

Automated vs. Traditional Reconstruction Workflows for Head and Neck CTA: Effects on Exam Duration and Variability

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Abstract

Background and Purpose

Rapid and reliable stroke imaging is critical for timely diagnosis and intervention. Traditional workflows for head and neck CT angiography (CTA) involve manual image reconstruction steps that can prolong exam completion times and increase variability. This study aimed to evaluate whether an automated, software-driven reconstruction workflow could reduce stroke CTA exam duration and improve efficiency without compromising image quality.

Materials and Methods

This HIPAA-compliant, retrospective study included 100 consecutive stroke CTA examinations performed on a single emergency department scanner (Siemens SOMATOM Force, Forchheim, Germany) between August and November 2022. Fifty scans were obtained immediately prior to implementation of the automated workflow and 50 scans after a one-month technologist training period post-implementation. Exclusion criteria included repeat imaging due to motion, exams adjacent to other CT angiograms or trauma panscans, and post-intervention cases with technologist adjustments to the automated sequence. All scans were acquired at 100 kVp with intravenous iohexol 350 (50 mL) at 4–5 mL/s, followed by bolus tracking. The primary outcome was total exam completion time; secondary outcomes included technologist active time and variability measures.

Results

Implementation of the automated workflow resulted in a significant reduction in median exam completion time compared with the traditional workflow. Automated processing decreased median exam time by approximately 8.5 minutes and reduced technologist active time by 14.1 minutes, with narrower standard deviations for both metrics. These improvements were achieved without changes in image acquisition parameters or diagnostic quality. The streamlined process eliminated repetitive manual reconstruction tasks, allowing technologists to focus on patient care and other critical responsibilities.

Conclusions

Transitioning to an automated reconstruction workflow for stroke CTA substantially improves efficiency by reducing exam duration and technologist workload. In practice settings where radiologists review images after full exam completion, this approach accelerates image availability in PACS, enabling faster detection and communication of critical findings. While immediate clinical impact may vary depending on real-time interpretation practices, earlier availability of reformatted images can facilitate prompt identification of large vessel occlusions and other emergent conditions. Adoption of automated workflows represents a practical strategy to optimize imaging operations amid increasing imaging volumes and technologist shortages.

INTRODUCTION

The mantra “time is brain” stresses the importance of rapid therapeutic intervention in the setting of stroke to minimize irreversible brain parenchymal injury[1]. Specifically, intra-arterial therapy administered within six hours of onset of symptoms is beneficial with respect to functional recovery[2]. The American Heart Association guidelines defines desirable times to neuroimaging and neurointervention[3]. Noncontrast head CT and CTA are standard of care in stroke assessment within a possible intervention window with the goal of excluding hemorrhage and identifying large vessel occlusion, which may be a target for intervention[4, 5].

Other advanced imaging techniques include MRI and CT/MR perfusion[4, 6]. While CT is the imaging modality of choice for hemorrhage, MRI, specifically diffusion weighted imaging, is well established as the more sensitive modality when it comes to detection of acute infarct[7]. However, this modality is limited by time and availability at most institutions. The role of CT and MR perfusion is controversial but studies have shown that it may be useful for extending therapy beyond the 6-hour window[4, 8].

The management of stroke patients is a time-sensitive process. Radiology is critical for management as imaging findings immediately guide therapy. However, stroke imaging is inherently a time-consuming process. Image acquisition requires coordination between multiple team members, including emergency medical technicians, CT technologists, nursing, neurologists and radiologists. Upon arrival at the CT scanner, the technologist must prepare the patient, which includes patient positioning, confirming IV placement and function as well as setting up the power injector.

Stroke imaging includes non-contrast head CT along with CTA of the head and neck. Image postprocessing includes multiplanar reformats and 3D reconstructions, which is time-consuming and yields over 3000 images. Traditionally, technologists must manually prescribe these reconstructions and precisely align reformations to the patient’s anatomy to ensure high image quality. Because stroke care is highly time-sensitive, optimizing the CT workflow is critical to expediting image review. While recent advances in scanner technology and software allow for automated anatomic alignment, our intervention goes a step further. We replace these laborious, technologist-driven manual steps with a fully automated, software-driven workflow. This change from a traditional workflow has been shown to improve image post-processing times in the emergency department[9, 10]. To this end, the purpose of this study was to test the hypothesis that an automated post-processing workflow reduces stroke CTA exam completion times and variability.

MATERIALS AND METHODS

This retrospective, HIPAA-compliant study was approved by the Institutional Review Board, and the requirement for informed consent was waived.

Setting:

The study was conducted at a Level 1 trauma and stroke center with over 70,000 annual patient visits. The Emergency Radiology Division provides 24/7 coverage by attending radiologists, fellows, and residents. To ensure immediate communication of critical findings, stroke scans undergo live review at the scanner console, followed by final interpretations via the Picture Archiving and Communication System (PACS) once all images are available.

Cohort:

A PACS search identified the final cohort of 100 consecutive head and neck CT angiograms (CTAs) performed between August 2022 and November 2022. The cohort comprised two groups:

- Pre-intervention Group: 50 consecutive scans performed immediately prior to implementing the automated workflow.
- Post-intervention Group: 50 consecutive scans performed following a 1-month technologist training and acclimatization period.

Exclusion criteria were applied as outlined in the flow diagram (Figure 1):

1. Examinations requiring repeat imaging due to motion artifacts.
2. Examinations performed immediately before or after another CT angiogram or a trauma pan-scan (to prevent timing data confounding from pending reconstruction queues).
3. Post-intervention examinations where the technologist manually altered the automated reconstruction workflow (identified by deviations in programmed series timestamps).

For any excluded scan, additional consecutive examinations were sequentially added until a final target of 50 valid scans per group was achieved.

Image Acquisition:

All examinations were performed on a Siemens SOMATOM Force scanner (Siemens Healthineers, Forchheim, Germany) using the following parameters:

- Tube Voltage: 100 kVp
- Reference Current-Time Product: 200 mAs
- Spiral Pitch Factor: 0.7
- Rotation Time: 0.25 seconds

Contrast material (50 mL of iohexol 350) was administered intravenously at a flow rate of 4–5 mL/s. Bolus tracking was used with a region of interest (ROI) placed in the descending aorta and an automated scan trigger threshold of 120 Hounsfield Units (HU).

Post-processing workflow

The standard institutional stroke protocol consists of a non-contrast head CT followed by a contrast-enhanced head and neck CTA. An immediate delay sequence through the head and neck is included to differentiate complete vascular occlusion from high-grade stenosis and to salvage suboptimal scan timings.

The structural sequences of both workflows are detailed in Figure 2, and specific image reconstructions are listed in Table 1.

Traditional Workflow

Technologists began with a lateral planning projection radiograph to prescribe the scan ranges and field of view (FOV). Following image acquisition, the non-contrast head CT was reconstructed in the axial plane for immediate preliminary scanner-side review. All remaining multiplanar reformations were then manually generated by the technologist prior to PACS transmission.

Automated Software-driven Workflow

Scan prescription and acquisition matched the traditional workflow, allowing radiologists to perform immediate preliminary reviews on axial non-contrast head CT reconstructions.

The primary study intervention was the integration of a software-driven post-processing workflow utilizing a freestanding server (Syngo.via, Siemens Healthineers, Forchheim, Germany). Thin axial source images were automatically routed to the server, which executed fully automated, anatomy-aligned reformations and transmitted them back to PACS without human intervention. In this automated protocol, standard sagittal oblique carotid reconstructions were replaced by automated 3D centerline spins.

Technologists were instructed not to interrupt automated reconstruction jobs, modify their execution order, or manually adjust anatomic alignment or FOV. During the initial 1-month training period, radiologists confirmed that the automated reformations provided adequate anatomic coverage and alignment prior to initiating data collection.

Data Collection:

Patient demographics (age and gender) and the identity of the performing technologist were recorded.

Overall imaging turnaround time consists of a technical component (exam order to completion) and an interpretive component (exam completion to report finalization). Because this study aimed to evaluate imaging availability to the radiologist, data collection was restricted to timestamps within the technical component.

Digital Imaging and Communications in Medicine (DICOM) metadata tags were extracted to calculate process intervals:

- Image Acquisition Time (DICOM tag 0008,0032): Recorded from the first image of the axial series for each scan phase to mark when the X-ray tube was active.
- Series Time (DICOM tag 0008,0031): Recorded from the final image of each series to mark completion.

Using these timestamps, two primary time intervals were calculated (Figure 2):

- Exam Time: Total examination duration, calculated as the interval between the first image acquisition timestamp of the non-contrast head CT and the final series creation timestamp of the entire study.
- Tech Time:
 - *Traditional Workflow*: The interval from the initial non-contrast head CT acquisition timestamp to the final series creation timestamp of the delayed head and neck CTA images (inclusive of manual reconstructions).
 - *Automated Workflow*: The interval from the initial non-contrast head CT acquisition timestamp to the acquisition timestamp of the delayed head and neck CTA (reflecting that no manual reconstructions were performed).

Statistical Analysis:

Patient demographics were summarized using descriptive statistics. Exam time and tech time were compared between the pre- and post-intervention groups using a linear mixed-effects model. The time period was treated as the sole fixed predictor, and the performing technologist was modeled as a random intercept to account for data clustering caused by individual technologists performing multiple procedures across both study periods. Kenward-Roger denominator degrees of freedom were applied.

Model assumptions were verified using the Shapiro-Wilk test. Although the time data exhibited a mild right skew, it did not meaningfully impact model assumptions or results; therefore, all data were analyzed on their raw scale and reported as mean values. Models were adjusted for patient age and gender to evaluate potential confounding, but no significant demographic effects were observed.

All hypothesis tests were two-tailed, and statistical significance was defined at $\alpha = 0.05$. Statistical analyses were performed using VSCode (Version 1.88.0, Microsoft, Redmond, WA, USA).

Table 1: Stroke CT reconstruction details.

Non-contrast Head CT	CTA Head and Neck	Delayed CTA Head and Neck
Axial 3 x 3 mm Soft Acquired plane	Axial 0.75 x 0.5 mm Soft Head and Neck Acquired plane	Axial 0.75 x 0.5 mm Soft Head and Neck Acquired plane
Axial 3 x 3 mm Soft Aligned to anatomy	Coronal 1.5 x 1 mm Soft Head and Neck Orthogonal to acquired plane	Axial 24 x 2 mm Soft MIP Head Aligned to anatomy
Axial 1 x 1 mm Bone Aligned to anatomy	Sagittal 1.5 x 1 mm Soft Head and Neck Orthogonal to acquired plane	
Coronal 3 x 3 mm Soft Aligned to anatomy	Axial 24 x 2 mm Soft MIP Head Aligned to anatomy	
Sagittal 3 x 3 mm Soft Aligned to anatomy	Coronal 24 x 2 mm Soft MIP Head Aligned to anatomy	
	Sagittal 24 x 2 mm Soft MIP Head Aligned to anatomy	
	*Sagittal Oblique 3 x 2 mm Neck Right carotid artery	
	*Sagittal Oblique 3 x 2 mm Neck Left carotid artery	
	**Left Carotid CPR Neck	
	**Right Carotid CPR Neck	

* Traditional Workflow Only

RESULTS

Patient demographic characteristics for the pre- and post-intervention cohorts are summarized in Table 2.

Table 2
Patient Demographics and descriptive statistics of exam and technologist time.

	Traditional	Automated	p-value*
	n = 50	n = 50	
Mean Age ± Standard Deviation	64 ± 15	60 ± 18	0.23
# (%) Female	34 (68%)	31 (62%)	0.40
Exam Time (min)			
Mean ± Standard Deviation (95% CI)	24.5 ± 41.6 (3.2–46.2)	7.8 ± 1.5 (-3.1-27.8)	0.02
Median (Q1; Q2; IQR)	16.0 (13.4; 21.4; 8.0)	7.5 (7.0; 8.4; 1.4)	
Tech Time (min)			
Mean ± Standard Deviation (95% CI)	24.5 ± 41.6 (3.6–45.7)	2.0 ± 0.4 (-8.7-33.5)	0.001
Median (Q1; Q2; IQR)	16.0 (13.4; 21.4; 8.0)	1.9 (1.8; 2.2; 0.4)	
Q1 = 1st quartile, Q3 = 3rd quartile, IQR=interquartile range			

The traditional workflow exams were performed by 26 unique computed tomography (CT) technologists, with a mean of 1.9 procedures per technologist (range: 1–7). The automated workflow exams were performed by 20 unique technologists, with a mean of 2.5 procedures per technologist (range: 1–9).

Workflow Timeline and Consistency

Figure 3 illustrates the procedural time points for all patients across both workflows. The traditional workflow demonstrated high variability in the temporal sequence of reconstruction timestamps, reflecting inconsistent manual reconstruction practices among technologists. Conversely, the automated workflow standardized the reconstruction sequence and successfully eliminated the long outlier processing times observed in the traditional cohort.

Primary Workflow Time Metrics

After accounting for variations in individual technologist working speed, as well as patient age and sex via a linear mixed-effects model, the automated workflow demonstrated statistically significant

reductions in total exam time, technologist work time, and temporal variability compared to the traditional workflow (Table 2 and Fig. 4).

The median exam and tech times under the traditional workflow were 16.0 minutes and 16.0 minutes, respectively. Under the automated workflow, the median exam time decreased to 7.5 minutes ($p = 0.02$) and the median tech time decreased to 1.9 minutes ($p < 0.001$).

Accordingly, the automated cohort achieved an 8.5-minute reduction in median exam time (95% CI: 3–28 minutes) and a 14.1-minute reduction in median tech time (95% CI: 9–34 minutes). Furthermore, process variability was markedly reduced; exam time standard deviations decreased from 41.6 minutes to 1.5 minutes, and tech time standard deviations decreased from 41.6 minutes to 0.4 minutes.

Figure 5 displays the cumulative proportion of examinations completed within specific time thresholds. In the automated workflow cohort, 100% of examinations were fully completed within 12 minutes, compared to only 4% of examinations in the traditional workflow cohort within the same timeframe.

DISCUSSION

This study evaluated the impact of transitioning from a traditional, manual post-processing method to a fully automated reconstruction workflow for stroke CT angiography (CTA). Our findings demonstrate that the automated software-driven workflow yields statistically significant reductions in overall exam times and tech times as well as their standard deviations, thus achieving a faster stroke imaging workflow with reduced variability.

The automated workflow decreased median exam time by 8.5 minutes and median tech time by 14.1 minutes. Notably, in the traditional workflow, technologist work time spanned the entirety of the examination because technologists remained actively engaged in manual multiplanar reformatting until the full study was finalized. Eliminating these repetitive, manual tasks directly drives the observed time savings. In the setting of widespread technologist shortages, optimizing workflow automation is imperative to maximize operational resources and accommodate rising diagnostic imaging volumes.

The downstream clinical impact of these efficiency gains depends largely on an institution's specific radiology practice model:

- **Asynchronous Review:** In the scenario where a radiologist is not physically stationed at the console for real-time review, interpretations are entirely dependent on examination completion and PACS availability. The automated workflow accelerates image availability in PACS, facilitating faster identification and communication of critical findings.
- **Synchronous Review (Real-Time Console Model):** When a radiologist reviews stroke scans live at the console, the non-contrast head CT is evaluated immediately for acute hemorrhage or large territorial infarction. While automation may not alter immediate triage in this scenario, the expedited availability of automated multiplanar reformations enables earlier detection of subsequent critical

findings, such as large vessel occlusions (LVOs), which directly dictate emergency revascularization eligibility.

In either practice model, minimizing overall scanner occupancy and total exam duration improves Emergency Department throughput by allowing subsequent acute patients to be imaged more promptly.

Implementing this automated system presented specific operational challenges. Despite a mandatory 1-month technologist acclimatization and training period, nine examinations had to be excluded from the final analysis due to manual workflow deviations. These deviations were primarily driven by newly hired or rotating technologists who were unfamiliar with the automated software protocols.

Furthermore, this automated paradigm introduces technical dependencies on a freestanding processing server (Syngo.via). Server downtime halts automated reformations, and concurrent high-volume processing of large-dataset examinations (such as trauma pan-scans) can introduce reconstruction queues. In such instances, technologists must be cross-trained to restart the server or temporarily resume manual processing. Depending on institutional resources, this single point of failure can be mitigated by establishing a backup server configuration.

This study has several limitations. First, it was conducted at a single academic institution utilizing a specialized stroke protocol with 24/7 on-site emergency radiology coverage; thus, these results may not fully generalize to community or teleradiology practice environments. Second, the composition of the technologist pools differed between the pre- and post-intervention cohorts, with the traditional cohort utilizing more unique technologists who performed fewer examinations each. While our linear mixed-effects model treated the technologist as a random intercept to adjust for individual working speeds, an intra-technologist pre- vs. post-intervention analysis would provide a more rigorous control, though it would require a substantially larger sample size.

In conclusion, an automated CT post-processing workflow for acute stroke imaging significantly decreases total examination times and minimizes workflow variability. This intervention ensures rapid, consistent image availability for interpreting radiologists. Given the time-sensitive nature of acute ischemic stroke management, this automated software-driven solution offers a meaningful clinical impact by accelerating imaging assessment and minimizing delays to critical management decisions.

Declarations

Human Ethics and Consent to Participate declarations: not applicable

Author Contribution

AS and HY were involved in project design. HY wrote the main manuscript text with major contributions from FS. FS prepared tables and figures. All authors reviewed and edited the manuscript.

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Figures

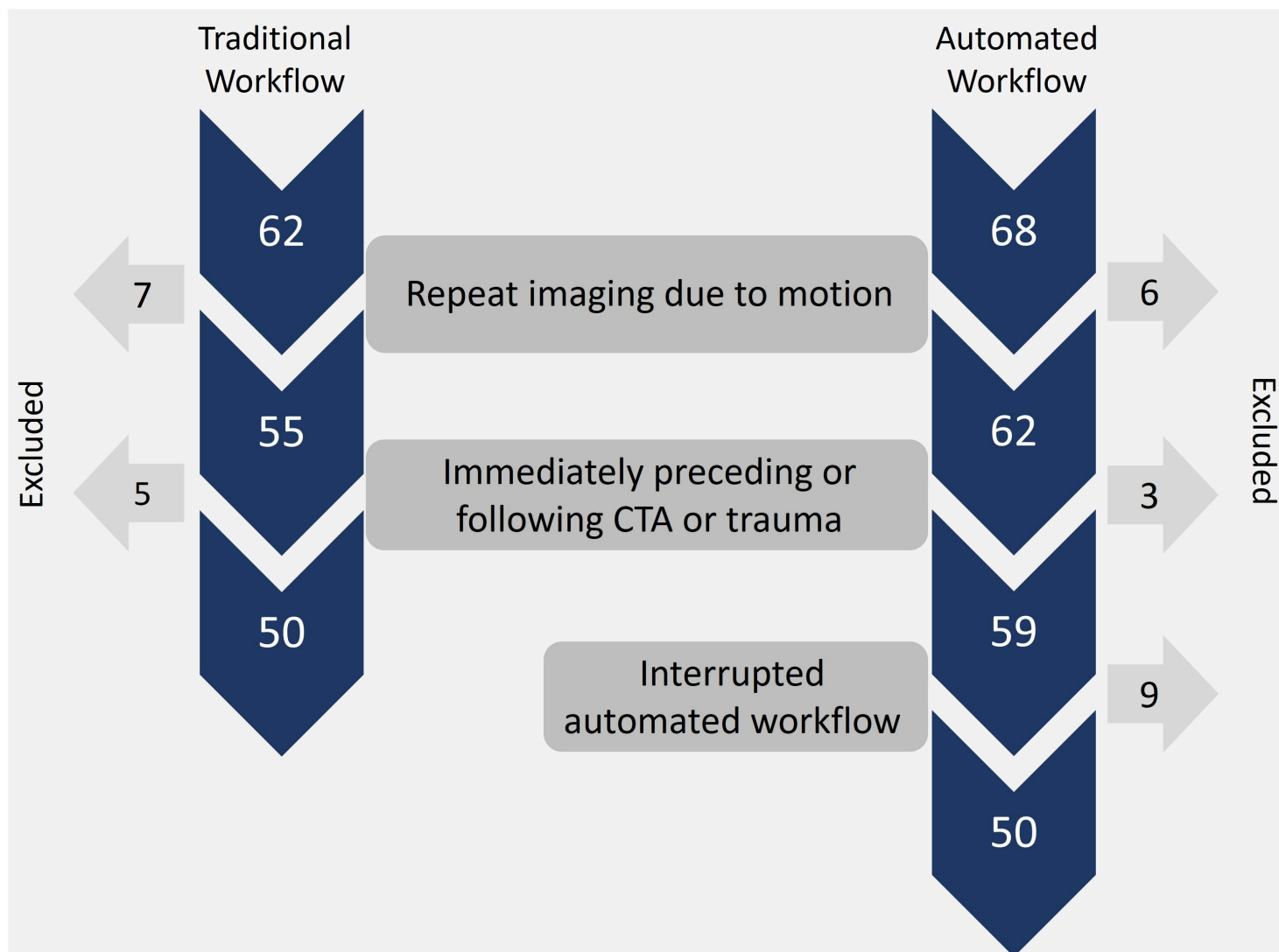


Figure 1

Total number of exams in the traditional cohort (left) and automated cohort (right). Examinations were excluded if any repeat imaging was performed due to motion artifact, were immediately preceded or followed by an examination with high image count (i.e. CTA or trauma panscan) or if the technologist interrupted the prescribed automated workflow sequence.

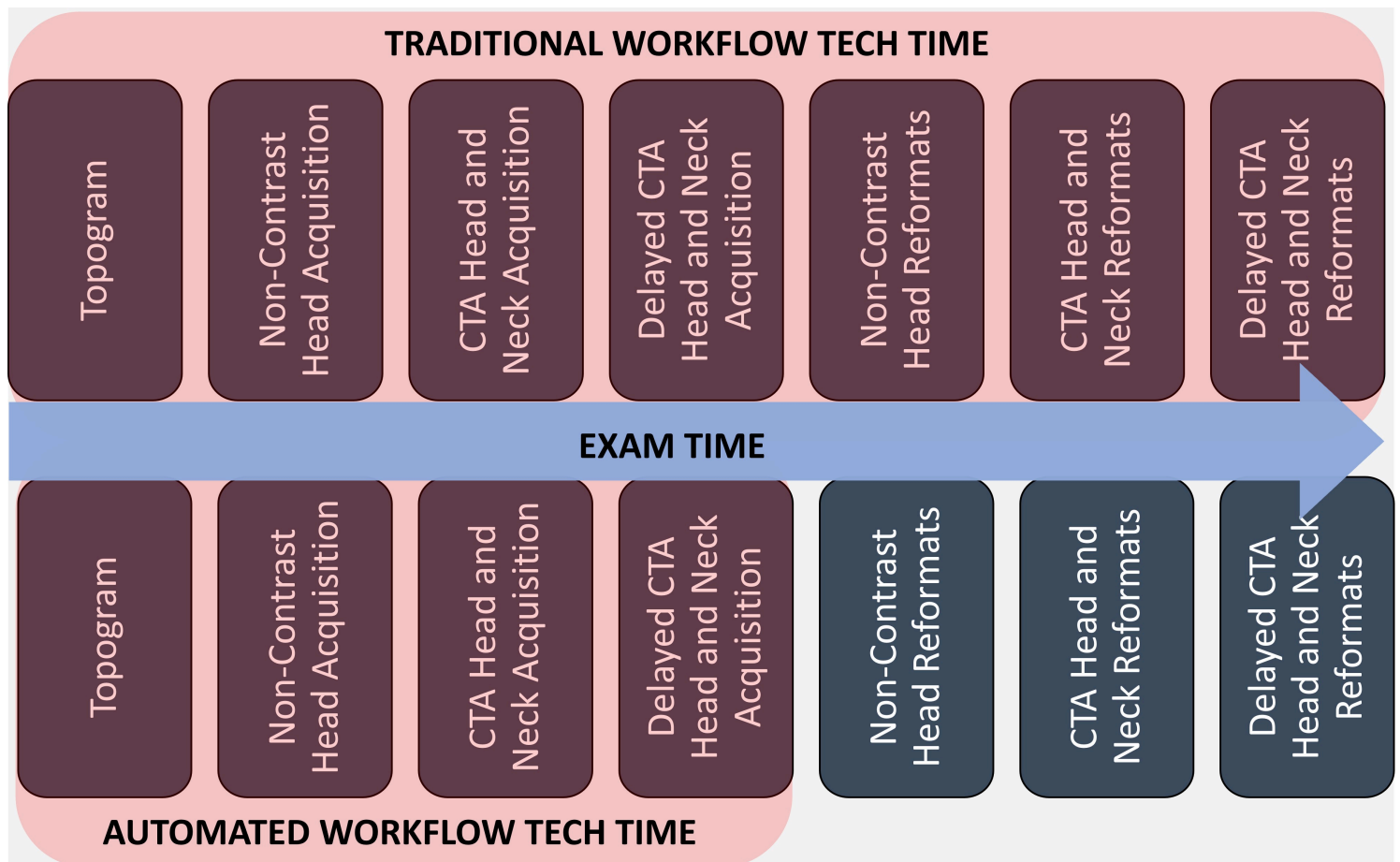


Figure 2

Sequence of events during a CTA head and neck using the traditional workflow (top) and automated workflow (bottom). Exam time is defined as the time from the first image acquisition to the last series creation time (blue arrow). In the traditional workflow, tech time is defined as the interval between the non-contrast head CT acquisition time and last series creation time for the CTA delayed images (red box). In the automated workflow, tech time is defined as the interval between the non-contrast head CT acquisition and CTA delayed image acquisition. Note that in the automated workflow, the delayed CTA acquisition concludes the tech time as no reconstructions are performed manually.

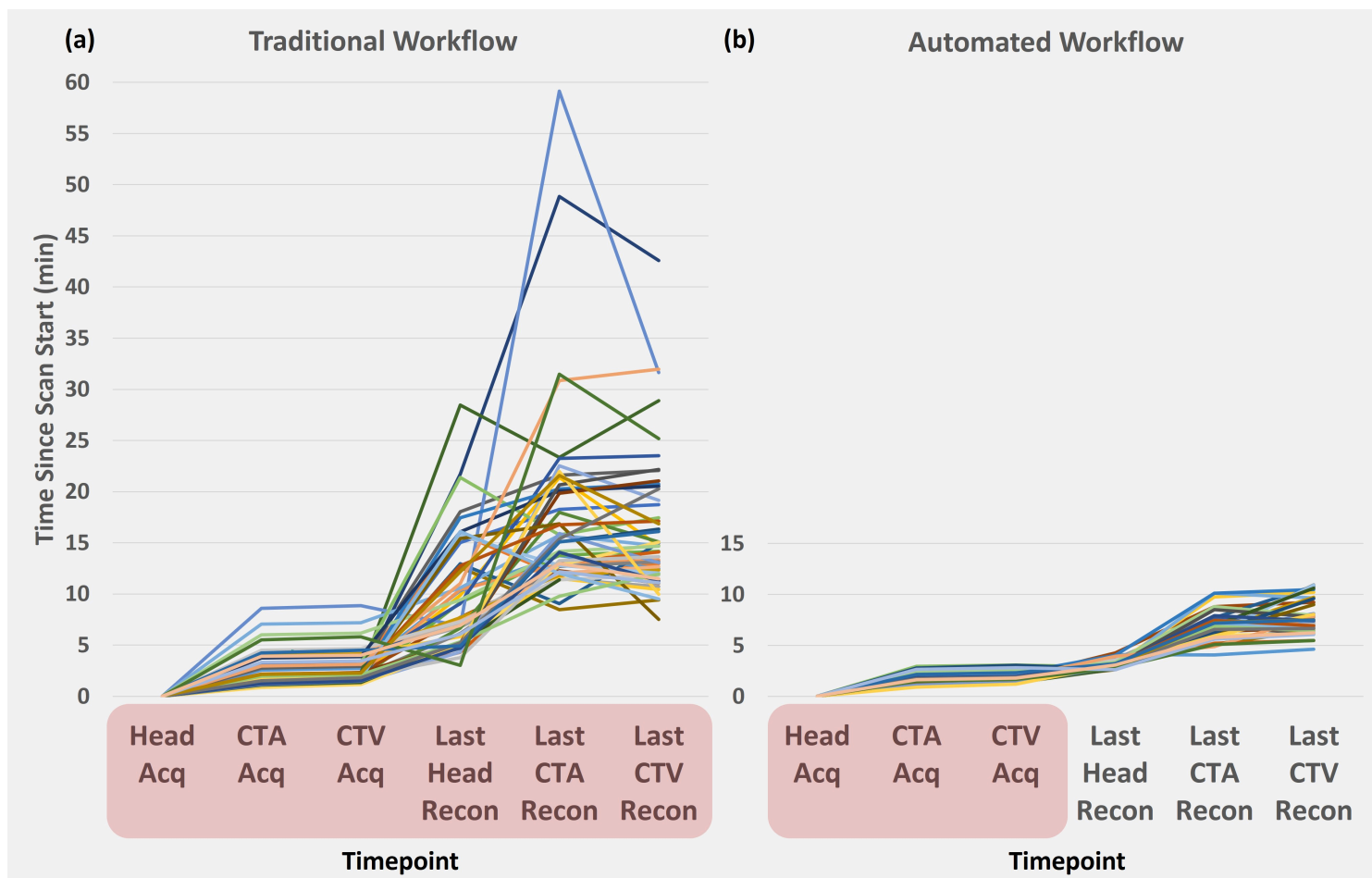


Figure 3

Graphic representation showing all data points in the traditional workflow (a) and automated workflow (b). Each colored line represents one CTA head and neck from beginning to end. Note the shaded red box along the x-axis highlighting the tech time in both traditional and automated workflows.

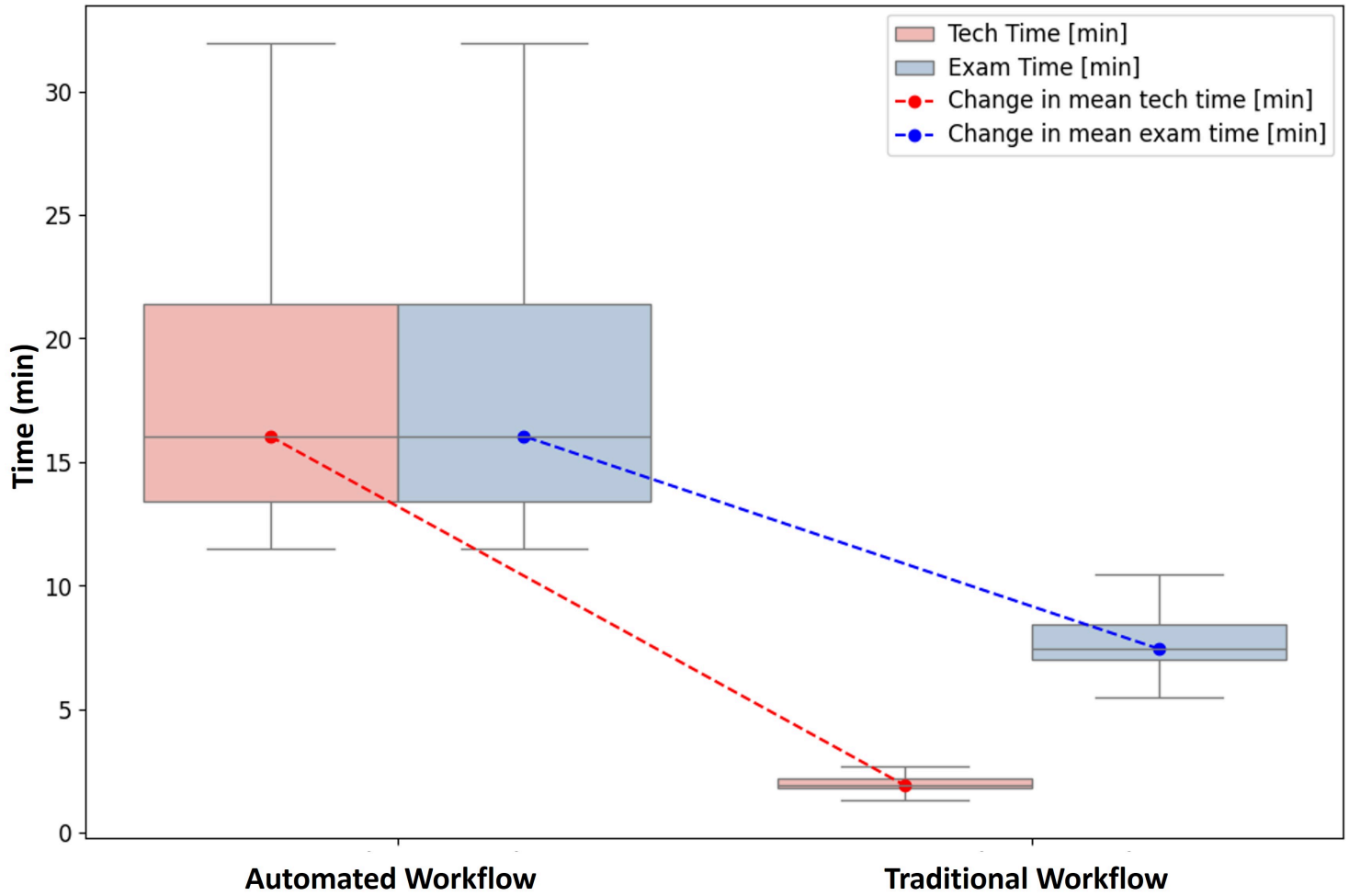


Figure 4

Boxplot displaying the exam and tech times for the traditional and automated workflows. Each box consists of the 25th to 75th percentiles at its lower and upper margins, respectively, and represents the interquartile range. The horizontal line through each box represents the 50th percentile. The lower and upper whiskers represent the minimum and maximum values sans outliers.

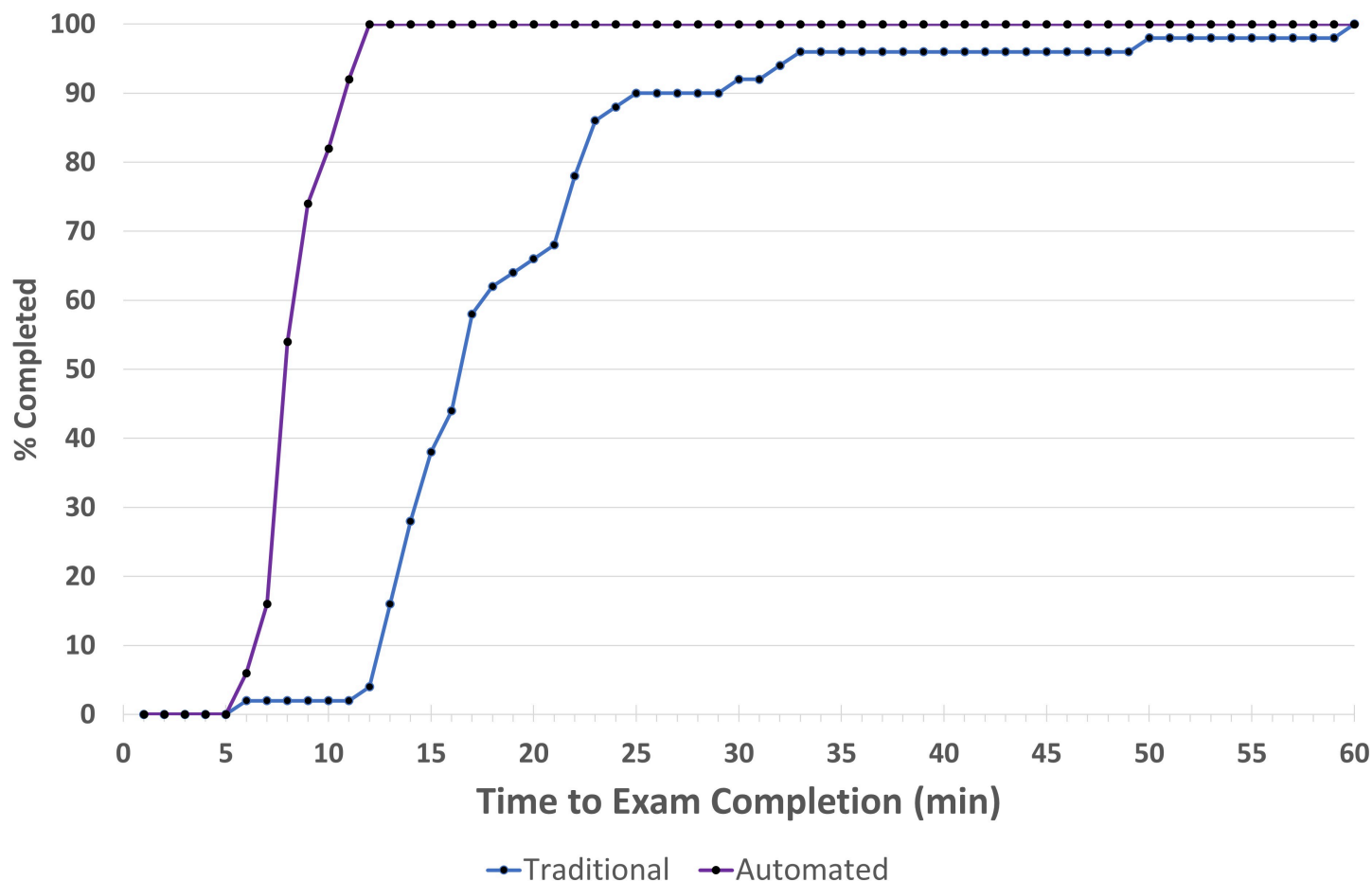


Figure 5

The percentage of exam times falling within the designated durations for both the traditional (blue) and automated (purple) workflows.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table2.jpg](#)
- [Table1.jpg](#)