Optimizing Door-to-Groin Puncture Time: The Mayo Clinic Experience

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Abstract

Objectives: To provide a better understanding of methods that can be used to improve patient outcomes by reducing the door-to-groin puncture (DTP) time and present the results of a stroke quality improvement project (QIP) conducted by Mayo Clinic Arizona’s stroke center.

Methods: We conducted a systematic literature search of Ovid MEDLINE(R), Ovid EMBASE, Scopus, and Web of Science for studies that evaluated DTP time reduction strategies. Those determined eligible for the purpose of this analysis were assessed for quality. The strategies for DTP time reduction were categorized on the basis of modified Target: Stroke Phase III recommendations and analyzed using a meta-analysis.

The Mayo Clinic QIP implemented a single-call activation system to reduce DTP times by decreasing the time from neurosurgery notification to case start.

Results: Fourteen studies were selected for the analysis, consisting of 2277 patients with acute ischemic stroke secondary to large-vessel occlusions. After intervention, all the studies showed a reduction in the DTP time, with the pooled DTP improvement being the standardized mean difference (1.37; 95% confidence interval, 1.20-1.93; \( \tau^2=1.09; P<.001 \)). The Mayo Clinic QIP similarly displayed a DTP time reduction, with the DTP time dropping from 125.1 to 82.5 minutes after strategy implementation.

Conclusion: Computed tomography flow modifications produced the largest and most consistent reduction in the DTP time. However, the reduction in the DTP time across all the studies suggests that any systematic protocol aimed at reducing the DTP time can produce a beneficial effect. The relative novelty of mechanical thrombectomy and the consequential lack of research call for future investigation into the efficacy of varying DTP time reduction strategies.

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hospital to groin puncture), only few studies have introduced and described new optimization strategies with this goal. In this systematic review, we aim to provide a better understanding of available measures intended for reducing the DTP time to improve clinical outcomes. A stroke quality improvement project (QIP) was conducted by Mayo Clinic Arizona’s stroke center focusing on the reduction of DTP times and these results will be presented in the context of the current literature.

METHODS

Literature Search
A systematic review of the literature was carried out following Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to search for studies that focused on reducing the time to MT for patients with AIS.11 A qualified health science librarian searched the online databases Ovid MEDLINE, Ovid EMBASE, Scopus, and Web of Science from inception to March 2, 2021, using the search strategy reported in Supplemental Table 1 (available online at http://www.mcpiqojournal.org).

Study Selection
The inclusion and exclusion criteria were set a priori. Studies that evaluated the efficacy of DTP time reduction strategies were selected for review. These strategies were defined as “any protocol put in place with the express purpose of reducing the time between hospital entry and groin puncture for MT on patients with AIS.” Both retrospective and prospective studies were included if they included patients diagnosed with AIS and undergoing MT, recorded the time from entry to the hospital to treatment, introduced and followed a formal protocol to reduce the DTP time, compared their results with existing data and reported the level of improvement, and were written in English. Studies were excluded if they were abstracts, case reports, conference lectures or proceedings, duplicative publications, or simple narrative reviews.

The title and abstracts of the retrieved studies were independently reviewed by 2 authors (I.R. and A.H.T.), who then each independently appraised the full text of the articles if they fulfilled the inclusion criteria. Any disagreements were settled by a third author (T.Y.E.A.). Eligible studies were included, and their references were screened to retrieve additional potentially relevant articles. Cohen kappa was used to measure interobserver agreement in selecting relevant papers on the basis of the prespecified inclusion criteria.

Data Extraction
A predesigned spreadsheet was used to organize the data extraction process on the basis of the following characteristics: study type, start date, study duration, sample size, care facility type, stroke center designation, and intervention strategy. One author (I.R.) extracted these data from the eligible studies, and accuracy was reviewed by 2 additional authors (P.P. and A.H.T.). The intervention strategies were categorized on the basis of recommendations provided by the Target: Stroke Phase III campaign manual (2019) and modified on the basis of prior recommendations from this campaign. These strategies included the following: (1) notification from emergency medical services (EMS), (2) stroke tools (including stroke severity scales, in-hospital toolkits, bedside timers, etc.), (3) a rapid triage protocol and stroke team notification, (4) a single-call activation system, (5) modified computed tomography (CT) flow, (6) rapid acquisition and interpretation of brain imaging, (7) modified laboratory testing, (8) a team-based approach, (9) prompt data feedback, (10) additional strategies not listed, and (11) strategy combinations.10

Data Synthesis and Quality Assessment
The primary outcomes of interest were quality improvement interventions adopted in each study and the difference in preintervention and postintervention DTP times (appraised as standardized mean difference [SMD]) after their implementation. For each article, the level of evidence was assessed following 2011 Oxford Centre for Evidence-Based Medicine guidelines, and 2 authors (I.R. and P.P.) independently appraised the risk of biases using the National Institutes of Health-Quality Assessment Tool for before-after (pre-post) studies with no control group (Supplemental Table 2, available online at http://www.mcpiqojournal.org).12,13
Statistical Analyses—Meta-Analysis

Analyses were performed using STATA, version 17 (StataCorp LLC). Continuous variables are presented as means and SDs or medians and interquartile ranges and categorical variables as frequencies and percentages. In studies that did not report the means and SDs of preintervention and postintervention DTP times, medians and interquartile ranges were directly converted to means and SDs, respectively. The SMD was calculated using Cohen’s d statistics as the mean difference between preintervention and postintervention DTP times divided per pooled SD.14 An indirect meta-analysis was conducted for SMD of preintervention and postintervention DTP times and graphically presented using forest plots with studies grouped on the basis of the type of intervention. The results of studies that implemented multiple combined interventions were grouped into 1 category for the meta-analysis because the high number of separate combinations would not have been an adequate representation of the literature. The Wilson score method was used to calculate confidence intervals, and the DerSimonian-Laird method for random-effect models was adopted to address the large amount of variability among studies, grouped in similar but nonidentical DTP time reduction strategies.15,16 Between-study heterogeneity was determined using the I² statistic. Two-tailed P values of <.05 were considered statistically significant.

Stroke QIP: Protocol

A stroke quality improvement protocol was implemented at our institution to reduce DTP times in the emergency treatment of patients with AIS. Cases of arrival at the emergency department (ED) and inpatient cases were included, and cases of transfer from outside hospitals were excluded. Control data were collected from patients admitted between January 1, 2018, and September 2, 2019. All adult patients admitted for MT were retrospectively evaluated and further separated into 2 distinct cohorts depending on their admission before or after the introduction of the protocol (before and after optimization). The baseline phase represented the total number of MT cases (n=44) from both the historical subphase (before protocol implementation, n=33) and current-state subphase (data collected from MT cases while awaiting approval from key stakeholders to implement the new protocol, n=11). Before protocol implementation, the average DTP time was 125 minutes.

The time from neurosurgery notification to case start was determined to be the greatest contributor to lengthy DTP times. To address this, a single-call activation system was implemented on September 3, 2019. This was achieved via a group page sent out by the house supervisor to on-duty neurosurgery, anesthesia, intensive care unit, interventional radiology, and vascular neurology representatives of stroke teams. The main goal was to achieve an average DTP time of less than 90 minutes by reducing the average time from neurosurgery notification to case start by greater than or equal to 15 minutes for all cases without adversely affecting staff satisfaction. To analyze any changes in the balancing measure, we surveyed key stakeholders to determine satisfaction.

The control plan included monitoring each case and code for stroke LVO activation, analyzing the resulting data, and establishing triggers for further workflow analysis. The triggers included an increase in the time from neurosurgery notification to case start by more than 45 minutes, resulting in DTP times of more than 90 minutes.

Statistical Analyses—QIP

Analysis of variance was performed in the historical subphase to determine which key factor was statistically significant (QIP results, Supplemental Figure 1, available online at http://www.mcpiqojournal.org). The data point “neurosurgery notification to case start time” was found to be the leading cause of prolonged DTP times. Because of documentation gaps in electronic health records, the number of cases with the time from neurosurgery notification to case start recorded was only 23; for the other 10 cases, the time of neurosurgery notification was not recorded. Consequently, the Tukey-Kramer t test was conducted (QIP results, Supplemental Figure 2, available online at http://www.
mcpiqojournal.org), which confirmed that it was the most statistically significant. The current-state subphase contributed 11 additional MT cases, and these data were added to the historical subphase to determine the total baseline phase. Because this total did not equal the total number of MT cases, a goodness-of-fit test was performed using the Shapiro-Wilk W test ($P=.9816$ \[QIP results, Supplemental Figures 3 and 4, available online at http://www.mcpiqojournal.org\]).

Data Availability
Data that have not been included in this article can be provided (anonymized) upon request from a qualified investigator.

RESULTS

Study Selection and Quality Assessment
Figure 1 displays a Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart demonstrating the process of study selection. The search strategy resulted in a total of 314 citations. From that total, 14 were determined to meet the a priori criteria (Table) and were ultimately included in the analysis. The search strategy resulted in a total of 314 citations. From that total, 14 were determined to meet the a priori criteria (Table) and were ultimately included in the qualitative and quantitative synthesis. All the articles were case-control observational studies with a IIIb level of evidence.17-30 Critical appraisal classified all the included studies as “good” quality (Supplemental Table 3, available online at http://www.mcpiqojournal.org). The interobserver agreement for selecting the relevant studies to be included was excellent ($k=0.78$).

Study Characteristics and Interventions for DTP Time Reduction
There were 14 studies selected for the analysis, involving a total of 2277 patients with AIS-LVO. There was a high amount of variability among the selected interventions: 1 study implemented a novel stroke tool, 2 used a rapid triage protocol and a stroke team notification system, 4 introduced modified CT flows, and 1 relied on a team-based approach for improvement. In addition, 6 studies used a combination of interventions, including those listed previously as well as EMS before notification, single-call activation systems, the rapid acquisition and interpretation of brain imaging, modified laboratory testing, and additional strategies not identified by the Target: Stroke initiative. No study relied on EMS before notification, single-call activation systems, the rapid acquisition and interpretation of brain imaging, modified laboratory testing, or prompt data feedback as single-strategy interventions, and as a result, these were not included in the meta-analysis.

Meta-Analysis: Comparison of Quality Improvement Interventions
Regardless of the type of intervention, all studies reported a reduction in the DTP time after intervention. The pooled DTP improvement was equal to SMD (1.37; 95% confidence interval, 1.20-1.93; $\tau^2=1.09$; $P<.001$). The meta-analyses are displayed in the form of forest plots (Figure 2). Among the 6 studies that implemented a combination of interventions, the number of strategies adopted for DTP time reduction ranged from 3 to 9; however, no correlation was found between the number of strategies employed and the degree of DTP time improvement ($P=.435$).

Stroke QIP: Results
The baseline preoptimization DTP time, determined from a sample of 23 MT cases, was 125.1 minutes, with the time from neurosurgery notification to case start averaging 61.1 minutes. Per QIP requirements, subsequent remeasurements were required after the current-state subphase. The first postintervention remeasurement was taken on October 3, 2019 (days 0-30 after implementation). During this period, there were 5 patients eligible for MT for AIS—3 from the ED and 2 from the inpatient department. The average reduction in the time from neurosurgery notification to case start was 33.8 minutes (the goal was ≤15 minutes), from 61.03 to 27.2 minutes (n=5, $P=.0005$). The average reduction in the DTP time was 34.8 minutes, from 124.8 to 90 minutes (n=5, $P=.0090$). There was also a decrease in phone calls made by either the neurosurgery service or the house supervisors from a minimum of 3 calls to 1 call.

The second remeasurement was performed on December 3, 2019 (days 31-90 after implementation), with data collected from 7 patients with AIS who were eligible for MT—all from the ED. The average reduction in the time from neurosurgery notification to
case start was 34.74 minutes, from 61.03 to 26.29 minutes (n=7, P=.0001), with the DTP time decreasing by 33.9 minutes, from 124.77 to 84.14 minutes (n=7, P=.0008). The number of phone calls did not change from the first to the second postintervention period. During the entire postintervention period, from September 3, 2019, to December 3, 2019, the time from neurosurgery notification to case start dropped to 28.8 minutes (P<.0001) and the DTP time dropped to 82.5 minutes (P<.0001). The number of phone calls the neurosurgeon had to make to mobilize necessary resources to initiate MT decreased (from 3 to 0).

There was a 96.8% response rate to the representative staff survey (91 of 94 responded). When resurveyed after intervention, the response rate was 75.51% (n=74). Before intervention, most of the key stakeholders reported dissatisfaction with the workflow (60.4%, n=55). After intervention, the respondents were largely either very satisfied (32.4%, n=24) or satisfied (36.5%, n=27) with the new workflow, with only 1.4% (n=1) being unsatisfied.

The control phase was measured between December 4, 2019, and April 30, 2022. Data were submitted for QIP for the control phase for 54 cases, with the average time from neurosurgery notification to case start being 46 minutes and the DTP time being 112 minutes.

**DISCUSSION**

Our analysis (Figure 2) showed that the pooled DTP times were significantly improved after optimization compared with those before optimization, suggesting that the implementation of any of the DTP reduction strategies described is beneficial. According to the SMD outcomes, the largest improvement in the DTP time was seen with adjustments to the rapid triage protocol and stroke team notification (SMD=2.44). However, the variation between the 2 studies that used this strategy was considerable: although Ribo et al had the highest SMD of any study (SMD=4.18), Mehta et al produced one of the lowest (SMD=0.71). This discrepancy likely arose from the way the studies were categorized. Although they both made changes to their triage protocol, Ribo et al initiated direct angiosuite transfer based on National Institutes of Health stroke scale scores, whereas Mehta et al mobilized neurointerventional and anesthesia teams in conjunction with imaging. The heterogeneity between these protocols was significant and direct comparative studies might be required.

Modifications to CT flow, the most used intervention by single-strategy studies (n=4) and 1 with lower variability, showed the second-best improvement in SMD outcomes (SMD=1.96). The changes in CT flow included a “no turn back approach” from the CT scan suite to the angiography suite and altering the flow so that imaging and treatment were performed in the same room. There was also an attempt to streamline the door-to-CT process, which included immediate transfer to the angiography suite, regardless of neurointerventional radiology team preparedness, and minimalistic room setup.
The relatively consistent improvement in the DTP time across these studies suggests that imaging is a good target for flow modification.\textsuperscript{18,22,25,28} The implementation of a novel stroke scale by Ohta et al\textsuperscript{30} also had a significant effect on DTP time but is difficult to accurately assess in comparison with other strategies because this was the only group to employ this strategy alone.\textsuperscript{30} A team-based approach, which involved stroke team education and stroke-specific simulation training, resulted in the smallest decreases in DTP time (SMD=1.42).\textsuperscript{23} It should also be noted that some strategies were implemented by very few studies—stroke tools (n=1), a rapid triage protocol and stroke team notification (n=2), and a team-based approach (n=1), which raises concerns regarding potential biases.

The use of combinations of interventions produced the fourth largest decrease (SMD=0.79), with no correlation with the number of strategies used. In this group, the most common changes implemented were EMS before notification (n=3), a rapid triage protocol and stroke team notification (n=2), and a team-based approach (n=1), which raises concerns regarding potential biases.

| Study | Pre-intervention | Post-intervention | SMD with 95% CI | Weight (%) |
|-------|------------------|-------------------|-----------------|------------|
| 1 - Stroke tools | | | | |
| Ohta et al., 2019 | 54 | 91 | 21.5 | 61 | 52 | 31.8 | 1.42 [1.01, 1.83] | 1.20 |
| Heterogeneity: $\tau^2=0.00$, $I^2=0$, $H^2=.$ | Test of $\theta_0=0$: $Q(0)=0.00$, $P=.$ |
| 2 - Rapid triage protocol and stroke team notification | | | | |
| Mehta et al., 2014 | 93 | 143 | 59.4 | 51 | 107 | 27.4 | 0.71 [0.36, 1.06] | 7.37 |
| Heterogeneity: $\tau^2=5.95$, $I^2=99.1\%$, $H^2=11.245$ | Test of $\theta_0=0$: $Q(1)=11.245$, $P=0.00$ |
| Ribot et al., 2018 | 161 | 77 | 15.6 | 40 | 18 | 4.4 | 2.44 [-0.96, 5.83] |
| Heterogeneity: $\tau^2=0.56$, $I^2=85.68\%$, $H^2=6.98$ | Test of $\theta_0=0$: $Q(3)=28.99$, $P=0.00$ |
| 3 - Modified CT flow | | | | |
| Qureshi et al., 2014 | 117 | 180 | 25.2 | 66 | 158 | 16.3 | 0.98 [0.66, 1.30] | 7.41 |
| Psychogios et al., 2017 | 44 | 54.5 | 15.6 | 30 | 20.5 | 7.4 | 2.63 [2.00, 3.26] | 6.93 |
| Kansagra et al., 2018 | 11 | 147 | 28.1 | 30 | 39 | 45.9 | 2.57 [1.68, 3.45] | 6.39 |
| BreHM et al., 2019 | 15 | 53 | 20.7 | 23 | 24 | 11.1 | 1.86 [1.09, 2.64] | 6.64 |
| Heterogeneity: $\tau^2=0.00$, $I^2=0$, $H^2=.$ | Test of $\theta_0=0$: $Q(0)=0.00$, $P=.$ |
| 4 - Team-based approach | | | | |
| BoHmann et al., 2018 | 80 | 212.5 | 87.9 | 184 | 184.2 | 78 | 0.35 [0.08, 0.61] | 7.46 |
| Heterogeneity: $\tau^2=0.00$, $I^2=0$, $H^2=.$ | Test of $\theta_0=0$: $Q(0)=0.00$, $P=.$ |
| 5 - Combination of interventions | | | | |
| Aghaebrahim et al., 2017 | 178 | 105 | 57.8 | 108 | 67 | 43 | 0.72 [0.47, 0.97] | 7.48 |
| Frei et al., 2017 | 113 | 66 | 39.3 | 267 | 47 | 25.9 | 0.62 [0.40, 0.85] | 7.50 |
| Komatsubara et al., 2017 | 14 | 186 | 71.9 | 14 | 125 | 74.1 | 0.84 [0.66, 1.16] | 6.64 |
| Cheung et al., 2018 | 23 | 116 | 43 | 16 | 88.5 | 41.5 | 0.65 [-0.01, 1.30] | 6.88 |
| Aghaebrahim et al., 2019 | 101 | 64 | 37 | 178 | 47 | 31.1 | 0.51 [0.26, 0.76] | 7.48 |
| Manners et al., 2019 | 136 | 95.4 | 29.6 | 69 | 57.3 | 20.7 | 1.41 [1.09, 1.73] | 7.41 |
| Heterogeneity: $\tau^2=0.09$, $I^2=78.53\%$, $H^2=4.66$ | Test of $\theta_0=0$: $Q(5)=21.51$, $P=0.00$ |
| Overall | | | | |
| Heterogeneity: $\tau^2=1.09$, $I^2=97.01\%$, $H^2=33.40$ | Test of $\theta_0=0$: $Q(13)=244.30$, $P=0.00$ |
| Test of group differences: $Q(4)=28.74$, $P=0.00$ | Random-effects REML model |

FIGURE 2. Forest plots displaying the results of the meta-analysis. CI, confidence interval; CT, computed tomography; REML, restricted maximum likelihood; SD, standard deviation; SMD, standardized mean difference.
protocol and stroke team notification (n=3), modified CT flow (n=3), and a team-based approach (n=3). Manners et al.\textsuperscript{29} appeared to select the most effective combination of strategies (SMD=1.41), which included the implementation of a stroke severity scale, direct communication between the rapid response and neurology teams, and the neurology team meeting the patient directly in the radiology department.\textsuperscript{29} The remaining multiple-strategy studies had a similar level of efficacy.

At our institution, the new paging system for stroke team notification significantly decreased the DTP time. However, although this system streamlined the MT workflow, it produced an unexpected administrative burden on the house supervisor and stroke coordinator. The house supervisor required immediate access to a computer to send out the activation alert, which was not always practical. System activation was transitioned to hospital operators because they were always at a computer and accustomed to sending inpatient stroke activation alerts. The new system also required the stroke coordinator to manually input the pager numbers of those responding to emergency MT cases; this task will also eventually transition to hospital operators.

Although still improved from the baseline, the control phase showed an increase in the time from neurosurgery notification to case start and in the DTP time. The pandemic impacted the number of eligible patients and decreased the number of activation alerts; consequently, errors in activation and uncertainty in the workflow were seen. To mitigate these errors, a plan was executed to increase education and communication until the key stakeholders were more familiar with their respective workflow. None of the other studies used a single-call activation system as a single-strategy intervention; so, our study cannot be directly compared with the literature in this review. Figure 3 describes what we believe to be the optimal flow for a patient with AIS-LVO.

The American Heart Association or American Stroke Association has set guidelines for areas that can be addressed to improve DTP times, but it is important to continue experimenting with innovative approaches. In literature published after our initial search, 1 group compared outcomes between dedicated on-call neurovascular staff and cross-trained operating staff, finding that having cross-trained...
### TABLE. Overview of All Included Studies*\(^{b}\)

| Serial no. | Reference, year | Level of evidence | Patients (before intervention), % female | Patients (after intervention), % female | Age (before intervention), y; median (SD) | Age (after intervention), y; median (SD) | Duration (mo) | Interventions (C=combo, S=single) | Intervention type | Hospital type (T=teaching, C=community) | DTP (before intervention) (Median in minutes) | DTP (after intervention) (Median in minutes) |
|------------|-----------------|-------------------|---------------------------------------|---------------------------------------|------------------------------------------|------------------------------------------|--------------|------------------------------------|-----------------|----------------------------------------|------------------------------------------|------------------------------------------|
| 1          | Mehta et al, 2014 | RCCS-IIIb         | 93 (49)                               | 51 (51)                               | 69±15                                    | 69 ± 15                                  | 21           | S                                  | 3               | C                                      | 143                                      | 107                                      |
| 2          | Qureshi et al, 2014 | PCCS-IIIb         | 117 (41)                              | 66 (49)                               | 64±15                                    | 67 ± 17                                  | 61           | S                                  | 5               | T                                      | 180                                      | 158                                      |
| 3          | Aghaebrahim et al, 2017 | PCCS-IIIb       | 178 (47.3)                            | 108 (47.7)                            | 67.8±15.4                                | 67.24 ± 14.1                             | 9            | C                                  | 11 (1, 3, 5, 7, 8) | T                                      | 105                                      | 67                                       |
| 4          | Frei et al, 2017 | RCCS-IIIb         | 113 (60.2)                            | 267 (50.2)                            | 69 (34-92)                               | 70 (19-94)                               | 18           | C                                  | 11 (1, 8, 10)   | C                                      | 66                                       | 47                                       |
| 5          | Komatsu et al, 2017 | RCCS-IIIb        | 14 (50)                               | 14 (57)                               | 80±3.9                                    | 82.2 ± 6.1                               | 11           | C                                  | 11 (5, 6, 10)  | T                                      | 186                                      | 125                                      |
| 6          | Psychogios et al, 2017 | RCCS-IIIb      | 44 (43.2)                             | 30 (53)                               | 75 (63-82)                               | 80 (69-86)                               | 6            | S                                  | 5               | T                                      | 54.5                                    | 20.5                                     |
| 7          | Bohmann et al, 2018 | RCCS-IIIb        | 80 (44)                               | 184 (54)                              | 70.5 (35-88)                             | 75 (25-94)                               | 11           | S                                  | 8               | C                                      | 212.5                                   | 184.2                                    |
| 8          | Cheung et al, 2018 | RCCS-IIIb        | 23 (39)                               | 16 (50)                               | 63.65 (17.92)                           | 70.81 (13.72)                           | 18           | C                                  | 11 (4, 8)       | T                                      | 116                                      | 88.5                                     |
| 9          | Kansagra et al, 2018 | RCCS-IIIb        | 11                                    | 30                                    | 8                                        | 5                                        | 8            | S                                  | 5               | T                                      | 147                                      | 39                                       |
| 10         | Ribo et al, 2018 | RCCS-IIIb        | 161 (46)                              | 40 (47.1)                             | 71.7±12.9                                | 71.5±15.5                               | 6            | S                                  | 3               | T                                      | 77                                       | 18                                       |
| 11         | Aghaebrahim et al, 2019 | PCCS-IIIb      | 178 (47.3)                            | 108 (47.7)                            | 67.8±15.4                                | 67.24±14.1                              | 9            | C                                  | 11 (1, 3, 5, 7, 8) | T                                      | 105                                      | 67                                       |
| 12         | Brehm et al, 2019 | RCCS-IIIb        | 15 (46)                               | 23 (39)                               | 78 (68-88)                              | 68 (61-78)                              | 5            | S                                  | 5               | C                                      | 53                                       | 24                                       |
| 13         | Manners et al, 2019 | RCCS-IIIb       | 136 (47.7)                            | 69 (46.3)                             | 67±14                                    | 66.5±14.3                               | 14           | C                                  | 11 (2, 3)       | T                                      | 95.4                                    | 57.3                                     |
| 14         | Ohta et al, 2019 | RCCS-IIIb        | 54                                    | 61                                    | 22                                        | 2                                        | 2            | C                                  | 91                           | 52                                      |

*\(^{a}\)DTP, door-to-puncture; PCCS-IIIb, prospective case-control study-IIIb; RCCS-IIIb, retrospective case-control study-IIIb.

*\(^{b}\)The intervention types were as follows: (1) notification from emergency medical services, (2) stroke tools, (3) rapid triage protocol and stroke team notification, (4) single-call activation system, (5) modified computed tomography flow, (6) rapid acquisition and interpretation of brain imaging, (7) modified laboratory testing, (8) team-based approach, (9) prompt data feedback, (10) additional strategies not listed, and (11) strategy combinations.
staff in the hospital at all times could avoid the bottle neck caused by waiting for an on-call neurovascular team. Another innovative development has been the use of the mobile application RapidAI, which analyzes the imaging of patients to detect LVOs and results in significantly lower DTP times.

We did not analyze “pre-hospital” strategies, such as mobile stroke units, but this remains an area where studies suggest there could be substantial DTP time reductions. Additionally, with the increased use of telemedicine in neurosurgery during the coronavirus disease 2019 pandemic, rapid advancements in our assessment and treatment of strokes in the prehospital setting could be on the horizon.

**CONCLUSION**

Accounting for the high level of heterogeneity seen among the studies implementing changes in the triage protocol, modifications to CT flow demonstrated the greatest and most consistent reduction in DTP time. There was no clear correlation between study length and DTP time reduction, suggesting that the type of intervention has a larger effect than the length of a given initiative. The relative lack of research in this area places limitations on the conclusions drawn by this review and calls for future investigation into the most efficient methods of DTP time reduction. It is important to add that the successful implementation and continued success of this QIP would not have been possible without the dedication and continued support of all multi-disciplinary teams involved.

**POTENTIAL COMPETING INTERESTS**

Dr Bendok is on the Data Safety Monitoring Board for the Boston Scientific EPI-A Carotid Stenting Trial for High Risk Surgical Patients (BEACH) trial and is the Principal Investigator and on the Steering Committee for the MEN-301 Study. Dr Krishna holds stock or stock options in Clear Point.

**SUPPLEMENTAL ONLINE MATERIAL**

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

**Abbreviations and Acronyms:**

- AIS, acute ischemic stroke
- CT, computed tomography
- DTP, door-to-groin puncture
- ED, emergency department
- LVO, large-vessel occlusion
- MT, mechanical thrombectomy
- QIP, quality improvement project
- SMD, standardized mean difference

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