inadequate study in Viz.ai (p=0.024) and RapidAI (p=0.018). Also, in Viz.ai, there were no intracranial hemorrhages in the dataset to determine how that would impact study adequacy. There were 11 total studies with a clip, coil, or other metal, and 4 of these studies were marked as inadequate by Viz.ai, and none of them were marked as inadequate by RapidAI. Statistically, in Viz.ai the presence of a clip, coil, or other metal predicted an inadequate study (p=0.042). In contrast, in RapidAI, all studies with clip, coil, or other metal were adequate (Table 3). We could not run a model with perfect separation, which was not included in the logistic regression with RapidAI. Additionally, we applied the DAWN and DEFUSE3 criteria to the 35 eligible patients and performed a Mcnemar test on the confusion matrix. There was no significant statistical difference in triaging patients to thrombectomy intervention based on the DAWN and DEFUSE-3 eligibility criteria, as shown in Figure 6. Eligibility criteria are shown in Table 4. We have calculated the mean of the difference between the Tmax >6s and CBF <30% volumes and found that the mean of the absolute value of the differences was 32.36 mL and 9.5 mL, respectively. We partitioned the data because our clinicians reported a larger discrepancy between the software packages with larger infarct core and penumbra values. For Tmax >6s, the mean absolute value of the difference was 16.81+/-15.65mL when volumes were less than the median of 78.5 and 38.40+/-38.47mL when the volumes were greater. For CBF <30%, the mean absolute difference was 1.8+/-2.3mL when volumes were less than the median

of 9.5 and 15.07+/-13.28mL when the volumes were greater. Additionally, we calculated the mean and standard deviation of the absolute difference between the volumes of Viz.ai and RapidAI. In patients when the LKW was >6 hours, the mean absolute difference of Tmax >6s was 34.05+/-35.08mL, and CBF <30% was 10.35+/-11.37mL. For patients with LKW <6 hours, the mean absolute difference of Tmax >6s was 33.00+/-40.06mL, and CBF <30% was 8.84+/-12.79mL.

DISCUSSION

Computed tomography perfusion imaging has become an important tool for triaging AIS patients and determining the need for recanalization. Automated imaging analyses are increasingly used as selection tools for the endovascular treatment (EVT) of LVO in the 6-to-24-hour time window. RapidAI software has been widely used in several large trials to estimate the volumes of ischemic core and perfusion lesions, with several guidelines relying on these trials[7-10]. We compared RapidAI and Viz.ai software packages directly on the same image set to determine agreement with commonly used perfusion map parameters, predictors of poor quality CT perfusion studies, and differences between RapidAI and Viz.ai on selecting LVO stroke patients based on DAWN or DEFUSE-3 criteria.

RapidAI CTP and Viz.ai CTP software packages were highly correlated with correlation coefficients of 0.82 and 0.77, respectively, but produced statistically significantly different irreversibly ischemic cores ($p<0.001$). This correlation remained significant in different time windows from the last known well. The software packages were highly correlated at an early time window (<6 hours), with Tmax>6 (correlation coefficient 0.86) and CBF <30% (correlation coefficient 0.71). There was also excellent correlation at an extended time window (> 6 hours) for Tmax>6 (correlation coefficient 0.87) and substantial for CBF <30% (correlation coefficient 0.87), but the estimates of the ischemic core were statistically significantly different by Wilcoxon Signed-Rank matched pairs test. This highlights that values can be correlated but different. For Tmax >6s, Viz.ai showed statistically significantly lower values than RapidAI at volumes lower than the median ($p<0.001$). In contrast, at volumes of TMax >6s higher than the median of 78.5mLs, Viz.ai predicted higher values than RapidAI ($p=0.029$). We have also shown that Viz.ai consistently predicts higher irreversibly infarcted core (CBF<30%) than RapidAI. The software differed by increased volumes at larger penumbra and core infarct values. It is also important to note that the linear regression used to create the line of the Tmax >6s plot had an intercept of 39 and a slope of 0.614. This indicates that RapidAI had larger predictions at lower volumes, and Viz.ai had larger values at larger volumes, consistent with the sub-analysis performed with the Wilcoxon Signed-Rank Test. This asymmetry in predictions may indicate that the core and penumbra are not accurate from one or either software. In future studies, we will examine how this impacts the final infarct volumes on MRI DWI sequences after thrombectomy. Our study illustrates that in clinical practice, RapidAI and Viz.ai software produce statistically significantly different but highly correlated perfusion maps, and differences in volumes that are produced do not significantly change which patients are selected for thrombectomy based on the predicted infarct core and penumbra volumes in the DAWN and DEFUSE-3 criteria. With the rise of large core infarct trials, the DAWN and DEFUSE-3 criteria are being used less in clinical practice, and the situations in which clinicians decide to use CT Perfusion are evolving[19-20]. With CT Perfusion being applied in different clinical scenarios, it is incredibly important that physicians understand that using different software packages may produce different results that can impact their decisions.

A recently published study[21] reviewed 242 patients with anterior circulation large vessel occlusion and compared pre-procedure prediction of final infarct volumes. They have used RapidAI version 4.5.0 (RapidAI-iSchemaView, Menlo Park, CA) to analyze CTP maps upon patient presentation. Then, Viz CTP version 1.3 (Viz.ai, Palo Alto, CA) automated software package was retrospectively applied to patients with ICA or MCA M1 occlusions. The median time from LKW to CTP time was 402 (IQR = 181–790) minutes. Similar to our findings, this study revealed that RapidAI and Viz.ai had excellent correlation for Tmax>6 (correlation coefficient 0.81) and substantial correlation for CBF <30% (correlation coefficient 0.76), but the study did not look directly at differences in volumes. Our study is unique because RapidAI and Viz.ai were mostly run concurrently with some images run after image collection to augment our sample size. Running the software packages concurrently provides a real-world comparison of the two software packages with their competing versions and gives insight to hospitals looking to adopt these packages. Performing a study at the same time period across several hospitals, and using competing versions increases the external validity of our study and limits the bias that can be introduced by running different versions at different points in time. Also, we included LVOs in MCA M1, MCA M2, and ACA as well as posterior circulation. We included ultra-early window patients presenting within 3 hours from the onset of symptoms and patients with unknown LKW. Median LKW to CTP time was 300 (IQR=142.5-607.5) minutes.

Our Wilcoxon Signed Rank Tests showed that Viz.ai consistently predicts larger core infarcts than RapidAI at all volumes and timeframes. Overestimation of the infarct core is well described in the literature and is considered a critical pitfall of CTP in patients presenting in the early time window[22]. Clinicians should be aware of this ghost infarct core (defined as initial core minus final infarct >10 mL) and exercise caution. We could not find a clear difference in predictions of the irreversibly ischemic core infarct when patients had CT Perfusion performed <6 hours and in >6 hours by either software package.

The estimation of the ischemic core volume and tissue at risk (penumbra) is an important step in the evaluation and triaging of patients with LVO. In a subgroup of our cohort (35 patients out of 129); we evaluated the performance of RapidAI and Viz.ai software packages in triaging patients with LVO based on DAWN and DEFUSE-3 selection criteria. Clinical and or neuroimaging eligibility criteria included in DAWN and DEFUSE-3 were applied for individual patient triaging to determine the concordance of treatment decisions based on these two software packages. Specifically, mismatched profiles and mismatched volumes were calculated accordingly using volumetric results. Then eligibility for mechanical thrombectomy was derived from each package for individual AIS patients, and the agreement of patient triage was measured (represented on the confusion matrix). We performed a Mcnemar test on the confusion matrix and found that there was no significant difference between triage classification based on DAWN criteria ($p=1.00$) which suggests that clinicians can use either software to triage LVO patients for the extended time window. This is consistent with a recent study from the University of Cincinnati that analyzed 54 patients in which the authors found no difference in the final decision to proceed with EVT using either software when both DEFUSE-3 and DAWN criteria were considered[23]. Another recent study compared RapidAI and RealNow software packages, and a diagnostic agreement based on DEFUSE-3 criteria was analyzed in a subgroup of patients. Concordance on triaging agreement was found

in 16/19 (84%) cases in subgroups with package-A-based ICV > 70mL, and 143/155 cases (92%) in the subgroup with ICV < 70mL. A subgroup with a large ischemic core, or core below 70mL led to discordance in mismatched profiles, which affected patient selection for mechanical thrombectomy[24].

Finally, we evaluated the factors that contributed to inadequate interpretation by the software packages. In both RapidAI and Viz.ai, we found that lower EF led to inadequate study (P = 0.018; 95% CI: 0.01, 0.113) and (P = 0.024; 95% CI: 0.008, 0.109); for RapidAI and Viz.ai respectively. To our knowledge, our study is the first to reveal this finding. A recent study evaluated CTA in 47 LVO patients and found low EF was a predictor for incorrect identification of LVO in both RapidAI and Viz.ai software packages[25]. A study that evaluated contrast curve truncation in CTP protocols found that reduced left ventricle EF and hypertension resulted in the truncation of CTP data and a lower quality study[26]. In our study, there were no intracranial hemorrhages in the dataset to determine how that would impact study adequacy. In Viz.ai software, we found that the presence of a clip, coil, or other metal predicted an inadequate study (P = 0.042; 95% CI: -3.225, -0.057), but the software only labeled 4/11 of the studies as inadequate. This is likely because the software has a step during preprocessing that detects images with metal and removes those images. This indicates that the software's metal detection algorithm could detect some of the metal. RapidAI has included the feature in a future version but was not available to us at the time of this publication.

There are several limitations in our study worth mentioning. This is a retrospective study design with an inherent risk of bias. However, the data is from three high-volume comprehensive stroke centers, and automated perfusion images were performed during an overlap period on the same patient population using RapidAI and Viz.ai. Secondly, we did not collect data on the brands of CT scanners used to obtain the images. The CTP acquisition protocol (slice thickness and collimator) information was not collected. Looking at final infarct volumes on MRI diffusion-weighted imaging is outside the scope of this study, but in a future study, we will certainly make volume measurements of this MRI diffusion-weighted imaging after thrombectomy and compare this volume to the CT Perfusion CBF <30% prediction of the irreversibly ischemic core. Our goal was to determine if there was a difference between the output of these two software packages to determine if clinicians could use this data to make similar conclusions, and we have found that Viz.ai produces higher values than RapidAI. In a future study, we will compare CBF and the final infarct volume and look at how the CT Perfusion maps may predict poor thrombectomy outcomes.

CONCLUSIONS

Viz.ai produced consistently higher predictions of irreversibly ischemic core infarct volumes than RapidAI. Viz.ai predicted lower combined core and penumbra values than RapidAI at lower volumes and predicted higher combined core and penumbra estimates than RapidAI at higher volumes. Users should be cautious of these differences in triaging patients for mechanical thrombectomy. Studies flagged as inadequate by Viz.ai and RapidAI were predicted by lower EF, and Viz.ai detected the presence of metal in some studies and marked them as inadequate.

REFERENCES

1. Malhotra K, Gornbein J, Saver JL. Ischemic Strokes Due to Large-Vessel Occlusions Contribute Disproportionately to Stroke-Related Dependence and Death: A Review. Front Neurol. 2017 Nov 30;8:651. doi: 10.3389/fneur.2017.00651. PMID: 29250029; PMCID: PMC5715197.
2. Kunz WG, Hunink MG, Almekhlafi MA, et al. Public health and cost consequences of time delays to thrombectomy for acute ischemic stroke. Neurology. 2020 Nov 3;95(18):e2465-e2475. doi: 10.1212/WNL.0000000000010867. Epub 2020 Sep 17. PMID: 32943483.
3. Goyal M, Menon BK, van Zwam WH, et al.Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet. 2016 Apr 23;387(10029):1723-31. doi: 10.1016/S0140-6736(16)00163-X. Epub 2016 Feb 18. PMID: 26898852.
4. Jovin TG, Nogueira RG, Lansberg MG, et al. Thrombectomy for anterior circulation stroke beyond 6 h from time last known well (AURORA): a systematic review and individual patient data meta-analysis. Lancet. 2022 Jan 15;399(10321):249-258. doi: 10.1016/S0140-6736(21)01341-6. Epub 2021 Nov 11. PMID: 34774198.
5. Saver JL. Time is brain--quantified. Stroke. 2006 Jan;37(1):263-6. doi:10.1161/01.STR.0000196957.55928.ab. Epub 2005 Dec 8. PMID: 16339467.
6. Khatri P, Yeatts SD, Mazighi M, et al. Time to angiographic reperfusion and clinical outcome after acute ischaemic stroke: an analysis of data from the Interventional Management of Stroke (IMS III) phase 3 trial. Lancet Neurol. 2014 Jun;13(6):567-74. doi: 10.1016/S1474-4422(14)70066-3. Epub 2014 Apr 27. PMID: 24784550; PMCID: PMC4174410.
7. Nogueira RG, Jadhav AP, Haussen DC, et al. Thrombectomy 6 to 24 Hours after Stroke with a Mismatch between Deficit and Infarct. N Engl J Med. 2018;378(1):11-21.
8. Albers GW, Marks MP, Kemp S, et al. Thrombectomy for Stroke at 6 to 16 Hours with Selection by Perfusion Imaging. N Engl J Med. 2018;378(8):708-718.
9. Warner JJ, Harrington RA, Sacco RL,et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: 2019 Update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke. Stroke. 2019 Dec;50(12):3331-3332. doi: 10.1161/STROKEAHA.119.027708. Epub 2019 Oct 30. PMID: 31662117.
10. Hassan AE, Ringheanu VM, Rabah RR, et al. Early experience utilizing artificial intelligence shows significant reduction in transfer times and length of stay in a hub and spoke model. Interv Neuroradiol. 2020 Oct;26(5):615-622. doi: 10.1177/1591019920953055. Epub 2020 Aug 26. PMID: 32847449; PMCID: PMC7645178.
11. Shlobin NA, Baig AA, Waqas M, et al. Artificial Intelligence for Large-Vessel Occlusion Stroke: A Systematic Review. World Neurosurg. 2022 Mar;159:207-220.e1. doi: 10.1016/j.wneu.2021.12.004. Epub 2021 Dec 8. PMID: 34896351; PMCID: PMC9172262.
12. Matsoukas S, Stein LK, Fifi JT. Artificial intelligence-assisted software significantly decreases all workflow metrics for large vessel occlusion transfer patients, within a large spoke and hub system. Cerebrovasc Dis Extra. 2023 Feb 14;13(1):41–6. doi: 10.1159/000529077. Epub ahead of print. PMID: 36787716; PMCID: PMC9999083.
13. Christensen S, Lansberg MG. CT perfusion in acute stroke: Practical guidance for implementation in clinical practice. J Cereb Blood Flow Metab. 2019;39(9):1664-1668.
14. Straka, Matus, Gregory W. Albers, and Roland Bammer. "Real-time diffusion-perfusion mismatch analysis in acute stroke." Journal of Magnetic Resonance Imaging 32.5 (2010): 1024-1037.
15. Chung, Kevin J., Danny De Sarno, and Ting-Yim Lee. "Quantitative Functional Imaging with CT Perfusion: Technical Considerations, Kinetic Modeling, and Applications." Frontiers in Physics 11: 1246973.
16. Wing SC, Markus HS. Interpreting CT perfusion in stroke. Pract Neurol. 2019 Apr;19(2):136-142. doi: 10.1136/practneurol-2018-001917. Epub 2018 Nov 13. PMID: 30425127.
17. Akoglu H. User's guide to correlation coefficients. Turk J Emerg Med. 2018;18(3):91-93. Published 2018 Aug 7. doi:10.1016/j.tjem.2018.08.001.
18. Virtanen, Pauli, et al. "SciPy 1.0: fundamental algorithms for scientific computing in Python." Nature methods 17.3 (2020): 261-272.
19. Sarraj, Amrou, et al. "Trial of endovascular thrombectomy for large ischemic strokes." New England Journal of Medicine 388.14 (2023): 1259-1271.
20. Yoshimura, Shinichi, et al. "Endovascular therapy for acute stroke with a large ischemic region." New England Journal of Medicine 386.14 (2022): 1303-1313.
21. Pisani L, Haussen DC, Mohammaden M, et al. Comparison of CT Perfusion Software Packages for Thrombectomy Eligibility [published online ahead of print, 2023 Jul 25]. Ann Neurol. 2023;10.1002/ana.26748.
22. Boned S, Padroni M, Rubiera M, et al. Admission CT perfusion may overestimate initial infarct core: the ghost infarct core concept. J Neurointerv Surg. 2017;9(1):66-69. doi:10.1136/neurintsurg-2016-012494
23. Stanton, Robert J., et al. "Differences in automated perfusion software: do they matter clinically?." Stroke: Vascular and Interventional Neurology 2.6 (2022): e000424.
24. Zhou X, Nan Y, Ju J, et al. Comparison of Two Software Packages for Perfusion Imaging: Ischemic Core and Penumbra Estimation and Patient Triage in Acute Ischemic Stroke. Cells. 2022;11(16):2547.
25. Delora A, Hadjialiakbari C, Percenti E, et al. Viz LVO versus Rapid LVO in detection of large vessel occlusion on CT angiography for acute stroke [published online ahead of print, 2023 Jun 24]. J Neurointerv Surg. 2023;jnis-2023-020445. doi:10.1136/jnis-2023-020445
26. Hartman JB, Moran S, Zhu C, et al. Use of CTA Test Dose to Trigger a Low Cardiac Output Protocol Improves Acute Stroke CTP Data Analyzed with RAPID Software. AJNR Am J Neuroradiol. 2022;43(3):388-393. doi:10.3174/ajnr.A7428

TABLES

Table 1: Descriptive statistics of study population (N=129)

Legend: This table summarizes the study population with Sex, Race, medical comorbidities, smoking status, intracranial hemorrhage, presence of coil, clip or other metal.

Summary Statistics	Sample Size	%
Sex		
Female	69	53.5
Male	60	46.5
Race		
Hispanic	47	36.4
White	44	34.1
Black	28	21.7
Other	10	7.8
Comorbidities		
Diabetes	49	38.0
HTN	101	78.3
HLD	56	43.4
CHF	20	15.5
Prior Stroke	24	18.6
Smoker		
Never	94	72.9
Current	29	22.5
Former	6	4.7
Clip, Coil or other Metal	11	8.5
ICH	0	0
LVO	129	100.0

Table 2A: RapidAI and Viz.ai Correlation Coefficients and Wilcoxon Signed-Rank Test for software packages output for all Output.

Legend: This table includes test statistic values and p-values for the output of RapidAI and Viz.ai. We calculated Spearman Rank Order correlation coefficients and Wilcoxon Signed-Rank matched pairs test.

Viz Rapid Correlation	Spearman Rank-Order correlation coefficient (95% CI), all time windows	P value	Wilcoxon Signed-Rank Test	Wilcoxon Signed-Rank Test P Value
Tmax >4s volume	0.666 (0.546,0.76)	<0.001	1484	<0.001
Tmax >6s volume	0.823 (0.751,0.876)	<0.001	2511	0.306
Tmax >8s volume	0.764 (0.672,0.833)	<0.001	2113	0.117
Tmax >10s volume	0.65 (0.526,0.747)	<0.001	1446.5	0.016
CBF <20% volume	0.665 (0.545,0.759)	<0.001	101	<0.001
CBF <30% volume	0.771 (0.681,0.838)	<0.001	636	<0.001
CBF <34% volume	0.823 (0.75,0.876)	<0.001	599.5	<0.001
CBF <38% volume	0.819 (0.745,0.873)	<0.001	865.5	<0.001
Mismatch Volume Tmax >6s & Volume CBF <30%	0.786 (0.702,0.849)	<0.001	2062	0.03
Mismatch Ratio Tmax >6s & Volume CBF <30%	0.797 (0.674,0.877)	<0.001	172	<0.001

Table 2B: RapidAI and Viz.ai Correlation Coefficients and Wilcoxon Signed-Rank Test for software packages output for time windows ≥6 hours.

Legend: We only included the patients for which the last known well was >6 hours. This table includes test statistic values and p-values for the output of RapidAI and Viz.ai. We calculated Spearman Rank Order correlation coefficients and Wilcoxon Signed-Rank matched pairs test.

Viz Rapid Correlation	Spearman rank-order correlation coefficient (95% CI) >6 hours	P-Value	Wilcoxon Signed-Rank Test	Wilcoxon Signed-Rank Test P Value
Tmax >6s volume	0.878 (0.78,0.934)	<.001	386	0.755
Tmax >10s volume	0.609 (0.368,0.774)	<.001	255	0.145
CBF <30% volume	0.7 (0.497,0.831)	<.001	160	0.007
Mismatch Volume Tmax >6s & Volume CBF <30%	0.869 (0.765,0.929)	<.001	336.5	0.455
Mismatch Ratio Tmax >6s & Volume CBF <30%	0.802 (0.583,0.913)	<.001	54.5	0.019

Table 2C: RapidAI and Viz.ai Correlation Coefficients and Wilcoxon Signed-Rank Test for software packages output for time windows <6 hours.

Legend: We only included the patients for which the last known well was <6 hours. This table includes test statistic values and p-values for the output of RapidAI and Viz.ai. We calculated Spearman Rank Order correlation coefficients and Wilcoxon Signed-Rank matched pairs test.

Viz Rapid Correlation	Spearman rank-order correlation coefficient (95% CI) <6 hours	P-Value	Wilcoxon Signed-Rank Test	Wilcoxon Signed-Rank Test P Value
Tmax >6s volume	0.743 (0.591,0.844)	<.001	598.50	0.410
Tmax >10s volume	0.628 (0.431,0.768)	<.001	295.00	0.032
CBF <30% volume	0.829 (0.72,0.898)	<.001	102.50	<0.001
Mismatch Volume Tmax >6s & Volume CBF <30%	0.691 (0.517,0.81)	<.001	480.00	0.086
Mismatch Ratio Tmax >6s & Volume CBF <30%	0.767 (0.533,0.892)	<.001	30.00	0.001

Table 3: Logistic regression study adequacy for RapidAI and Viz.ai.

Legend: We performed a logistic regression to find predictors of adequate and inadequate studies. The table includes P-Values, confidence intervals, and coefficients for each predictor.

Viz Adequate Study	**Coefficient**	**Standard Error**	**Z**	**P>|z|**	**[0.025**	**0.975]**
Age	-0.0179	0.021	-0.858	0.391	-0.059	0.023
Sex	0.0418	0.634	0.066	0.947	-1.2	1.284
Diabetes	-0.1406	0.628	-0.224	0.823	-1.371	1.09
CHF	1.422	1.082	1.314	0.189	-0.699	3.543
Ejection Fraction	0.0583	0.026	2.265	0.024	0.008	0.109
Clip Coil or other Metal	-1.6559	0.816	-2.029	0.042	-3.255	-0.057
NIH on Arrival	-0.0187	0.034	-0.557	0.577	-0.084	0.047
RapidAI Adequate Study	**Coefficient**	**Standard Error**	**Z**	**P>|z|**	**[0.025**	**0.975]**
Age	-0.019	0.021	-0.898	0.369	-0.061	0.023
Sex	0.2462	0.662	0.372	0.71	-1.052	1.544
Diabetes	-0.0579	0.652	-0.089	0.929	-1.335	1.219
CHF	1.4731	1.089	1.353	0.176	-0.661	3.607
Ejection Fraction	0.0615	0.026	2.357	0.018	0.01	0.113
NIH on Arrival	0.0368	0.034	1.088	0.277	-0.03	0.103

Table 4: DAWN and DEFUSE-3 Eligibility Criteria

Legend. We have reproduced the DAWN and DEFUSE 3 eligibility criteria in this table for reference.

	DAWN[8]	DEFUSE-3[7]
Eligibility	6-24 hours	6-16 hours
Occlusion location	ICA or Proximal MCA	ICA or Proximal MCA
Infarct volume	Age > 80 + NIHSS > 10 = <21mL	<70mL
	Age < 80 + NIHSS > 10 = 21-31mL	
	Age < 80 + NIHSS > 20 = 31-51mL	
Mismatch Ratio	None	>1.8
Imaging	CT or MRI with RapidAI	CT or MRI with RapidAI

Figures

Figure 1: Flowchart for patients with LVO and adequate studies.

Legend: This flowchart illustrates 468 patients with acute ischemic stroke who underwent a CTP study. 305 patients had concurrent RapidAI and Viz.ai perfusion maps available. Analysis was performed on 108 LVO patients after excluding inadequate studies.

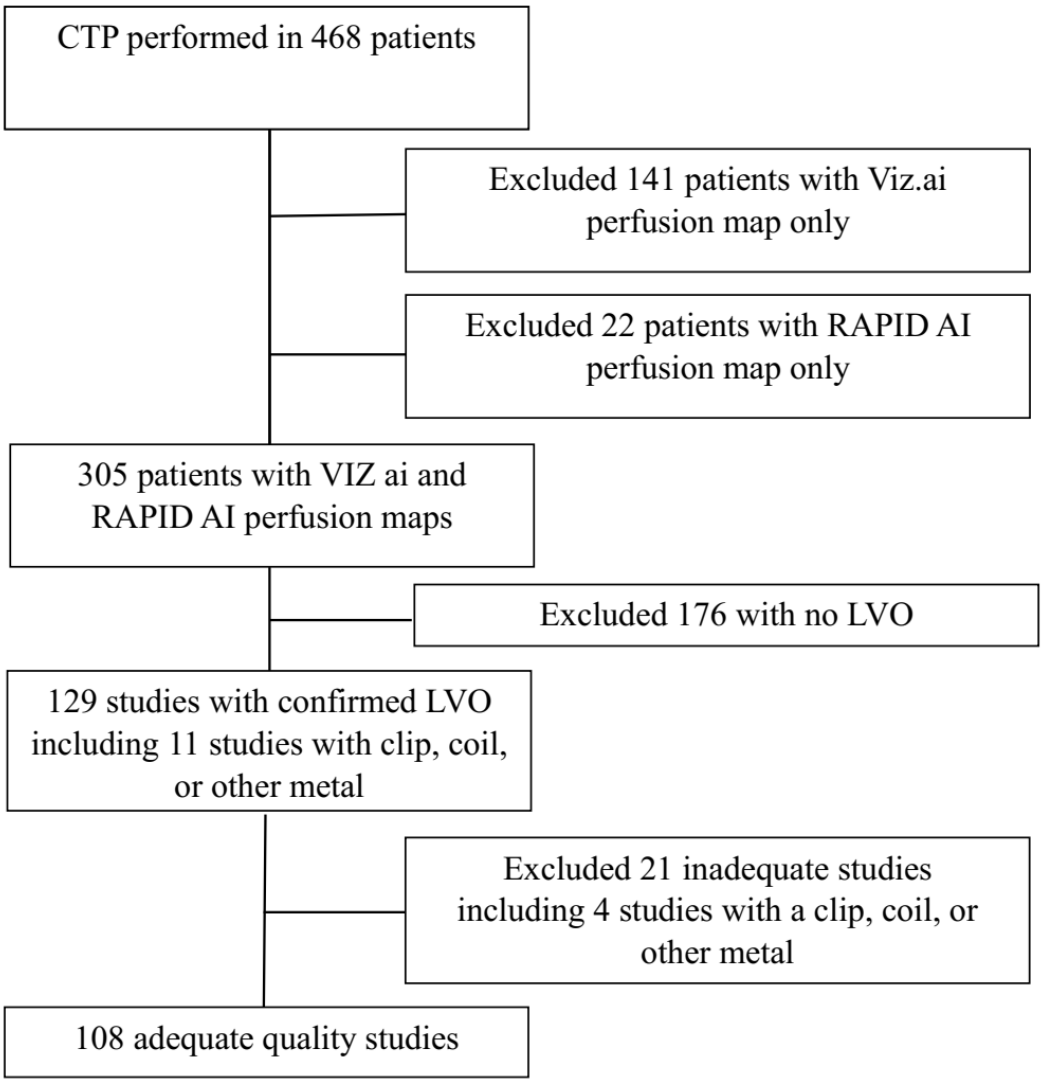

Figure 2: Tmax RapidAI and Viz.ai Scatter Plot of Values with Regression Lines

Legend: This figure shows scatter plots and regression lines for a. Tmax >4s, b. Tmax >6s, c. Tmax >8s, and d. Tmax >10s. The regression equation is noted in the top left of each subplot.

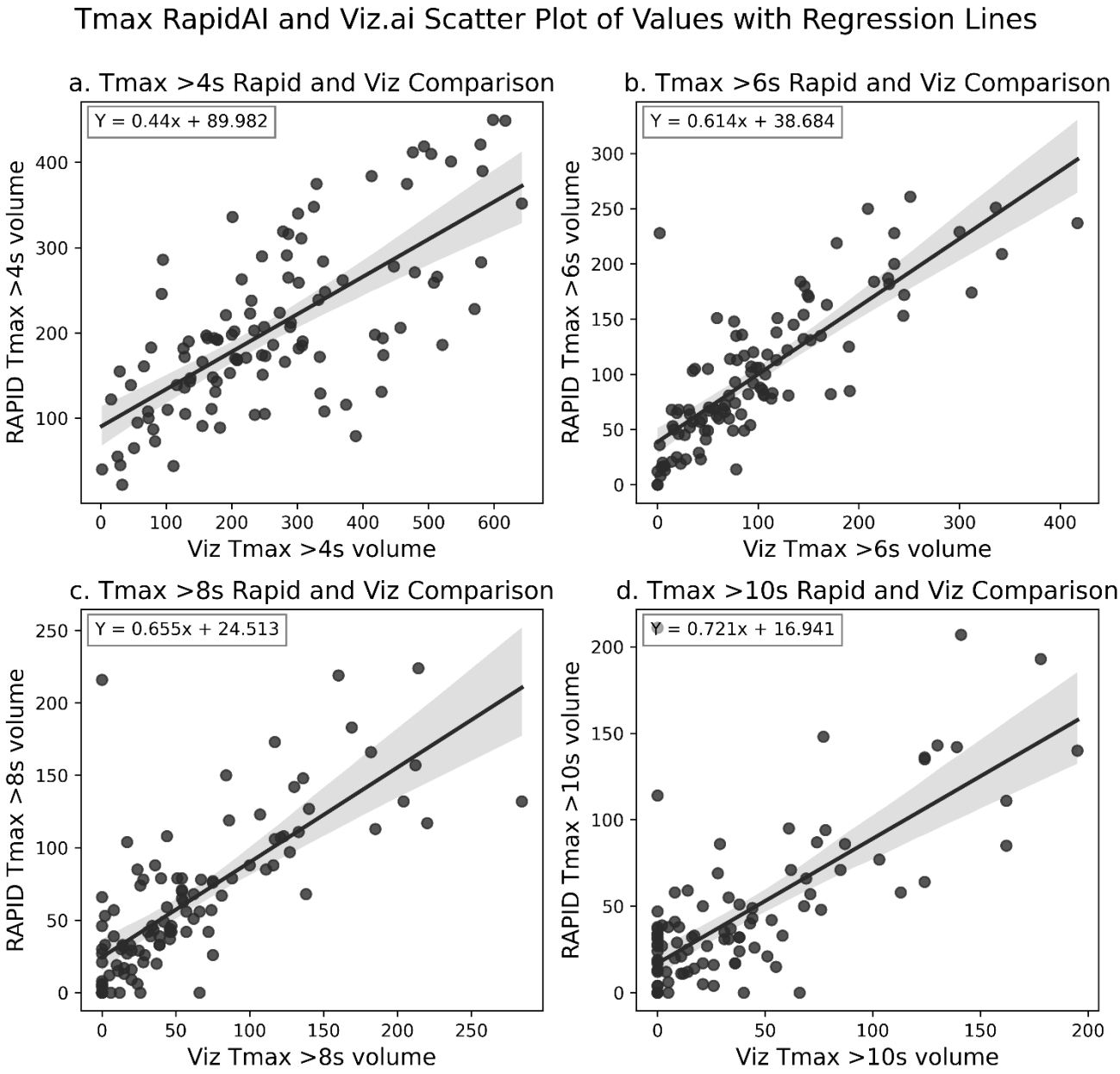

Figure 3: CBF RapidAI and Viz.ai Scatter Plot of Values with Regression Lines

Legend: This figure shows scatter plots and regression lines for a. CBF <20%, b. CBF <30%, c. CBF <34%, and d. CBF <38%. The regression equation is noted in the top left of each subplot.

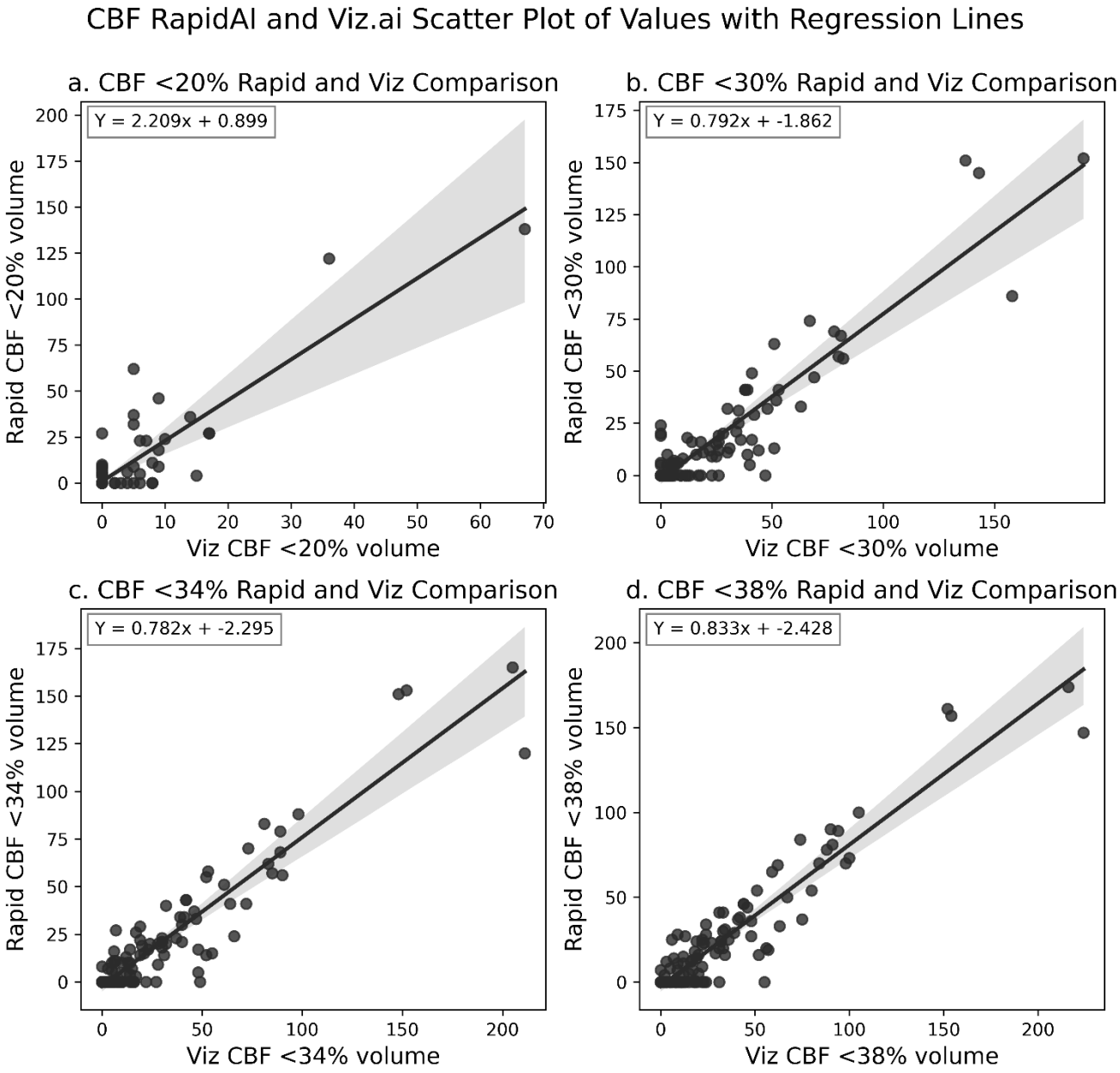

Figure 4: Mismatch volume comparison between RapidAI and Viz.ai

Legend: This figure shows a scatter plot and a regression equation between the mismatch volumes calculated from the CBF <30% and the Tmax <6s. The regression equation is shown in the top left of the plot.

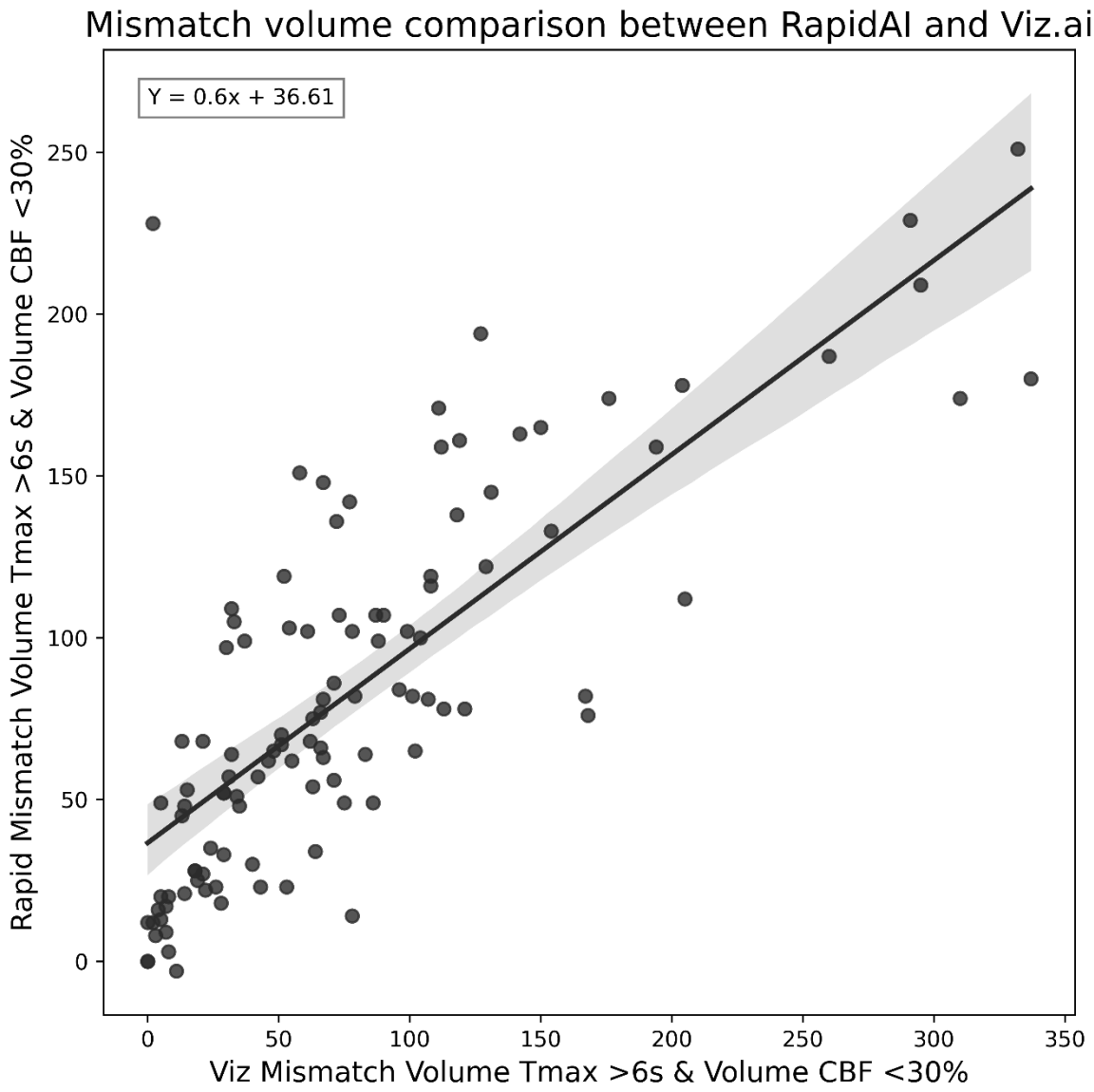

Figure 5: Mismatch ratio comparison between RapidAI and Viz.ai

Legend: This figure shows a scatter plot and a regression equation between the mismatch ratio calculated from the CBF <30% and the Tmax <6s. The regression equation is shown in the top left of the plot. If either software produced a nan or inf value the point was removed from the plot.

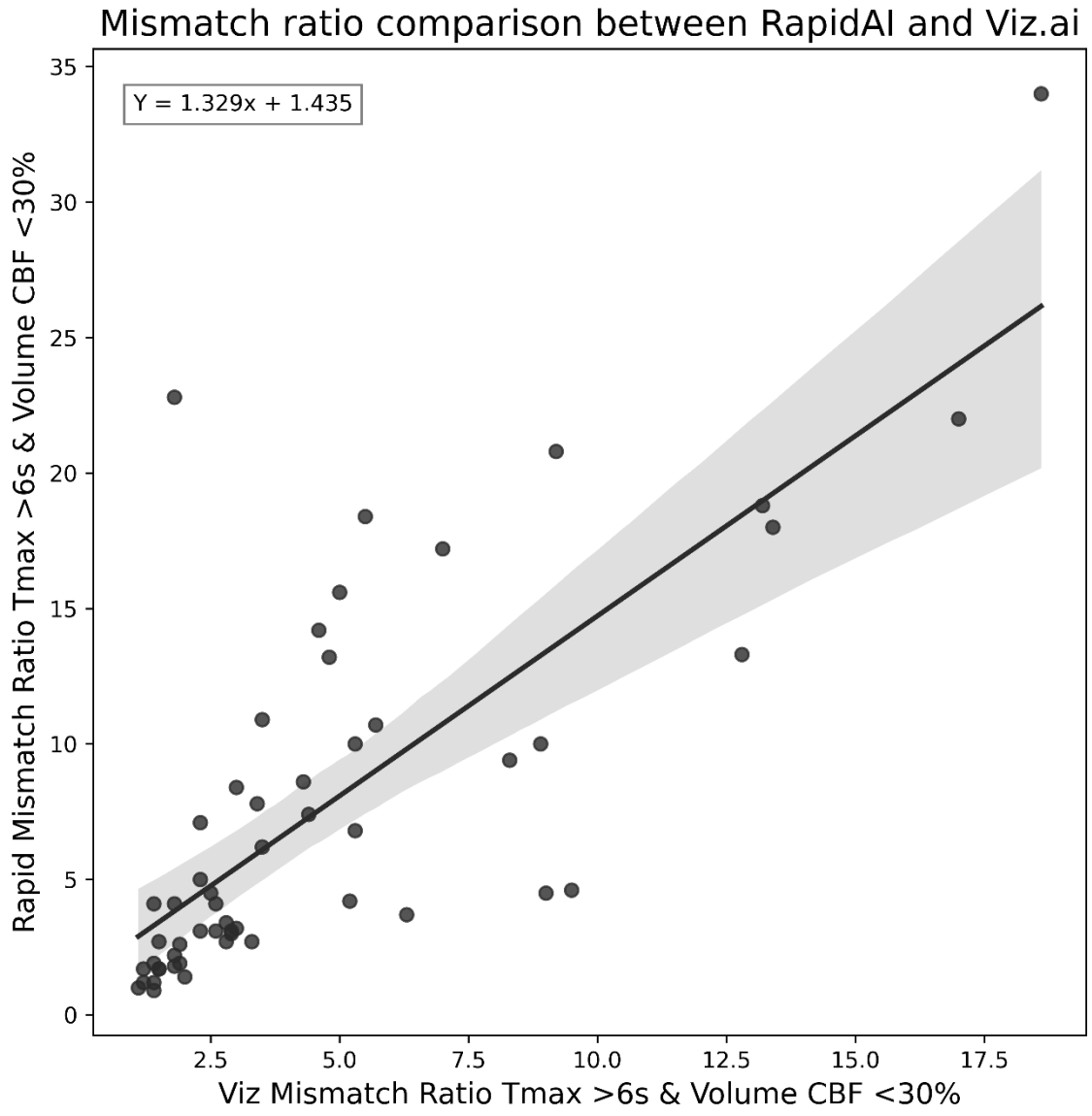

Figure 6: DAWN and DEFUSE-3 Confusion Matrices

Legend: This figure shows the DAWN and DEFUSE-3 confusion matrices for patients who had an ICA or proximal MCA occlusion. These matrices show if a patient is a candidate for thrombectomy based on these criteria. A Mcnemar test was performed on these matrices that did not show a statistically significant marginal inhomogeneity of states.